Name: ________________________ Period: ________

Lesson 1: What happens when these substances are mixed together?

Experiment

Procedure

1. Squirt water on a block of wood and place a beaker directly on top of the water.
2. Measure 32 grams of barium hydroxide octahydrate and record its temperature.
3. Measure 10 grams of ammonium chloride and record its temperature.
4. Combine the two solids and mix them well. Record all observations.
5. Record the temperature of the mixture. You might have to take the temperature multiple times to make sure you get the final temperature.

Substance	Temperature
Barium hydroxide alone	
Ammonium chloride alone	
Temperature of mixture.	

Observations

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Class Discussion

Think about the phenomenon you just observed.

Q1 What other phenomena have you observed where mixing things of the same temperature together results in similar types of changes?

Similar Phenomena	What makes it similar?

Q2 Based on what we know, how and why do we think the temperature goes down?

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Q3 How would we know if a chemical reaction is happening?

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Q4 Do we have any evidence that combining barium hydroxide and ammonium chloride is a chemical reaction? What is our evidence?

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Planning An Investigation
Q5 What questions are your class trying to answer with this next investigation?

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Q6 What data would you need to collect in order to answer each question?

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Investigation in Small Groups

Feel free to modify the suggested procedure in order to better answer the questions you class came up with!

Materials

You will want to mix together these three things in a 100-mL beaker:

a. ~10 mL of room-temperature water.
b. 5 heaping spoons of pink lemonade powder
c. 5 heaping spoons of baking soda

Procedure

What additional steps or materials do you need to add to a procedure in order to get all the data you need in order to answer your question. Create a procedure that includes when you plan to collect data in the steps below.

1.

2.

3.

4.

Observations *(Make a data table in the space provided to record all of this data you want to collect.)*

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Class Discussion

Q7 What evidence-based claims can your class now make in answer to your questions? What is your claim and what is your evidence for each?

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On your own

Q8 Draw a model that answers the question related to one of the two phenomena you investigated, "Why did mixing some substances together at room temperature result in it getting colder?" Make sure to include a key for your model.

Which of the two phenomena will this be a model for? ____________________________________

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Model Presentations

Q9 Pay extra attention to what different people decided to include, or not include, in their model.

Summary of classmate's explanation	What is represented in this model?	How are they represented?

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Summary of classmate's explanation	What is represented in this model?	How are they represented?

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Consensus Building:

Q10 What evidence do we want to make sure our model accounts for? (e.g., a temperature drop). Create a Model in Progress board that includes:

1) What we want to make sure our models show
2) How we will represent those features on our models

What features did we decide in our class to include in our models as we collect more evidence?

Feature	How we will represent it

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Q11 How are we defining temperature?

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Driving Question Board

Q12 Now that we've gotten this far, what are ALL of the questions we still have about these phenomena? Write down all of your questions on post-it notes provided by your teacher.

As a class, make a Driving Question Board with any and all questions we still have.

Try and group similar questions with one another. If you hear someone ask a question that is similar to your, make sure you put your question in the same category!

Next Steps and Future Investigations

Q13 Brainstorm some investigations we could conduct to try to answer some of the questions on our **Driving Question Board**

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Name: ________________________ Period: ________

Lesson 2: Do only chemical reactions get colder?

Experiment in groups

Procedure

1. Measure and record the temperature of ~50 mL of room-temperature water below.
2. Measure 3g of salt (potassium chloride, KCl) and record its temperature.
3. Add the salt to the water and stir it in.
4. Record the lowest temperature of the mixture. Graph the temperature change.

Note: You might want to take the lowest temperature multiple times to make sure you actually take the temperature at its coldest!

Substance	Temperature
Potassium chloride alone	
Water alone	
Mixture at lowest temperature	

Q1 Record additional observations below.

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Class Discussion: Sharing Evidence

Collect all of the class data in this table. What pattern are we noticing?

Group Number	Temperature Change

Q2 What do we think is happening to the salt when it dissolves?

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Q3 Why would there be a temperature drop in the water when the salt dissolves?

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Q4 How might this be similar to or different from the chemical reactions we've already seen?

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Q5 What new questions do we have that we need to figure out?

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Q6 What evidence can we collect to tell a physical change and a chemical reaction apart?

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Experiment in groups **Choose and circle a topic to design an investigation around:**

1) Collect evidence to find out whether salt dissolving is a physical change
2) Collect evidence to see if changing the amount of salt or water impacts our results
3) Collect evidence to see if salt disappears when it is added to water
4) Collect evidence to see if the amount of total stuff is staying the same
5) Other: ____

Q7 Make a prediction as to what you will find after conducting your experiment.

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Q8 What are the procedures I will plan to use to figure this out?

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Q9 What materials will I need?

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Data	Observations

Q10 Conclusions:

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Class Discussion: Sharing Evidence

Q11 Use this space to keep track of all of the evidence the class has collected. Add any appropriate evidence to our Model in Progress Board.

Evidence	What This Tells Us

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Small Group Work

Q12 Is dissolving potassium chloride in water a physical change or a chemical reaction? Make sure to support your answer with evidence.

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Q13 What happens when something, like potassium chloride, is dissolving in water?

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Remember: Thermal energy is a measure of how quickly particles are moving (aka how hot it is) and how many particles there are (aka how much stuff there is).

Q14 Does everything have thermal energy? Explain.

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Q15 So, where is the thermal energy in the water going when salt dissolves? Draw and/or describe your answer.

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Group Discussion

Share our theories and new questions. Add any new questions to the Driving Question Board

Q16 Record here the ideas that your class has come to consensus about at this point:

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Q17 What new questions do we have?

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Name: ________________________ Period: ________

Lesson 2: What happens when a salt dissolves in water?

Experiment at home

Come up with a procedure to investigate whether table salt (sodium chloride, NaCl) is still in water after it has been dissolved or if it has changed into something else. Make sure to record your procedure below:

Procedure

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____

Q1 Do you think that the salt was still in the water after it dissolved and you could no longer see it? Support your answer with evidence.

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Name: ________________________ Period: ________

Lesson 2a: How does air cool some things down and warm other things up?

Experiment in groups

Procedure

1. Choose a condition: Hot water or Ice water
2. Measure and record the temperature of ~50 mL of water below
3. Measure and record the temperature of the air surrounding the water below
4. Seal the system in a sealed container
5. Wait 5 minutes
6. Open the box and retake the temperature of the air and the water

Substance	Temperature
Initial temperature of water	
Final temperature of water	
Temperature change water	
Initial temperature of air	
Final temperature of air	
Temperature change air	

Class Data

Collect all of the class data in this table. What pattern are we noticing?

Hot or Cold?	**Temperature Change of Water**	**Temperature Change of Air**

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Individually

Q1 Draw a model that answers the question, “How and why does water get colder (or warmer) when it sits out in the open?” Make sure to include all of the features of a model that the class has already decided on.

Small Group Work

Q2 Share your model with your group. Choose one of the group’s models, or come up with a new one, that you think best explains, “How and why does water get colder (or warmer) when it sits out in the open?” Make sure your model also explain why the air changed temperatures as well.

