This segment allows students to investigate chemical reactions and consider a range of factors in order to predict reaction products, to develop particle drawings that represent the rearrangement of atoms during a reaction type, and to develop a strategy for balancing and classifying chemical equations.

Student Science Performance

Grade or course: 9-12 Chemistry	**Title:** Investigating Chemical Reactions
Topic: Chemical Reactions	

Performance Expectation for GSE:

SC2. Obtain, evaluate, and communicate information about the chemical and physical properties of matter resulting from the ability of atoms to form bonds.

g. Develop a model to illustrate the release or absorption of energy (endothermic or exothermic) from a chemical reaction system depends upon the changes in total bond energy.

SC3. Obtain, evaluate, and communicate information about how the Law of Conservation of Matter is used to determine chemical composition in compounds and chemical reactions.

a. Use mathematics and computational thinking to balance chemical reactions (i.e., synthesis, decomposition, single replacement, double replacement, and combustion) and construct an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
b. Plan and carry out an investigation to determine that a new chemical has been formed by identifying indicators of a chemical reaction (e.g. precipitate formation, gas evolution, color change, water production, and changes in energy to the system).

SC4. Obtain, evaluate, and communicate information about how to refine the design of a chemical system by applying engineering principles to manipulate the factors that affect a chemical reaction.

a. Plan and carry out an investigation to provide evidence of the effects of changing concentration, temperature, and pressure on chemical reactions.
(*Clarification statement:* Pressure should not be tested experimentally.)
b. Construct an argument using collision theory and transition state theory to explain the role of activation energy in chemical reactions.
(*Clarification statement:* Reaction coordinate diagrams could be used to visualize graphically changes in energy (direction flow and quantity) during the progress of a chemical reaction.)
c. Construct an explanation of the effects of a catalyst on chemical reactions and apply it to everyday examples.
d. Refine the design of a chemical system by altering the conditions that would change forward and reverse reaction rates and the amount of products at equilibrium.
(*Clarification statement*: Emphasis is on the application of LeChatelier's principle.)

SC5. Obtain, evaluate, and communicate information about the Kinetic Molecular Theory to model atomic and molecular motion in chemical and physical processes.

a. Plan and carry out an investigation to calculate the amount of heat absorbed or released by chemical or physical processes.
(*Clarification statement:* Calculation of the enthalpy, heat change, and Hess' Law are addressed in this element.)

Performance Expectations for Instruction:

- Investigate and research chemical reactions in order to predict the products and explain the changes occurring at the microscopic level.
- Use mathematics and computational thinking to develop a strategy to balance chemical reactions.

- Classify chemical reactions as synthesis, decomposition, single replacement, double replacement (including neutralization), and combustion.
- Investigate how the solubility of ions in water affects the products in chemical reactions and represent this using net ionic equations.

Additional notes on student supports

Materials
Introductory Phenomenon Activity
Per group: Petri dish (small beaker); 2 wooden graphite pencils; 9V battery; masking tape; connector wires with alligator clips on both ends; distilled water; Universal indicator; Sodium sulfate Na_2SO_4 (or any salt)
PHET Simulation - Laptops
Demo: Lead nitrate (aq) ($Pb(NO_3)_2$); Potassium iodide (KI) (aq); pipette; beakers
Predicting products Activity:
24 hole well plate; wash bottle; goggles; micro-pipettes; cotton swabs (cleaning well-plate); apron; Sodium iodide, 0.2 M (NaI); 0.2M Cobalt (II) chloride, ($CoCl_2$); Sodium carbonate, 0.2M Na_2CO_3); 0.2M Copper (II) chloride,($CuCl_2$); Sodium phosphate, 0.2M (Na_3PO_4); 0.2M Aluminum chloride, ($AlCl_3$); Sodium sulfate, 0.2M (Na_2SO_4); 0.2M Barium chloride, ($BaCl_2$); Sodium hydroxide, 0.2M (NaOH); 0.2M Nickel (II) chloride, ($NiCl_2$)

Students will continuously obtain, evaluate, and communicate information. This is not a linear process. Students will communicate through writing and discussions to allow for formative assessment. This benefits the teacher, student, and whole group to guide instruction to clarify misconceptions or extend content.

