Chemistry Students Design Effective, and Inexpensive Hand-Warmers to

**Sell at the Student Store**

grade level(s): High School 10-11 subjects: general chemistry

authors:

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**Problem Statement:**

Following the results of a recent student-body poll, students indicated a strong preference for the sale of disposable hand-warmers at the student store. Chemistry and Algebra II students at MPHS, JHS, and EHS were approached by DECA and student store because they want to start selling hand-warmers during the winter months and need the chemistry and Algebra II students to do the research and design of these devices. The objective is to design an effective hand-warmer and consider the impact of the following on their decision: cost, effectiveness, safety, and environment impact.

**Conceptual Storyline:**

Students will be exploring the concept of heat transfer (aka calorimetry) by investigating the heat of solution of various soluble ionic salts. Using laboratory data, MSDS information, and the cost of the compound as provided from a chemical supplier, students will be asked to consider which salt would best fit their designed product. For example, if they are designing an instant-cold pack for athletic-trainers, the heat solution should be endothermic, relatively inexpensive, and non-toxic. Working in teams of four, students will need to investigate the concepts of enthalpy, endo- and exothermicity, calorimetry, heat of solution, and specific heat. All students will first explore through guided inquiry the concept of heat capacity by calibrating a Styrofoam cup calorimeter. They then explore the relationship between temperature change, mass of solution, and specific heat by measuring the heat of solution for Magnesium Sulfate. Following this common experience, they explore the heat of solution for various ionic solids and use the data to determine the best solid for their intended application. Through this project they will apply skills including but not limited to, mathematical analysis and comparison of data to MSDS and cost specifications, critical thinking, and communication of results in order to persuade, influence, and inform.

**Standards (NGSS, CCSS, CTE):**

**CCSS-M**

MP.1 Make sense of problems and persevere in solving them.

MP.2 Reason abstractly and quantitatively.

MP.3 Make a viable argument and critique the reasoning of others.

MP.4 Model with mathematics.

MP.6 Attend to precision.

HSN.Q.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

HSN.Q.2 Define appropriate quantities for the purpose of descriptive modeling.

HSN.Q.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

HSA.CED.1 Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

HSA.REI.3 Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

HSS.ID.6 Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.

HSS.ID.6a Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.

HSS.ID.6c Fit a linear function for a scatter plot that suggests a linear association.

HSS.ID.7 Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.

**NGSS**

HS-PS1-2 Construct and revise 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.

HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

HS-PS3-4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

**21st Century Skills:**

|  |  |
| --- | --- |
| **Skill** | **3 Big Ideas** |
| Communication | -Students will be creating a poster to share work with others.  -Students write a persuasive letter to convince student store to choose their design. |
| Enthusiasm and Attitude | -Connected problem to student store  -Students brainstorm ideas at beginning |
| Teamwork | -Students are assigned in groups to do the project  -Students are assigned roles?  -Students spend time coming up with group norms? |
| Networking |  |
| Problem Solving and Critical Thinking |  |
| Professionalism | -Students will share posters with students in different class.  -Students will “critique” other student’s posters.  -Could we ask store to respond to letter? |

**Locally and/or Personally Relevant for Students:**

Nearly all students will have personal experience with hand warming devices. They may have never considered the science and/or Math involved in these products. This topic will have real life relevance and allow them to see how their understanding of math and science relate to everyday products.

**Connections to career and educational pathways:**

This lesson connects to a wide range of careers. Throughout the lesson students will learn about different aspects that go into everyday products. There are environmental issues, quality control, manufacturing, and advertising to name a few. At the end of the unit students will spend a lesson exploring the different careers and educational pathways associated with this problem based lesson.