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Q3 *Model Presentations:*

Summary of Model	Questions about the Model

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Group Discussion: Consensus Building

Q4 What do we know about how thermal energy is transferred?

Q5 Does room temperature water have thermal energy? How do we know? What is our evidence?

Q6 Is there anything that does not have thermal energy?

Q7 What could be an example of two solids that have different amounts of thermal energy?

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Q8 Are there any new features that we have realized we want to include in future models? If so, record them here:

Feature	How we will represent it

Add any appropriate evidence to our Model in Progress Board.

Name: ________________________ Period: ________

Lesson 3: Why is the thermal energy decreasing when potassium chloride dissolves in water?

Small Groups

We saw how the temperature of water drops when potassium chloride (KCl) is dissolved in it.

Q1 Draw a model that explains, "Why does the thermal energy decrease when potassium chloride is dissolved in water?"

Remember what your class has already decided is important to include in models!

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Q2 *Model Presentations:*

Summary of Model	Thoughts and Questions about the Model

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Summary of Model	Thoughts and Questions about the Model

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Class Discussion:

Q3 What has the class agreed on?

Q4 What questions do you still have?

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Name: ________________________ Period: ________

Lesson 4: What Makes Atoms Stick Together?

Class brainstorming

Q1 Make a list of different types of connections. How can we physically attach one object to another?

____ ____

____ ____

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Investigation

Q2 Use the connection types from the above brainstorming in the first column of the table. For each type of connection identify its strengths and weaknesses as a physical representation of the connection between particles and explain your reasoning. Make sure to use what you know about the substructure of atoms in your response.

And circle the one that your group thinks is most useful as a physical representation of the connection between atoms.

Physical Representation	How is this connection similar to the connection between particles?	How is this connection different from the connection between particles?

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Physical Representation	**How is this connection similar to the connection between particles?**	**How is this connection different from the connection between particles?**

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Physical Representation	How is this connection similar to the connection between particles?	How is this connection different from the connection between particles?

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Class Discussion: Presentations

Q3 Use this space to record brief notes about other groups' choice and any questions you might have on them.

What physical representation did they choose?	Questions for the presenting group

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Class Discussion: Consensus Building

Q4 What connection did the class agree on as the best physical representation of the connection between particles?

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Q5 Why does the class think this connection is the best representation of the connection between particles?

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Q6 What weaknesses, if any, does the class think this representation has?

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Q7 What aspects of this connection between particles do we want to make sure incorporate in our future models where we try to explain why the temperature drops when we dissolve salt in water?

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Q8 What will we call this connection between particles?

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Q9 Draw a general model of the connection between atoms, based on the physical representation we selected today. Use this model to try and answer the question, “Why is energy needed to break the connection between atoms?”

Q20 Use the model you drew above to explain why energy might be needed to break the connection between atoms.

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Name: ________________________ Period: ________

Lesson 5: Are magnets a good model for the connections between particles?

Small Groups: Brainstorm

Q1 Your teacher has provided materials you can use in this next investigation. Use this space to record your ideas (and your classmates' ideas) for how you could use these materials to physically model bonds breaking.

What do we need to represent and how will we represent it?	
How will we collect data to see if the kinetic energy of particles is decreasing when bonds are broken?	

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Small Groups: Investigation

Q2 Draw a diagram of your setup here:

Q3 Record your observations and data below:

Data	Observations

Small Groups: Data Analysis and Interpretation

Q4 What is your evidence that the kinetic energy of particles decreased when a bond was broken?

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Q5 What happened to the objects that were magnetically bonded when you didn't transfer enough energy to them to break their bond? What type of motion did you notice in the system?

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Q6 Do you think the same thing could happen with potassium chloride in water? Why or why not?

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Q7 Do you think this happens when we dissolve anything in water? Why or why not?

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Q8 If we use this as a model for what happens when salt dissolves, then where does the energy come from to break the bonds in the salt?

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Q9 Does the temperature of the water impact this process at all? If so, how?

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Class consensus

Q10 How have we decided to refer to the minimum amount of energy required to break apart two atoms?

____

Small Groups

Q11 Update your model from Lesson 3 that explains, “Why does the thermal energy decrease when potassium chloride is dissolved in water?” **Make sure to now include what we now know about how particles are connected by bonds.**

Remember what your class has already decided is important to include in models!

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Q12 *Model Presentations:*

Summary of Model: Why is thermal energy decreasing when KCl dissolves?	Thoughts and Questions about the Model

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Summary of Model: Why is thermal energy decreasing when KCl dissolves?	Thoughts and Questions about the Model

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Class Consensus

Q13 What explanation has the class agreed on that explains why the temperature drops when potassium chloride dissolves in water? Make sure your explanation is at the particle level!

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Q14 Are magnets are a useful model for explaining why the temperature of substances drop, when the bonds between the particles that make them up are broken? Explain.

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Q15 What questions do you still have?

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Name: _______________________ Period: ________

Lesson 6: Are all bonds the same?

Investigation: Virtual Lab
We are trying to see if all bonds are the same. In order to investigate this question quickly we will be using a virtual laboratory where we dissolve the following salts in water: potassium chloride, ammonium nitrate, sodium chloride, sodium nitrate, and ammonium chloride.

Q1 Before we start, do you think that there will be a difference in what we see when we dissolve a different salt in water? Explain. Remember, so far we have only seen what happens when we dissolve potassium chloride (KCl) in water!

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Data Collection
Q2 Record the results from the virtual lab below. *Before the class runs the experiment, make sure you predict whether the temperature change will be **larger, smaller, or the same** as the temperature change we saw when we dissolved potassium chloride (KCl) in water.*

Name of Salt	Amount of Salt	Amount of Water	Prediction?	Temp. Change

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Name of Salt	Amount of Salt	Amount of Water	Prediction?	Temp. Change

Q3 What pattern(s) do you see in this data?

____

____

____

Small Group Investigation

Q4 Do think it requires the same amount of energy to pull all magnets apart? Why or why not?

____

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Q5 Why do you think that the temperature change was different for different salts?

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Q6 How can we now explain the patterns we see in the data?

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Class Discussion: Consensus Building

Q7 Do all atoms form bonds of the same strength? What is your evidence?

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Q8 What term did we decide to use to describe substances with lots of very strong bonds?

____

Q9 What is the class consensus as to why dissolving different salts results in different changes in temperature?

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____

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We have been talking about why dissolving salt in water makes the temperature drop, but we also saw two different phenomena that we are also trying to explain. Let's go back to those reactions and see if our new knowledge can help us come up with explanations for those phenomena as well!

Q10 Why do you think the temperature dropped when room temperature water was mixed with room temperature pink lemonade and baking soda?

Support your answer with evidence.

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Q11 Why do you think that the temperature dropped when two room temperature powders, barium hydroxide and ammonium chloride, were mixed together? (Remember, we did not add water into the beaker in this reaction!)

Support your answer with evidence.

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Ba	O	O
H	H	N
H	H	H
H	Cl	Cl

Name: ________________________ Period: ________

Lesson 7: Why did barium hydroxide and ammonium chloride absorb energy?