Engaging Learners	**Phenomenon** Introductory Activity: Students perform the electrolysis of water so they observe how applying an electrical current to a solution of water and universal indicator (plus a salt to improve the conductivity of water), results in a red color at the positive electrode and a blue/purple color at the negative electrode. The link to the activity is: Electrolysis of water activity. ("File:Electrolysis.svg." *Wikimedia Commons, the free media repository*. 4 Mar 2016, 19:55 UTC. 18 Jul 2017, 19:10) *Teacher tips:* ● *Use sodium sulfate instead of table salt.* ● *Add a few drops of universal indicator to the distilled water. This should turn the solution green indicating it is neutral.*
	Obtaining 1. Students perform the experiment in groups of 2-3. 2. Students individually record their observations and come up with questions that they would like to answer based on their data. *Some suggestions:* ○ *What caused the color change at each electrode? Why were 2 colors produced?* ○ *Is this a chemical or a physical change? How do we know?* ○ *If a chemical change, what reaction occurred? What compounds or elements were involved?* ○ *Why was energy, the form of electricity, added to the system?* ○ *If a chemical reaction, how is it represented or written?*

	◦ *What type of reaction is this?* ◦ *How does the law of conservation of matter apply to the particles reacting?* 3. In groups, the students obtain information relating to their question (*Teacher may need to guide to make sure that students are answering questions related to the topic.*) on chemical changes, indicators of a reaction, energy changes during a reaction, classification of reactions, and steps involved in balancing a chemical equation to represent a reaction. 4. *Enrichment opportunity: Students may explore the concept of redox reactions in addition to the decomposition reaction.*
	Evaluating In groups, students will write a paragraph that summarizes their research. *Teacher Notes: student paragraphs should include a balanced equation and should identify that the reaction was the electrolytic decomposition of water yielding hydrogen gas and oxygen gas at each electrode, the color changes resulted from the simultaneous presence of hydrogen and hydroxide ions representing that a reaction had occurred at each electrode. Supporting evidence includes bubbles and color changes along with energy exchanges as signs of a chemical reaction. (Additionally, some students may research acid-base indicators and explain the color changes occurring at the electrodes. This leads into an investigation into acid-base reactions.)*
	Communicating Students share their paragraphs with other groups. Students may revise their conclusions and explanations based on input from other groups. *There are several ways for students to share:* ● *One student can present their data to the class.* ● *One group member stays at their station to share their data while the other group members rotate stations and listen/interact to presentations by other students.*
Exploring	*Obtaining* *Chemical reactions:* 1. Teachers will provide students with an online link to a simulation that explores the balancing of chemical equations. (Attribution: PhET Interactive Simulations University of Colorado Boulder https://phet.colorado.edu *PHET is a free and interactive simulation provided by the University of Colorado. It is used online or as a download. Teachers may register to access additional resources related to the simulation.)* Students will work in a group of two students through the simulation and play level one of the balancing equation game. They develop a strategy that helped them balance the chemical equations. Teachers should also instruct students to compute the reaction type - synthesis, decomposition, single replacement, double replacement, and combustion. 2. As students start level two of the balancing equation game, they should take turns in their group in using this strategy to balance and classify the equations. Encourage students to modify their

	strategies as needed. *Chemical reactions and energy:* 1. Students explore the phenomenon that dissolving salts in water can be used to raise or lower the solution temperature. 2. Students collect data and are challenged to design a cold pack that is effective, environmentally safe, and inexpensive—given certain criteria. 3. Students complete an argumentation session based on their data. Cold Pack Challenge Lab with teacher notes.
	Communicating ● In a paragraph and working through an example, each group writes down the strategy that allows them to balance the equation. ● Each group should critically compare their strategy with other groups to ensure they are not omitting any steps.
	Evaluating The teacher should evaluate students' ability to balance chemical equations by ● monitoring students during the simulation and evaluating their paragraph describing the steps to balancing and classifying a chemical reaction. ● provide students 5-10 equations to balance and classify.
	Formative Assessment of Student Learning
Explaining Finalizing Model	*Obtaining* Groups of 2-3 students should utilize their research and prior knowledge of particle diagrams to choose one of their balanced equations and draw a particle diagram that represents or models the changes in the particles during that type of reaction.
	Evaluating A diagram should include: ● correct number of atoms involved in the balanced reaction; ● correct bonding and orientation of atoms. ● atoms within polyatomic ions should not be separated and should be represented as a group that stays together during the reaction.
	Communicating The students produce a poster or video that models the reaction. ● The posters are presented or displayed in the classroom. ● Alternatively, students can make a time-lapse video showing the particles rearranging during the reaction, displaying the before and after stages as a continuum.
Elaborating Applying Model to Solve a Problems	**Phenomenon** **Teacher Demo:** Add drops of aqueous potassium iodide to aqueous lead nitrate in a beaker. (*Students will have already observed the clear solution turn yellow in a prior activity on chemical and physical changes. Also, they are familiar with potassium iodide from the Elephant's Toothpaste activity*)