Class Discussion: Recap

Q1 Can the model that we developed yesterday be applied to to help us explain we observed when we mixed room temperature pink lemonade, baking soda, and water together?

Why or why not?

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____

____

Q2 Can the model that we developed yesterday be applied to to help us explain we observed when we mixed two room temperature powders, barium hydroxide and ammonium chloride together?

Why or why not?

____

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____

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Class Discussion: Revisiting the Original Phenomena

Q3 What were the class' observations about the reaction between barium hydroxide and ammonium chloride? Feel free to go back to your first packet to see what you wrote while observing the reaction!

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Q4 The two powders are barium hydroxide [$Ba(OH)_2$] and ammonium chloride [NH_4Cl]. Use this information about their chemical formulas to predict some possible products from the reaction:

____

____

Q5 After you identify all of the products, record the products of the actual chemical reaction below:

$Ba(OH)_2$ (s) + NH_4Cl (s) → ____

Small Group Work

Q6 Using pieces of paper to represent atoms, and tape to represent bond, build the reactants in the reaction above. Then try and break apart the least number of "taped" connection between the atoms in order to get the parts you need to put together the products from them.

What happens to the bonds in this chemical reaction?

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Class Discussion: Consensus Building

Q7 Based on our investigations thus far, can we come up with a definition for a CHEMICAL REACTION? Give at least one example of a chemical reaction.

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Q8 Based on our investigations thus far, can we come up with a definition for a PHYSICAL CHANGE? Give at least one example of a physical change.

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Individually: Updating Our Model

Q9 Draw a model that explains, "Why does the temperature drop when two room temperature powders, barium hydroxide and ammonium chloride, were mixed together?"

Remember what your class has already decided is important to include in models!

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Small Groups

Share your models in your small groups. Work to answer the questions below and then work together to draw one consensus model that your whole groups feels explains, "Why does the temperature drop when two room temperature powders, barium hydroxide and ammonium chloride, were mixed together?"

Q10 What is the difference between the motion of the particles in a solid vs. a liquid? Feel free to draw a *quick* picture if that helps with your explanation.

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Q11 What is the difference between the motion of the particles in a warm solid vs. a cooler solid? Feel free to draw a *quick* picture if that helps with your explanation.

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Q12 Where do you think the kinetic energy is coming from in the actual reaction to break these bonds? Support your answer with evidence.

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Q13 *Model Presentations*

Remember when students are presenting to:

- Ask clarifying questions about things you don't understand
- Provide additional evidence (if you have any) in support of or against the model being presented
- Share if the model being presented changed your mind and explain why it did

Summary of Model: Why is thermal energy decreasing when the two powders mixed?	Thoughts and Questions about the Model

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Summary of Model: Why is thermal energy decreasing when the two powders mixed?	Thoughts and Questions about the Model

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

Consensus Discussion

Q14 What did the class decide about where the kinetic energy is coming from to break bonds in the reaction between barium hydroxide and ammonium chloride?

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Q15 Generally, what did the class decide was the explanation for why the temperature sometimes drops when room temperature substances are mixed together?

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Q16 What questions do we still have? Record any new questions that you have thought of during this discussion in the space below.

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Make sure to add new questions to the Driving Question Board!

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Li	Na	K
Li	Na	K
H	H	O
H	H	O

Name: _________________________ Period: ________

Lesson 8: Do all complex reactions absorb energy and make their environment colder?

Prediction

Q1 What do you think will happen to the temperature if we mix room temperature water with room temperature metal? Support your answer with evidence.

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Q2 *Demonstration*

Observations	
Phenomenon #1	
What did we add to the water? **What happened when we added it to the water?** **Initial temp of metal:** **Initial temp of water:** **Final temp:**	
Phenomenon #2	
What did we add to the water? **What happened when we added it to the water?** **Initial temp of metal:** **Initial temp of water:** **Final temp:**	

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Phenomenon #3	
What did we add to the water? **What happened when we added it to the water?** **Initial temp of metal:** **Initial temp of water:** **Final temp:**	

Class Discussion

Q3 What patterns do you notice in these three phenomena?

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Q4 Do we think this is a chemical reaction or a physical change? What is our evidence?

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Q5 In our previous lessons we have looked at a chemical reactions and physical changes that have resulted in a drop in temperature. How and why do you think dropping these metals in water cause the temperature to ***increase***?

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Small Group Work

Q6 In the case of the first reaction you saw between lithium metal (Li) and water (H_2O), what do you think the products might be?

____

____

Q7 Record the products of all three reactions below:

Li (s) + H_2O (l) → ____

Na (s) + H_2O (l) → ____

K (s) + H_2O (l) → ____

Q8 Using pieces of paper to represent atoms, and tape to represent bond, build the reactants in the reaction above. Then try and break apart the least number of “taped” connection between the atoms in order to get the parts you need to put together the products from them.

What happens to the bonds in this chemical reaction?

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Q9 If bonds are being broken in all of these reactions, why do you think that the temperature of these reactions increase? Remember that both the metals and the water started at room temperature!

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Class Discussion

Q10 What does the class decide to call chemical reactions that result in an increase in temperature?

____

Q11 Record any new or remaining questions below. Add any new questions to the driving question board.

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Name: ________________________ Period: ________

Lesson 9: Part 1 - Why do some reactions warm things up?

Small group work

Q1 What are your current ideas as to why the reaction is getting hotter?

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Q2 Could you test your idea using the same materials and equipment that you used in Lesson 5 with the glass marbles, metal marbles, magnets, and ruler? If so, how? If not, what would you use instead?

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Q3 How would you represent a bond being formed in your model? Draw or describe your ideas

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Q4 What would we need to see to convince ourselves that, kinetic energy is being released when a magnetic bond is being formed?

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Small Group Investigation

Q5 Draw a diagram of your setup here:

Q6 Record your observations and data below:

Data	Observations

Things to Try:

There are lots of pieces to your setup! Investigate what happens when you change some things!

- **Try moving the metallic ball that is forming the bond closer and farther from the magnet before releasing it.**
- **Try adding a non-magnetic marble in the system**
- **Try changing the strength of the magnet under the ruler**
- **Record your additional observations above**

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Making Sense of Your Data

Q8 How is it possible that you (or other groups of students) were able to release a metal ball at rest to start with (no kinetic energy) at certain places in this system, and get a glass marble that also was at rest to start with (no kinetic energy) to come flying out of the system?

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Q9 How might these results help explain where the energy is coming from when an alkali metal reacts with water?

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Next Steps

Q10 How could we know whether the height of a dropped ball impacts the amount of energy released by the time it reaches the floor? What are some things we could measure?

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Lesson 9: Part 2 - Why do some reactions warm things up?

Investigation 2 - Class designed investigation

Q11 What was the results of the first investigation the class decided to conduct to see if height affects the amount of energy a ball has before it hits the ground?

Investigation 3 - Making Sense of the Slow Motion Videos

Q12 What did the slow motion videos show us was happening to the speed of the two dropped balls over time?

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Q13 What did the slow motion video tell you about the speed of the ball dropped from a bigger height right before it hit the ground compared to the speed of the ball dropped from a lesser height?