	Obtaining Students will conduct research in order to answer the following questions: 1. What type of reaction is occurring? Propose a balanced equation for the reaction and classify the reaction type. 2. There are three types of reactions that this reaction type can undergo. Briefly describe the three reactions and the differences in products formed by each. 3. Explain why some substances are soluble in water and others are not. Explain the purpose of solubility rules. Your teacher will give you a chart of the solubility rules to analyze. 4. Perform the double replacement reactions and collect data. A sample reaction matrix is included below. *A student worksheet for this investigation is linked below. Teacher may choose to remove the questions and may also choose to get students to develop their own reaction matrix. These are included in the version below.* Example of student sheet Sample Reaction Matrix *as shown below*

A B -->	$CoCl_2$	$CuCl_2$	$AlCl_3$	$NiCl_2$	$BaCl_2$
NaI					
Na_2CO_3					
Na_3PO_4					
Na_2SO_4					
NaOH					

Students elaborate on chemical reaction rates with the Redefining Equilibrium Lab. Students build an understanding of equilibrium and how changes in temperature, reactant and product concentrations, and pressure affect a reaction. This lab takes students through several investigations of reaction rates; students will also develop and test models to explain equilibrium position.

Teacher Notes: Suggested procedure:

1. *Students should only need to test 2 mL of FeSCN stock for each test. With this amount, they only need to add about 10 drops of*

	additional reactant or product to observe a color change. 2. *Students should only need to test 2 mL of $CuCl_2$ stock for each test. With this amount, they only need to add about 5 drops of NaCl or $AgNO_3$ to observe a color change.* 3. *Multiple trials will reduce error and average results.* 4. *Students need to test at least three different amounts of additional reactant and three different temperatures.* 5. *Show students how to make ice bath and hot water bath. Solutions should NOT be placed directly on hot plates. Temperature of hot bath should not exceed 60C.*
	Evaluating ▪ From the data, students select **FIVE** of the reactions that resulted in precipitate formation. ▪ A balanced equation is written for each of the five precipitation reactions where students predict the products formed. ▪ Students apply the solubility rules to underline and name the precipitates in each of the five reactions. ▪ In two of the five reactions, students write both a complete and a net ionic equation representing the behavior of the ions at the microscopic level.
	Communicating Individually students balance five of the reactions and check their results with their group partners. Each student chooses a different set of equations to write a complete and balanced net ionic equation that represents the behavior of the ions at the microscopic level.
Evaluation	***Assessment of Student Learning***
	Formative Assessment ● *Paragraph written by student describing a strategy to balance and classify chemical reaction with teacher feedback.* ● *Online balancing of equations during simulation - monitored by teacher and help given to students as needed.* ● *Data table for lab - monitored by teacher to ensure students are following procedure correctly.* ● *Post lab questions and model analysis from equilibrium lab.* ● *Student communication of research at each stage with teacher monitoring to correct any misconceptions as they arise or guide the students in a different direction.* ● *Summative Assessment* ○ *Worksheet Balancing and Classifying Chemical Equations.* ○ *Poster or time-lapse video modeling the rearrangement of atoms during a chemical reaction.* ○ *Five balanced equations from investigation that demonstrate knowledge of balancing, solubility rules and prediction of products.*

SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	• Asking questions and defining problems. • Developing and applying models • Constructing explanations • Planning and carrying out investigations • Engaging in argument from evidence • Using mathematics and computational thinking. • Obtaining, evaluating and communicating information.
Crosscutting Concepts	• Patterns • Scale, proportion, and quantity • Systems and system models
Disciplinary Core Ideas	From A Framework for K-12 Science Education: • PS1.A: Structure and Properties of Matter • PS1.B: Chemical Reactions • PS2.B: Types of Interactions • PS2.C: Stability and Instability in Physical Systems • PS3.A: Definitions of Energy • PS3.B: Conservation of Energy and Energy Transfer

Additional Supports for struggling learners:

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.