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Conclusions

Q14 Construct a model as a class in the space below to represent the changes in kinetic energy (KE) & gravitational potential energy (PE) for the 3e different ball positions that the ball is released from.

Q15 How might a similar model help us explain where the energy is coming from when an alkali metal reacts with water?

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Next Steps

Q16 Imagine you hired a computer programer design a computer simulation for you to replace each of the materials with a virtual version of them, so that they interacted in a manner similar to those in the marble track experiments.

Together with your classmates, come up with design specifications for this virtual model.

Design specifications for your system	
What materials would you need to represent from our marble track experiments in order to simulate both bonds breaking and bonds forming in the same system of reactant and product molecules?	
Because this be a simulation, you could also program the software so that you could remove the effect of some interactions, or amplify the effect of others. **What kind of interactions would you want to be able amplify or remove?**	
Sometimes in our marble track system it was hard to keep track of all the pieces very **What kind of measurement tools would you want to build into the system?**	

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Background Information. Watch the ScreenCast video introducing the computer simulation that you will use in the next three investigations. Then go back to your list of things you wanted to see included in the computer simulation that you made on the previous page. Look back at your table on the last page. Put a checkmark next to each each thing that appears to be a part of this simulation that was on your list.

Q17 In the ScreenCast, how does the speed of the particle entering the system compare to the speed of the particle leaving the system when there are no magnets under the track?

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Q18 Why would this only happen when track-friction-energy-loss is set to 0%?

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Investigation 1 :
How does adding bonds affect the motion of the particles?

Purpose: Conduct an investigation to gather evidence to support an argument that answers the question, "How does adding bonds affect the motion of the particles?"

Q30 Predict: If you release a stationary particle B (which is metallic and attracted to magnets) on the the left side of the track, and object 1 is a weak magnet placed under the track to the right, which way should particle B move (example setup shown below)?

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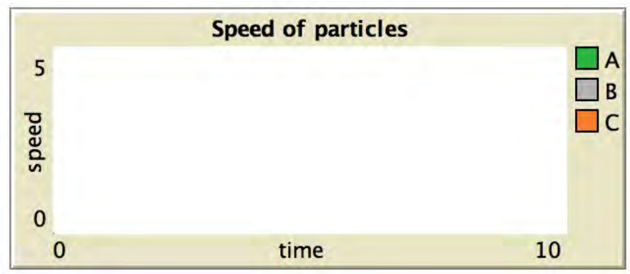
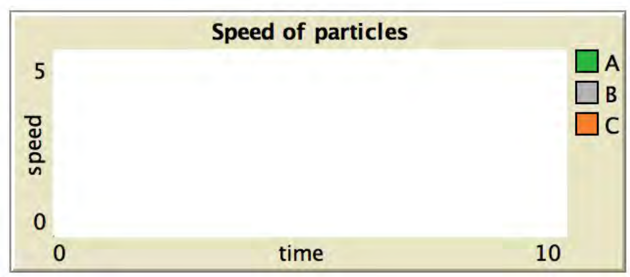
Sketch what you predict would happen to the speed of particle B over time? Draw your prediction to the right.



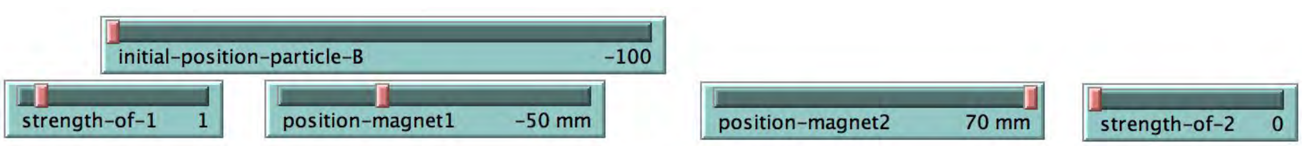
If everything is the same as above, except you use a much stronger magnet in the system for object 1, how does your predicted graph speed of particle B over time compare to the sketch you made above? Draw your prediction to the right.



Procedure:

1. Set the INITIAL-SPEED-PARTICLE-A to 0, so that it doesn't enter the system.

2. Set the STRENGTH-OF-1 slider to a weak magnet value (either 1 or 2 or 3). Make sure the rest of the sliders are set to the values shown below:



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3. Press the ***SETUP*** to initialize the model

4. Then press ***GO/STOP*** to run the model.

5. Record you observations in the space below.

6. Increase the value of the STRENGTH-OF-1 slider to any value from 4 to 8 and repeat the last three steps.

Observations - Investigation 1:

Making Sense of Investigation 1

Q19 What causes particle B to speed up in certain parts of the system?

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Q20 What causes particle B to slow down in other parts of the system?

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Q21 In the simulation particle B moves back and forth from the left side of magnet to the right side of the magnet and then back again to the left, repeating this pattern as it oscillates back and forth? When you used an actual metal ball and released it at a distance from a real magnet, did is also exhibit this oscillating (wobbling back and forth) behavior for a bit? Explain

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Q22 Why is the kinetic energy of the the particle oscillating up and down over time?

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Investigation 2 : How does forming a bonds affect the speed of particles entering and exiting the system?

Purpose: Conduct an investigation to gather evidence to help answer the question, "How does forming a bond affect the speed of particles in the system?:

Q23 Predict. If you release particle B (metallic) far away from object 2 (which is the only magnet in the system) and nd you will place particle C (which is glass and not attracted to magnets) on top of object 2, then what, if anything, will happen to particle C?

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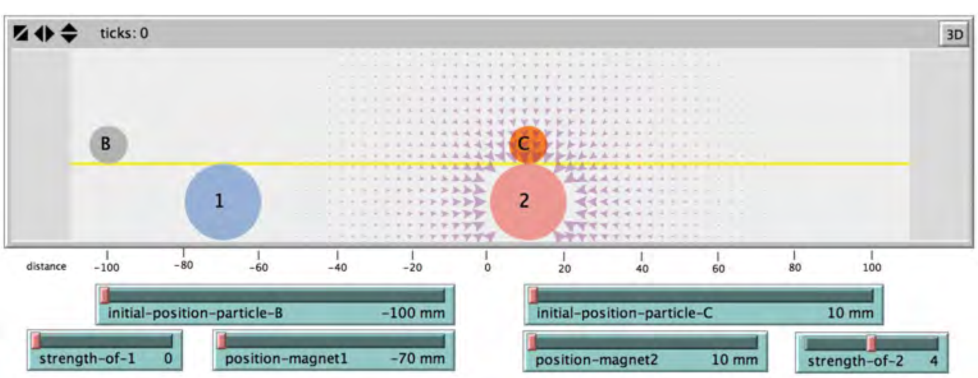

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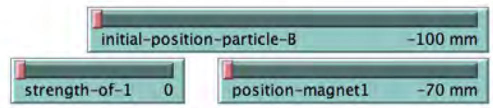
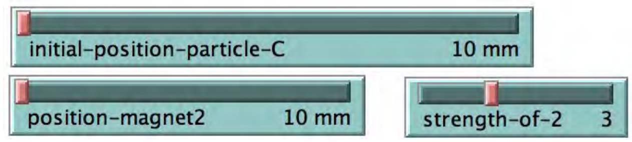
Procedure:

3. Set the INITIAL-SPEED-PARTICLE-A to 0, so that it doesn't enter the system.

4. Set the STRENGTH-OF-1 slider to a (0) and move it to the left side of the system (by decreasing POSITION-MAGNET1. Keep particle B to the far left of the of the system. Notice all of these sliders are set to the far left settings.

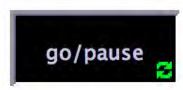


5. Set the STRENGTH-OF-2 slider to be a weak magnet (a value between 1 to 3) and move it as far left as you can (by decreasing POSITION-MAGNET2). Also move the INITIAL-POSITION-PARTICLE-C as far to to the left as you can. This should put particle C right above magnet 2.
Here is an example of these settings:



7. Press the ***SETUP*** to initialize the model

8. Then press ***GO/STOP*** to run the model.



9. Record your observations in the space below.

10. Increase the value of the STRENGTH-OF-2 slider to any value from 4 to 8 and repeat the last three steps.

Observations - Investigation 2:

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Making Sense of Investigation 2

Q24 Why does particle C leave the system at a higher speed when a stronger magnet is used for object 2, if particle C isn't attracted to magnets?

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Q25 What is causing this increase in the speed of the particles exiting the system, compared to the initial speed of the particles in the system?

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Investigation 3 : How does breaking bonds affect the speed of particles entering and exiting the system?

Purpose: Conduct an investigation to gather evidence to help answer the question, "How does breaking a bond affect the speed of particles in the system?:

Q40 Predict. If you shoot particle A (a glass marble) into particle B (metallic) which is bonded on top of object A (a weak magnet), fast enough so that particle B leaves the system, how will the speed of particle B leaving the system compare to particle A entering the system?

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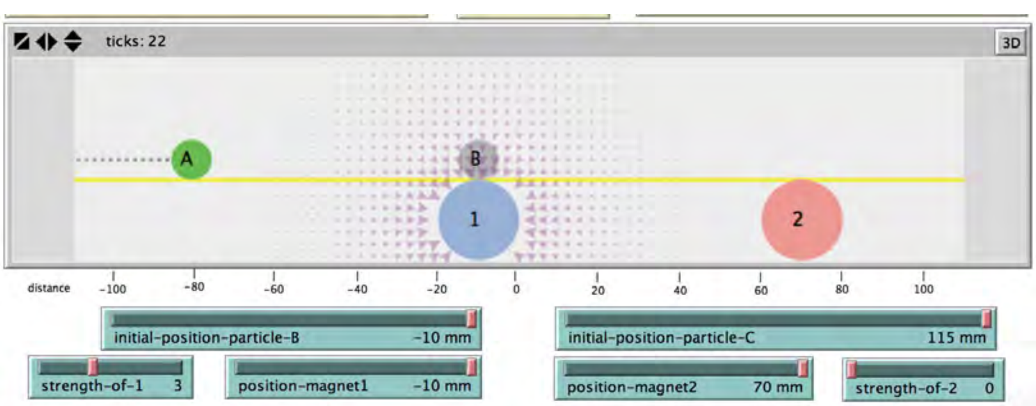

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Procedure:

1. Remove Magnet 2, by setting STRENGTH-OF-2 to 0.

2. Remove particle C by sliding INITIAL-position-particle-C to 115 mm (this will place it off the track and outside the system)

3. Line up the INITIAL-POSITION-PARTICLE-B to the same value as POSITION-MAGNET1

4. Set the STRENGTH-OF-1 to any value you wish greater than 0.

5. Set the INITIAL-SPEED-PARTICLE-A to any value greater than 0.

6. Press the ***SETUP*** to initialize the model

7. Then press ***GO/STOP*** to run the model.

8. Adjust either the STRENGTH-OF-1 or INITIAL-SPEED-PARTICLE-A and repeat the last two steps, until you are able to break the bond of particle B with object 1, and get particle B to leave the system.

9. Record what you notice about the final speed of particle B compared to the initial speed of particle A below.

Observations - Investigation 3:

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Making Sense of Investigation 3

Q26 How does the speed of the particles exiting the system, compare to the speed of the particles entering the system?

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Q27 What is causing this change in the speed of the particles exiting the system, compare to the speed of the particles entering the system?

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Q28 How does these results compare to your observations from your investigations with real marbles, magnets, and rulers?

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Class Discussion: Consensus Building

Q29 When bonds are formed, do they always release the same amount of energy? What is your evidence? Think back to the phenomena we have seen and see if you can think of a real life example that supports this idea.

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Q30 When bonds are broken, do they always release the same amount of energy? What is your evidence? Think back to the phenomena we have seen and see if you can think of a real life example that supports this idea.

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Q31 Once kinetic energy is used to break a bond can we ever get that kinetic energy back? Or does it disappear forever?

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Q32 In the reactions with alkali metals, bonds are both broken and formed. Keeping this in mind why do you think the reaction between alkali metals and water resulted in energy being released?

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Class Discussion: Consensus Building

Q33 If all chemical reactions require breaking some bonds and forming new bonds, why do some reactions result in an increase in energy while others result in a decrease in energy?

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Q34 How might we investigate this question further with our computer model?

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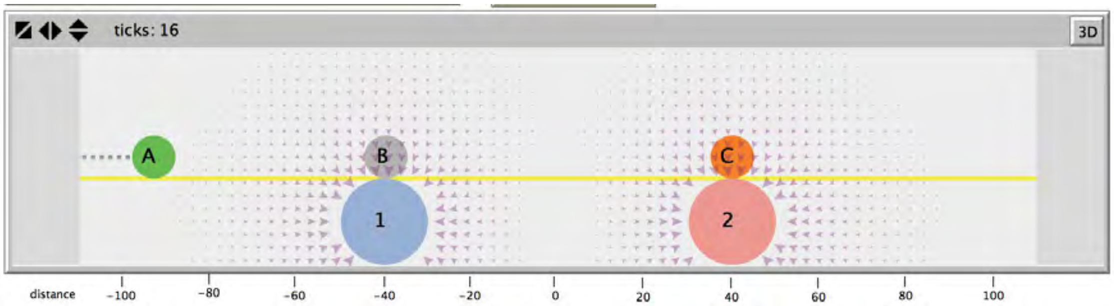
Name: ________________________ Period: ________

Lesson 10: Why do some chemical reactions get cold and others get hot?

Investigation 4 : How does BOTH forming bonds and breaking bonds affect the speed of particles entering and exiting the system?

Purpose: Design and conduct an investigation, using a computational simulation, to answer the question, "How will both forming a breaking and forming bonds of different strengths affect the speed of particles entering and exiting the system?"

Condition 1 The strength of magnet 1 is equal to the strength of magnet 2. For example:



Q1 Predict: How would the speed of particle C exiting the system compare to the speed of particle A entering the system in condition 1?

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Condition 2 The strength of magnet 1 is **weaker** than the strength of magnet 2.
Q2 Predict: How would the speed of particle C exiting the system compare to the speed of particle A entering the system in condition 2?

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Condition 3 The strength of magnet 1 is **stronger** than the strength of magnet 2.
Q3 Predict: How would the speed of particle C exiting the system compare to the speed of particle A entering the system in Condition 3?