General supports for the following categories:

Reading:	Writing:	Math:
1. Provide reading support by reading aloud or doing partner reads 2. Have the teacher model what they are thinking when reading the text 3. Annotate the text with students so that they may refer to it as they work through the lab	1. The teacher can provide a sentence starter for the students. 2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic). 3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.	1. Provide calculators as needed. 2. Provide graph paper as needed.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. The teacher should provide information to students in various formats to reach as many students as possible.
2. The students should be given adequate time to complete each part of the lesson.
3. The students should be allowed to express their knowledge in various formats.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.

Engage:

1. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student grouping.
2. The teacher should consider giving students question stems and an organizer for students to begin generating questions.
3. The teacher should have students share the questions that they generate. Then have the students discuss which questions seem most important. The teacher can then help students, using guiding questions, narrow down the list to find the most important questions that relate to the standard and lesson.
4. The teacher should consider giving students sources to use in their research.
5. The teacher should consider providing multiple ways for students to communicate their knowledge of the material. These formats could include writing, drawing or designing a presentation.
6. The teacher should provide students with time to revise their work after getting input and feedback

from other groups.

Exploring:

1. The teacher should provide students with the activity sheet.
2. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student grouping.
3. The teacher should find a spot within the lesson, stop the lesson, to have students share strategies that they are using to balance the equations. The teacher can quickly correct misconceptions and this will allow students that are having difficulties see how others are solving the equations.
4. The teacher should consider giving an organizer for students to collect data, record research and begin to design the cold pack.
5. The teacher should have clear and consistent guidelines for students to present or share their work. This should help students feel more comfortable sharing their work with the class.
6. The teacher should consider providing multiple ways for students to communicate their knowledge of the material. These formats could include writing, drawing or designing a presentation.
7. Students may need additional time to complete their assignment, share and revise.
8. The teacher should consider a formative assessment and then review, re-teach or enrich as needed.

Explaining:

1. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student grouping.
2. The teacher should consider giving students a rubric to evaluate their work. This increases student ownership of the work.
3. The teacher should consider providing multiple ways for students to communicate their knowledge of the material. These formats could include writing, drawing or designing a presentation.

Elaborating:

1. The teacher may need to do the demo more than once so that students can make observations.
2. The teacher should consider giving students sources to use for their research.
3. The teacher should consider providing students an organizer to record their observations, research and data.
4. The teacher should give students the reaction matrix and show students how to use it, have students practice using it in groups and then practice using it individually.
5. The teacher should remind students of lab safety procedures.
6. The teacher should remind students of directions as needed.
7. The teacher should give students an organizer to collect data and balance equations.
8. The teacher should consider a formative assessment and re-teaching, reviewing or enriching as needed.

Evaluating:

1. The teacher should consider providing multiple ways for students to communicate their knowledge of the material. These formats could include writing, drawing or designing a presentation.
2. Students may need additional time to complete their assignments.

The Instant Cold Pack Challenge

Phenomenon: *Dissolving of salts in water can be used to raise the temperature in hand warmers or can be used to lower the temperature in cold packs.*

Guiding Question: *Which salt should be used to make an effective and inexpensive cold pack?*

Obtaining:

Lab Challenge: Design an effective, environmentally safe, and inexpensive instant cold pack that meets the following criteria:

- Decreases in temperature by at least 2 – 10 °C as quickly as possible,
- Has a volume of about 60 mL,
- Costs as little as possible to make,
- Uses chemicals that are as safe and environmentally friendly as possible.

Introduction:

Have you ever had a sports injury and used a first aid instant cold pack? Cold packs contain 2 plastic bags – one bag contains an ionic compound (salt) and the other bag contains water. Squeezing the cold pack breaks the bags and allows their contents to mix. The dissolving of the salt in water results in an enthalpy change and a decrease in the overall temperature.

Background research:

When an ionic solid dissolves in water, the following 3 processes have to happen:

- Bonds between cations and anions in the ionic lattice are broken
- Intermolecular forces (hydrogen bonds) between water molecules are also broken and
- New attractions between water molecules and anions and water molecules and cations are formed.

The enthalpy change associated with the sum of these 3 processes is called the heat of solution ΔH_{soln}. At constant pressure, ΔH_{soln} is equal to the heat (q) lost or gained by the surroundings.

When heat is absorbed, the enthalpy change, *q*, is endothermic, and the enthalpy change is positive.

When heat is released, the change is exothermic, and the value of *q* is negative. Recall that heat (q) can be calculated by:

$$q = mC_s\Delta T$$

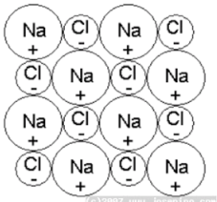
In this experiment, you will collect data that will allow you to calculate the enthalpy of solution occurring in aqueous solution. The data necessary to calculate the heat of solution can be obtained using a device called a calorimeter. This is an insulated container designed to minimize heat loss to the environment.

Prelab Research Summary:

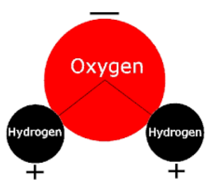
1. Explain how the dissolving of salts can be in a first aid cold pack?

2. Make a model that demonstrates the three processes involved in dissolving a salt. Also, indicate if you think each process is endothermic or exothermic. Use the representations below in your diagram.

NaCl before dissolving



Water molecule



STEP 1	STEP 2	STEP 3

Safety: All the salts used are tissue irritants and toxic by ingestion. Wear goggles and aprons. Wash hands with soap and water before leaving the laboratory.

Materials:

Thermometers/probes	Coffee cup calorimeter (2 cups)	Ammonium nitrate	Spatula
Balance	Sodium thiosulfate	Ammonium chloride	
Graduated cylinder	Magnesium sulfate	Deionized water	

Conduct an investigation: **Determine the heat energy change associated with each salt.**
Questions to consider in developing your investigation:

- What type of measurements or observations will you need to make?
- Is it important to know the change in temperature or just the final temperature?
- How does the mass of the water or mass of salt affect your calculations?
- How will you develop and organize a data table to collect your data?
- How will you minimize error?
- How will you calculate the heat energy change associated with each salt?
- How will you calculate the molar ΔH_{soln} for each compound?

Prices of Salts:

Salt	Amount (in grams)	Price
NH_4Cl	1000	$13.90
NH_4NO_3	500	$8.95
$MgSO_4$	100	$1.17
$Na_2S_2O_3$	500	$8.55

Initial Argument:
Once you have finished collecting and analyzing your data, you will need to develop an initial argument. Your argument must include a claim, which is your answer to the guiding question. Based on the cost information provided, and your experimental work, toxicity data and calculations, assess which chemical you believe will make the most cost-effective cold pack. ***You must supply evidence in support of your claim.*** You must justify your evidence – use a scientific concept or principle to explain why your evidence is relevant. This should also offer an explanation as to why some salts dissolving are exothermic and some are endothermic.

Claim:

Data and calculations to support your claim:

Argumentation Session:

All groups will share their written arguments with the rest of the class. Groups are encouraged to:

- Give each other feedback and critiques. The goal is to identify errors in techniques/ calculations or flaws in reasoning.
- Share procedures, data and calculations so other groups can evaluate your work and their approach.

Analysis Questions:

1. Did you change your claim after sharing with other groups? Outline your new claim and the reasons for changing your claim?

2. Changes in matter are generally classified as physical or chemical, based on whether new substances are formed through the process. Does dissolving represent a physical change, a chemical change, or an intermediate change? Explain your reasoning, including evidence from the animation you viewed.

Data table 1: Make a data table that shows the measurements for massing the calorimeter.

Data table 2: Make a table to show the change in temperature of the solution over time.