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Procedure:

1. In each of the conditions you test, make sure that particle B starts in a position right above object 1 (bonded to it), and particle C starts in a position right above object 2.

2. Adjust the slider for **StrengthOf1** and **StrengthOf2** to test each condition.

3. Adjust the **initial-speed-particle-A** until you get particle C to leave the system for that condition.

4. Record your results.

5. Repeat for the other 2 conditions.

Observations - Investigation 4:	
Scenario 1 (magnet 1 is just as strong as magnet 2)	
Scenario 2 (magnet 1 is weaker than magnet 2)	
Scenario 3 (magnet 1 is stronger than magnet 2)	

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Making Sense of Investigation 4

Q4 Why do breaking and forming bonds, sometimes result in particles exiting the system faster than they entered it?

Q5 Why do breaking and forming bonds, sometimes result in particles exiting the system slower than they entered it?

Q6 Why do breaking and forming bonds, sometimes result in particles exiting the system as the same speed as they entered it?

Q7 What is causing these different outcomes?

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Conclusions

After using the computer models, what did we find from our last three investigations:

Q8 INVESTIGATION 2: *How and why* does forming bonds affect the speed of particles entering and exiting the system?

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Q9 INVESTIGATION 3: *How and why* does breaking bonds affect the speed of particles entering and exiting the system?

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Q10 INVESTIGATION 4: How does BOTH forming bonds and breaking bonds affect the speed of particles entering and exiting the system?

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Q11 Do all chemical reactions result in the same change in energy? Why or why not?

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Q12 Use the elements of the system above to explain and/or model why some chemical reactions result in a drop in temperature while others result in an increase in temperature increase:

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Class Discussion

Q13 Consider our current definition of a chemical reaction. Is it possible to have a chemical reaction that is not exothermic or endothermic? If so, how?

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Q14 What determines if a reaction is endothermic or exothermic?

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Q15 Do we have any way of predicting how much energy will be released when a bond is formed?

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Small Group Modeling

Q16 Choose one of the chemical reactions we have seen in this unit. Use what you know now to see if you can make a model that answers the question: ***How and why is there a change in temperature in these chemical reactions between room temperature substances?***

You may want to use some of the vocabulary words we have define over this unit to help you in any explanation you provide!

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How and why is there a change in temperature your chosen chemical reaction between room temperature substances?

Record your chemical reaction here:

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Class Discussion

Q17 After seeing your classmates presentations, does the current class consensus model actually explain all of the phenomena that we saw in this unit? If it doesn't, make sure you say how!

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Q18 As a class, try and make a ***general*** model that is not specific to any one reaction but still explains why some chemical reactions result in a drop in temperature while others result in an increase in temperature increase.

You might want to have one model for chemical reactions that result in a drop in temperature and a second model that explains chemical reactions that result in an increase in temperature.

Make sure your model includes a way of seeing a difference between the energy before the chemical reaction and the energy after the chemical reaction.

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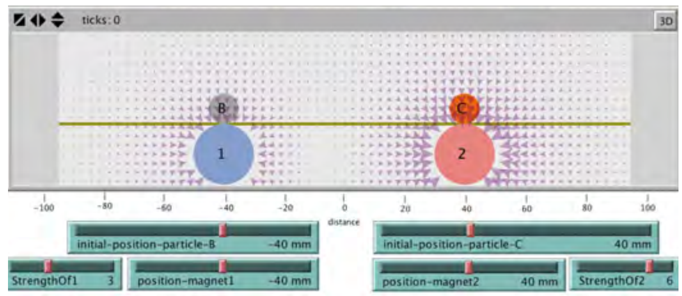
Name: _________________________ Period: _________

Lesson 11: How do scientists represent the changes in energy in endothermic and exothermic reactions?

The screenshots below are from a simulation run with the settings shown to the right:



Q1 Which is the stronger bond in this simulation run, the bond that will be broken or the bond that will be formed?

____

Q2 How should the speed of the particles that leave this system compare to the speed of the particles entering this system?

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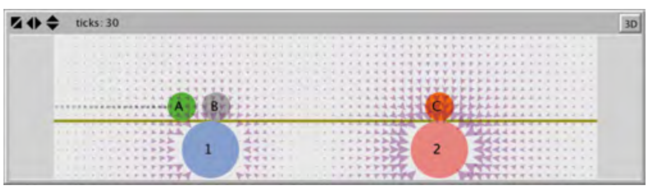
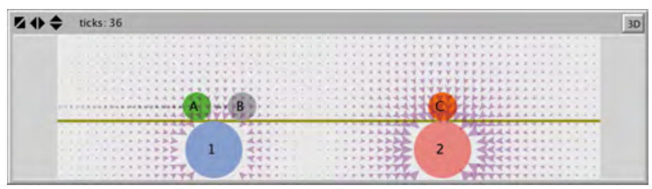
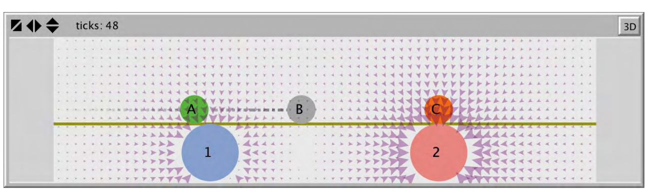
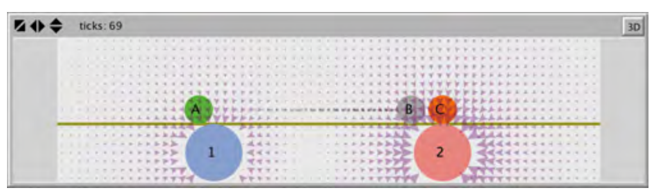
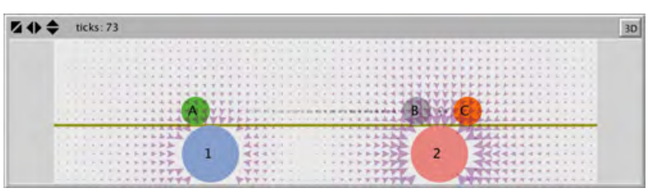
Q3 Label one screenshot **START OF REACTION** for the one which best represents the moment right when the reactant particles start pulling apart from each other. Label one screenshot **END OF REACTION** for the moment right after the reactant particles come together.

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This graph to right shows how the speed of different particles in that simulation compare overtime.

Q4 What features of this graph helps you see this must be representing an exothermic reaction (releases energy to the surroundings) rather than an endothermic reaction (absorbs energy from the surroundings)?