Data table 3: Class Data Summary

Substance	Cost per 100g ($)	Initial Temp C	Final Temp C	Temp. Change C	Cost per 5.00g ($)
NH_4Cl	1.390				0.0695
NH_4NO_3	1.79				0.0895
$MgSO_4$	1.17				0.0585
$Na_2S_2O_3$	1.71				0.0855

Data Table 4: Conduct internet research to find the following:

Substance	Toxicity data	Heat of Solution
NH_4Cl		14.6 Kj/mol
NH_4NO_3		25.69 kj/mol
$MgSO_4$		-91.2 kj/mol
$Na_2S_2O_3$		???

Data:

Calculations:

1. Calculate the heat of solution: $q_{soln} = mC_p\Delta T$ where m = mass of the 100 mL of water.

Calculate the molar heat of solution for your salt. Molar heat of solution is calculated as the amount of energy released when one mole of a substance is dissolved.

Teacher Notes:

Suggested procedure: Get each group to test 2 salts and share data with another group.

1. Mass your calorimeter.
2. Measure exactly 100.0 mL water in a graduated cylinder and pour into your calorimeter. Measure and record the initial temperature of the water.
3. Measure 5.00 g of your salt into a measuring tray. While monitoring the temperature of the water, quickly add all of the salt to the calorimeter. Stir.

1. Record the highest temperature reached. Remass to get the final mass of the calorimeter and hence the solution. Mass of solution is important.
2. Dilute the resulting solution with water and dispose of it per your teacher's instructions.
3. Get data from the other groups for each of the other salts analyzed.
4. As you conduct your experiment, keep detailed written records. Be sure to list all steps taken as you perform your experiment, and all measurements and observations made during the experiment.

Return to Instructional Segment

LAB - REACTIONS IN SOLUTIONS – PRECIPITATION

Guiding Question:

What are the products of precipitation reactions? Apply your knowledge of solubility rules and ion reorganization to write balanced equations that summarize the microscopic changes these reactions undergo.

Phenomenon: Teacher Demo – Adding drops of a solution of potassium iodide into a lead nitrate solution

Record your observations and conduct research in order to explain this phenomenon.

Research:

1. What type of reaction is occurring? Propose a balanced equation for the reaction and classify the reaction type.

2. There are three types of reactions that this reaction type can undergo. Briefly describe the three reactions and the differences in products formed by each.

3. Explain why some substances are soluble in water and others are not. Explain the purpose of solubility rules. Reference the solubility rules in your textbooks.

4. Write chemical equations for the following electrolyte dissolving in water:
    a. Copper (II) chloride

Exploring:

Apply your knowledge of solubility rules and balancing equations to predict the products of the following reactions.

Materials:

24 hole well plate for performing tests
Wash bottle
Goggles
Micro-pipettes
Cotton swabs for cleaning well-plate
Apron

Group A

Sodium iodide, 0.2 M NaI

Sodium carbonate, 0.2M Na_2CO_3

Sodium phosphate, 0.2M Na_3PO_4

Sodium sulfate, 0.2M Na_2SO_4

Sodium hydroxide, 0.2M NaOH

Group B

0.2M Cobalt (II) chloride, $CoCl_2$

0.2M Copper (II) chloride, $CuCl_2$

0.2M Aluminum chloride, $AlCl_3$

0.2M Barium chloride, $BaCl_2$

0.2M Nickel (II) chloride, $NiCl_2$

Safety:

➢ ***Safety goggles and an apron must be worn at all times. Some compounds are toxic. You are using small quantities so avoid contact and wash hands thoroughly before leaving the laboratory. Retain stock solutions in dropper bottles for future investigations. Dispose of waste from well-plates in paper towels (as solid waste) in trash cans.***

Design a Procedure:

Develop a procedure to test how the substances will react with one another. Some tips to aid your investigation:

1. Place the microwell plate over white paper with text. If you cannot read the text, then a precipitate has formed.
2. Use 4-5 drops of each reagent for each test. Test all possible combinations of Group A with Group B and create a reaction matrix to record your observations.
3. Be patient, not all reactions occur immediately.
4. If there are any combinations about which you are in doubt, repeat those tests. Check with other groups.

Data Table: Produce a reaction matrix to organize your data collection.

Communication:

Students should share their data with other groups as they may need to revise and repeat some reactions.

Error Analysis - How could you improve your experiment? Discuss any errors and how they affected data.

Communication and Evaluation:

Data Analysis:

- From your data, select **FIVE** of the reactions that resulted in precipitate formation.
- Write a balanced equation for each of the five precipitation reactions.
- Apply solubility rules to underline and name the precipitates in each of the six reactions.
- In two of the five reactions, write a complete and net ionic equations representing the behavior of the ions at the microscopic level.

Return to Instructional Segment

Sample Reaction Matrix

A B→	$CoCl_2$	$CuCl_2$	$AlCl_3$	$NiCl_2$	$BaCl_2$
NaI					
Na_2CO_3					
Na_3PO_4					
Na_2SO_4					
NaOH					

Return to Instructional Segment

Redefining Equilibrium Lab

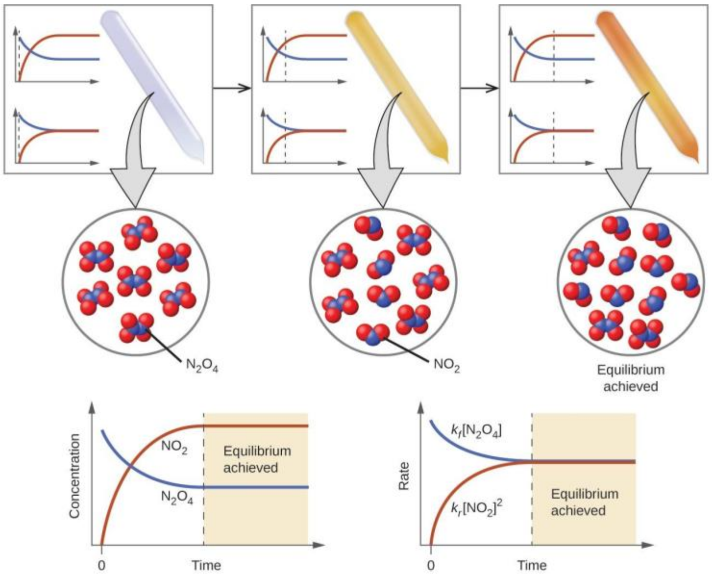
Phenomenon: Students observe color changes in a reaction as the reactants interact and change into the products as they approach equilibrium.

Guiding Question: How and why do changes in temperature, reactant concentration, and product concentration, affect the equilibrium point of a reaction?

Obtaining:

Introduction:

Consider the steps in how a reaction occurs: initially a reaction starts with just reactants in the beaker and no products. The reactants start to interact with one another and begin to transform into the products. The rate at which the reactants transform into products will start to decrease over time (as concentration of reactants decreases). The concentration of products is now increasing. However, at some point, some of the products will revert back into reactants. The rate at which the products revert back into the reactants will increase as the concentration of products increases. Eventually, a point will be reached where the rate of the forward reaction (reactants → products) and the rate of the reverse reactions (products → reactants) are occurring at the same rate.



This is ***equilibrium***, where the rate of the forward reaction is equal to the rate of the reverse reaction. The equilibrium point of a chemical reaction occurs when the concentration of the reactants and products is stable or unchanging.

Equilibrium is not static and can be changed. You will explore how three factors affect the equilibrium point of a reaction. You will develop a conceptual model that you can use to explain your observations and can use to make predictions for any reaction.

Safety: Iron nitrate is a tissue irritant & can stain skin & clothing. The other chemicals are toxic by ingestion and corrosive. Wear goggles, gloves & aprons. Wash hands with soap and water before leaving the laboratory. Use cautions when working with hot plates because they can burn skin.

Materials Available:

-Thermometers	- 0.1 M Iron (III) nitrate, $Fe(NO_3)_3$	- 2 beakers, 250 mL
-6 Test tubes/Rack	- 0.1 M Potassium Thiocyanate, KSCN	- Distilled water & Ice
-Graduated cylinder	- Beaker, 50 mL	-Beral pipettes

Engaging: Observing Phenomenon:

Iron (III) nitrate (yellow solution) reacts with potassium thiocyanate (Colorless solution) to form iron thiocyanate complex ions (orange red solution) according to the following reaction:

$$Fe^{3+}(aq) + SCN^{-}(aq) \leftarrow\rightarrow FeSCN^{2+}(aq)$$

Yellow Colorless Orange-red

1. Create a stock solution of $FeSCN^{2+}$ by mixing:
   40 mL of distilled water + 1 mL of 0.1 M Iron (III) nitrate, + 2 ml of 0.1 M KSCN.
2. Add 2 mL of this stock solution to several different test tubes to create a control and several to test.
3. Then change the temperature, reactant concentration or product concentration as needed. Leave the control for comparison purposes. Only 10 drops of reagent should be added when added reactant or product.