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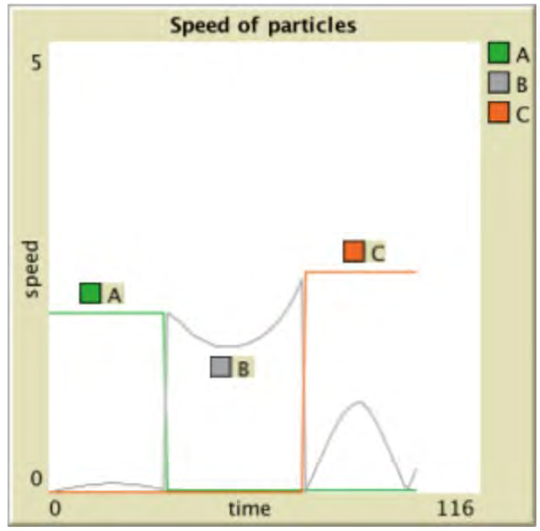

Q5 Label a point on the graph that best represents the start of the reaction, right when the reactant particles start pulling apart from each other. Label this point **START OF REACTION.**

Q6 Label a point in the graph that best represents the end of the reaction, right after the reactant particles come together. Label this point **END OF REACTION.**

Q7 Notice that there is a point in time on the graph, where the speed of the particles in the simulation is at a minimum. It is lower than it was before bonds were broken, and lower than after new bonds were formed. Label this point as **MINIMUM AVG. SPEED OF PARTICLES**.

Q8 Look back at the first page. Which screenshot, represents the point in time when this is happening? Label that one **MINIMUM AVG. SPEED OF PARTICLES**.

Q9 Is particle B closer to particle A at this point in time, or closer to particle C at this point in time?

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Q10 If the average kinetic energy of the particles would be at their lowest point (minimum value) when they are at they are located at this point in space, what could you then also say about the average potential energy of those particles at this point in space?

a) The average potential energy of those particles would be at a minimum value.
b) The average potential energy of those particles would be at a maximum value.
c) The average potential energy of those particles doesn't change during the reaction.

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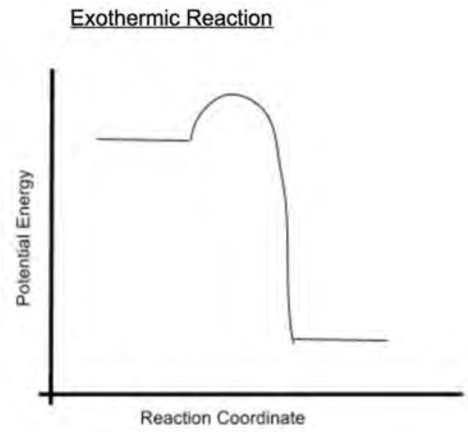
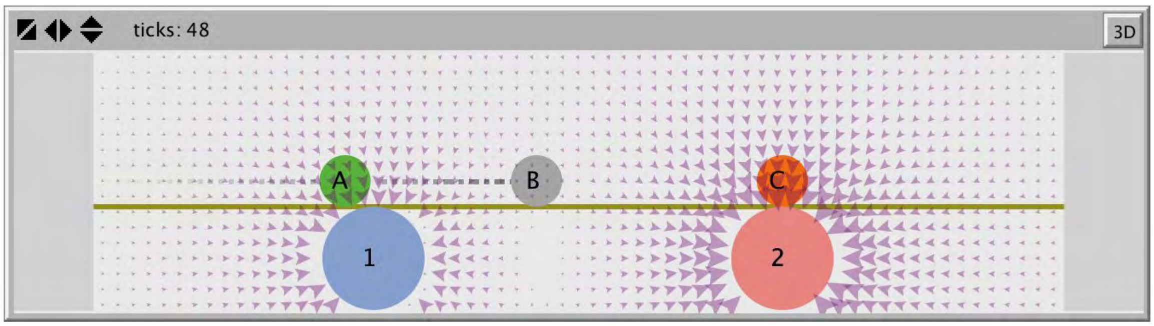
Scientists have developed another type of graph to represent changes in the potential energy in the system as particles move across space. This type of graph is called a ***reaction coordinate diagram***. Notice also that the y-axis isn't keeping track of kinetic energy, it is keeping track of potential energy. And it isn't keeping track of energy vs. time, it is keeping track of energy vs. coordinate (distance). This of the x-axis as the position of particle B.



Q11 Label the maximum potential energy shown on this graph as: **MAXIMUM PE**.

This screenshot shows where particle B would be located, when the system is at a maximum potential energy value.



Q12 Why would the system be at a maximum potential energy value when particle B has gotten to this location?

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Q13 Label a point on the graph that best represents the start of the reaction, right when the reactant particles start pulling apart from each other, as **START OF REACTION.** Label another point right after the reactant particles come together, as **END OF REACTION.**

Q14 Why would the shape of a graph for potential energy vs. distance (like the one above) be inverted compared to the shape of the graph for speed of particles vs. time (on the previous page)?

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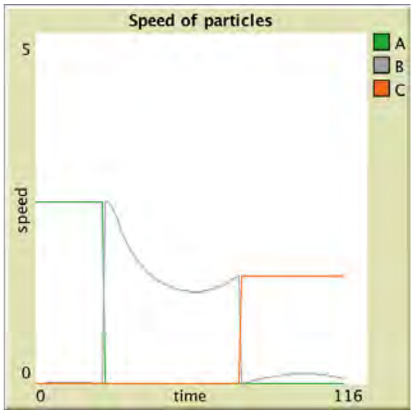
These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.



The graph to the right shows a different simulation run for an endothermic reaction.

Q15 What features of this graph helps you see this must be representing an exothermic reaction (releases energy to the surroundings) rather than an endothermic reaction (absorbs energy from the surroundings)?

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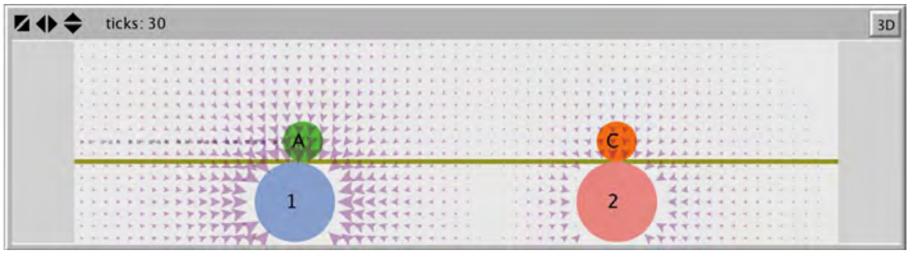
____

Q16 Which bonds are stronger in this simulation - the bonds of the reactants or the bonds of products?

____

Q17 Notice that again there is a point in time on the graph, where the speed of the particles in the simulation is at a minimum. It is lower than it was before bonds were broken, and lower than after new bonds were formed. Label this point as **MINIMUM AVG. SPEED OF PARTICLES**.

Q18 Based on the information above, draw where particle B would need to be between A and C, for the system to have a **MAXIMUM PE** on the screenshot shown here:

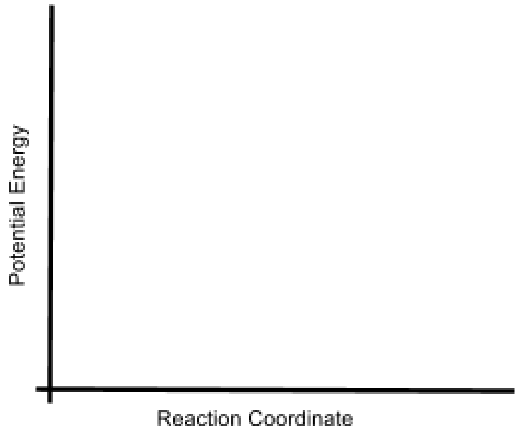


Q19 Sketch what the Reaction Coordinate Diagram would look like for this endothermic reaction pulling apart from each other.