Investigation 1: Changing the Reactant Concentration.

Predict the Change to the system:

Predicted change if Fe^{3+} is added:____

Predicted change if SCN^{-} is added:____

Procedure:

1. Label 3 test-tubes 1, 2 & 3. Place 2 mL of stock solution in each test-tube in your test tube rack. Test-tube 1 will act as your control for color comparison.
2. Add 10 drops of iron (III) nitrate to test-tube 2. Record your observations in your data table.
3. Add 10 drops of KSCN to test-tube 3.

Data table:

Conclusion: *Restate your purpose and comment on whether your predictions were correct. Analyze your data and make a conclusion.*

Investigation 2: Changing the Product Concentration.

Predict the change to the system if more product is added:

Procedure: *(Recall: Only add 10 drops)*

1. Pour out the contents of test-tube 2 and 3 into the waste container at the teacher station. Replace test-tube 2 only with 2 mL of stock solution.
2. Add 10 drops of iron thiocyanate to test-tube 2. Record your observations. Predict the change if you add another 10 drops.
3. Add 10 more drops of product. Record the changes in the table below.

Data table:

Conclusion: *Restate your purpose and comment on whether your prediction was correct. Analyze your data and make a conclusion.*

Investigation 3: Changing the temperature of the system. *(Hot bath temperatures should not exceed 60°C.)*

Predict the changes to the system when the following changes are made:

Temperature increase:

____

Temperature increase:

____

Procedure:

1. Pour out the contents of test-tube 2 into the waste container at the teacher station. Replace test-tube 2 and 3 with 2 mL of stock solution.
2. Create a water bath by adding tapwater to a 250 mL beaker and placing on a hot plate. Allow the water temperature to reach anywhere in the range of 50-55°*C*). Use a thermometer to monitor the temperature.
3. Once you reach your desired temperature, remove the water bath and place test-tube 2 in the water for 5 mins. Record the temperature of the bath and any color changes that occur in your test-tube. Compare with your control.
4. Remove test-tube 2 and empty its contents into the waste beaker.
5. Pour out the hot water and half fill your beaker with tap water. Add ice to fill. Stir well and record the temperature of your water.
6. Add test-tube 3 to the ice-bath and record any changes that occur in the test-tube. Again compare with your control.

Data table

Conclusion: *Restate your purpose and comment on whether your prediction was correct. Analyze your data and make a conclusion.*

Once you have carried out your three experiments:

- Develop a conceptual model to provide an underlying reasoning for your findings about the effect of temperature, changes in reactant concentration and changes in product concentration on the equilibrium point of a reaction.

- Your model should include an explanation of what is happening on the microscopic level during the reaction. The collision theory of reaction rates and the concept of chemical equilibrium should serve as a foundation for your model.

1. **Model to explain how adding or removing a reactant affects a reaction.**

2. **Model to explain how adding or removing a product affects the equilibrium of a reaction.**

3. **Model to explain how changing the temperature of a system affects the equilibrium of a reaction.**

Test Your Model on a New System:

- Use your model to make accurate predictions about how temperature, and concentration affect equilibrium of a new system in the questions below.

Analysis Questions:

1. Paper coated with cobalt chloride is sold commercially as test strips for estimating humidity. The following reaction occurs between cobalt chloride and water:

$$CoCl_2(s) + H_2O(g) \rightarrow CoCl_2{\bullet}6H_2O(s)$$

Blue Pink

   a. What color will the test strip be when the humidity is low (20%), and what color will it be when the humidity is high (80%)? Explain your answer.

   b. The test strips come with a color chart to estimate humidity levels. What color do you think the paper will be when the humidity is about 50%? Explain your answer.

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