Label a point in the graph that best represents the moment right when the reactant particles start pulling apart from each other. Label this point **START OF REACTION.**

Label a point in the graph that best represents the moment right after the reactant particles come together. Label this point **END OF REACTION.**

There will be a point on this graph, where the speed of the particles in the simulation is at a minimum. Label this point **MINIMUM AVG. SPEED OF PARTICLES.**



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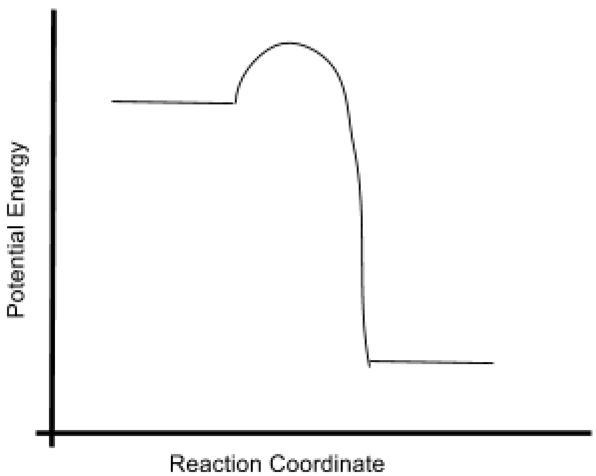
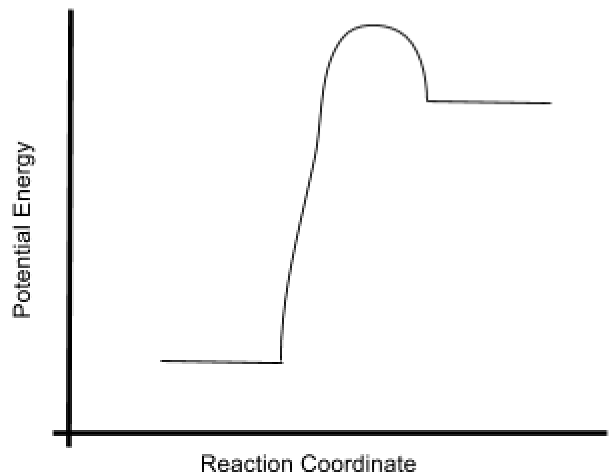
Conclusions

Exothermic Reaction



Endothermic Reaction



Q20 Activation energy (E_a) is the amount of energy you have to put into the system to get the reactant particles (e.g. particle B) to a position that is far enough away from what it used to be bonded to (e.g. particle A) so that it automatically bonds with a product particle (e.g. particle C), rather than fall back to bond with particle A.

- As a class label the energy of activation (E_a) for both reactions on the graphs above.

Q21 The enthalpy of reaction ($\triangle H_{rxn}$) is defined as the total change in energy due to a chemical reaction.

- As a class label the enthalpy of reaction ($\triangle H_{rxn}$) for both reactions on the graphs above.

Q22 In reactions that result in a temperature increase, why would do you think the enthalpy of reaction would be positive or negative?   In reactions that result in a temperature decrease, do you think the enthalpy of reaction is positive or negative?

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Name: ________________________ Period: ________

Lesson 12: Can we predict whether a chemical reaction will be exothermic or endothermic?

Small Groups

Q1 What information would you need to know to calculate if a chemical reaction is exothermic or endothermic?

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Q2 Come up with a mathematical equation that could help you calculate whether a chemical reaction is endo- or exothermic

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Q3 According to your equation, would an exothermic reaction have a positive (+) or negative (-) value?

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Q4 According to your equation, would an endothermic reaction have a positive (+) or negative (-) value?

____

Class Consensus

Q5 After reaching class consensus, record the FINAL version of the mathematical equation you would use to calculate if a chemical reaction is exo- or endothermic below:

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Small Groups

The following table has the average bond energies for some common bonds. These values are reported in kilojoules per mole (kJ/mol).

Average Bond Energies (kJ/mol)					
H–H	436 kJ/mol	C–H	413 kJ/mol	C=C	614 kJ/mol
H–Cl	431 kJ/mol	C–C	348 kJ/mol	C≡C	839 kJ/mol
H–F	567 kJ/mol	C–N	293 kJ/mol	C=O	799 kJ/mol
N–H	391 kJ/mol	C–O	358 kJ/mol	O=O	495 kJ/mol
N–O	201 kJ/mol	C–F	485 kJ/mol	C≡O	1072 kJ/mol
O–H	463 kJ/mol	C–Cl	328 kJ/mol	C=N	615 kJ/mol
O–O	146 kJ/mol	C–S	259 kJ/mol	N=N	418 kJ/mol
F–F	155 kJ/mol	Cl–Cl	242 kJ/mol	N≡N	941 kJ/mol
				C≡N	891 kJ/mol

Q6 This table gives you the average amount of energy needed to break a bond. However, remember that in chemical reactions bonds are both broken and formed. Do you think that there is useful information that we can get from this table about forming bonds?

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Q7 How is the amount of energy used when bonds are broken related to the amount of energy released when that same bond is formed?

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Q8 Estimate the enthalpy change (ΔH_{rxn}) of the following reactions using the bond energies given to you on page 2. Label each reaction exothermic or endothermic.

1)

H–H + Cl–Cl → H–Cl + H–Cl

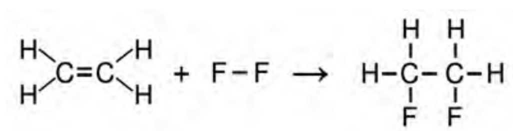
Endothermic or exothermic?

2)

H–H + F–F → H–F + H–F

Endothermic or exothermic?

3)



Endothermic or exothermic?

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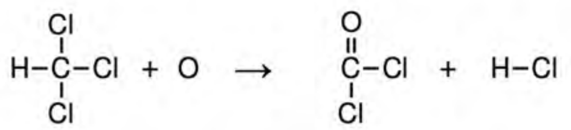
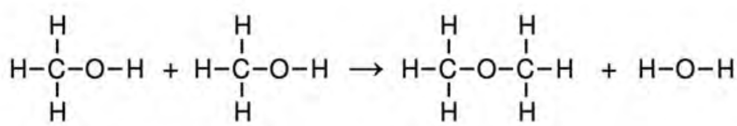
4)



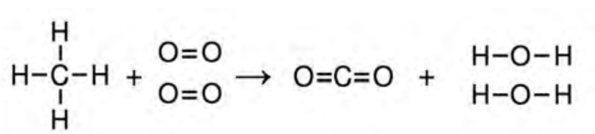
Endothermic or exothermic?

5)



Endothermic or exothermic?

6)



Endothermic or exothermic?

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Driving Question Board

Q9 Go back to the Driving Question Board. Are there any questions there that you have not yet answered? Do you have any new questions now that you are done with this unit?

Record any new or unanswered questions below:

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