**Table of Content/Overview of Unit**

I. UNDERSTAND THE PROBLEM:

Lesson 1: Students are introduced to the Problem

* Students are assembled into teams of 4
* Create KWL charts
* Begin exploratory POGIL activity on ‘Calorimetry’ (1 day)

II. EXPLORE THE PROBLEM:

Lesson 2: Students finish ‘Calorimetry’ activity

* Begin writing Flow-Charts for Exploratory lab on Calorimetry (1 day)

Lesson 3: Students Conduct a Lab on Calorimetry (2 day)

* Students learn the process of measuring the heat of solution with MgSO4
* They will use this experience as the basis for designing their own procedures to test 3 other compounds

Lesson 4: Students explore chemical safety

* Teacher leads class through an MSDS page on MgSO4 and how to find relevant information for safety, toxicity, and environmental impact
* Students research the cost of the compound as found in a chemical supply catalog. (1 day)

Lesson 5: Create a procedure and flow-chart (1 day)

* Using the MgSO4 procedure as a template, students in teams of 4 design and construct a written procedure, a flow-chart, and all requisite data tables for 3 new compounds.

Lesson 6: Conduct Calorimetry Experiments

* Collect and analyze the calorimetry data for 3 separate compounds (3 days)

III. RESOLVE THE PROBLEM:

Lesson 7: Students Share and Evaluate Data

* As a class construct a Pugh chart for deciding which chemical is best for a hand warmer and why (1 day)

Lesson 8: Organize and Communicate Results

* Students write a persuasive letter and create a poster/advertisement for their hand warmer. (2 days)

**Storyboard for Design a Better Hand-Warmer**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Lesson :1Introduce the problem:   * What do you know? * What do you need to know?   Begin POGIL activity on ‘calorimetry’ |  | Lesson 2: Finish POGIL - calorimetry  Introduce Calorimetry Flowchart intro lab |  | Lesson 3: Introductory Lab & Discuss the Data  (Day 1) |  | Lesson 3: Introductory Lab & Discuss the Data  (Day 2) |  | Lesson 4: Introduce hand-warmer solutes & have kids research MSDS, cost, etc. Teacher facilitates discussion on designing experiment |
| **Day 1**  Reveal ‘student store’ interest in having chem/alg II students research the construction of a better handwarmer. Ask kids what information they would need to know  Background on calorimetry – POGIL |  | **Day 2**  Discus POGIL activity, read background info. on calorimeters, & design on intro lab (mixing water part a, and MgSO4 part b). Flow-chart |  | **Day 3**  Hand-warmer lab intro activity (parts a & b) |  | **Day 4** |  | **Day 5**  What’s an MSDS? How much do chemicals cost?  Students work on interpreting information from an MSDS and a cost-invoice for chemicals. |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Lesson 4: Students work in teams to design procedures and flow charts |  | Lesson 5: Lab Day 1 |  | Lesson 5: Lab Day 2 |  | Lesson 6: Student Team Time to analyze data, write persuasive letter, create media/poster  Pugh Chart? |  | Lesson 6: Student Team Time to analyze data, write persuasive letter, create media/poster |
| **Day 6**  Students have class time to design their procedures and flow-charts for collecting data on q for different substances (each group gets 2) |  | **Day 7**  Students collect data for compound 1 |  | **Day 8** Students collect data for compound 2 |  | **Day 9** |  | **Day 10** |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Lesson 6: Student Team Time to analyze data, write persuasive letter, create media/poster |  | Lesson 7: Students vote on previous periods’ team work to vote on the best overall concept |  |  |  |  |  |  |
| **Day 11** |  | **Day 12** |  |  |  |  |  |  |

**I. UNDERSTAND THE PROBLEM**

**Lesson 1: Introduce the Problem**

**“What do we need to know in order to make a Hand Warmer?”**

**Problem Statement:**

What do students need to know in order to design a hand-warmer that is effective and also considers the impact of the following on their decision: cost, effectiveness, safety, and environment impact?

This lesson introduces students to the problem and has them consider (in teams of 4) what information they already know about hand warmers, and what information they need to collect.

**Learning Objectives:**

* Students will identify what information is needed in order to collect data on calorimetry based on the completion of a POGIL activity.

**Materials:**

* Calendar of Events for Project
* Pretest
* Copy of “Letter from Student Store”
* POGIL activity on “Calorimetry” (1 per student)
* Flip chart + markers for teacher/recorder to write KWL
* Students will need paper and pen/pencil.

**Lesson Preparation:**

* Have a completed ‘answer key’ for the POGIL activity (see materials appendix)
* Review powerpoint for lesson flow/time structure. (see materials appendix)

**Time Required:** 60 minutes: 1.25 class periods

**Grouping of students for instruction:**

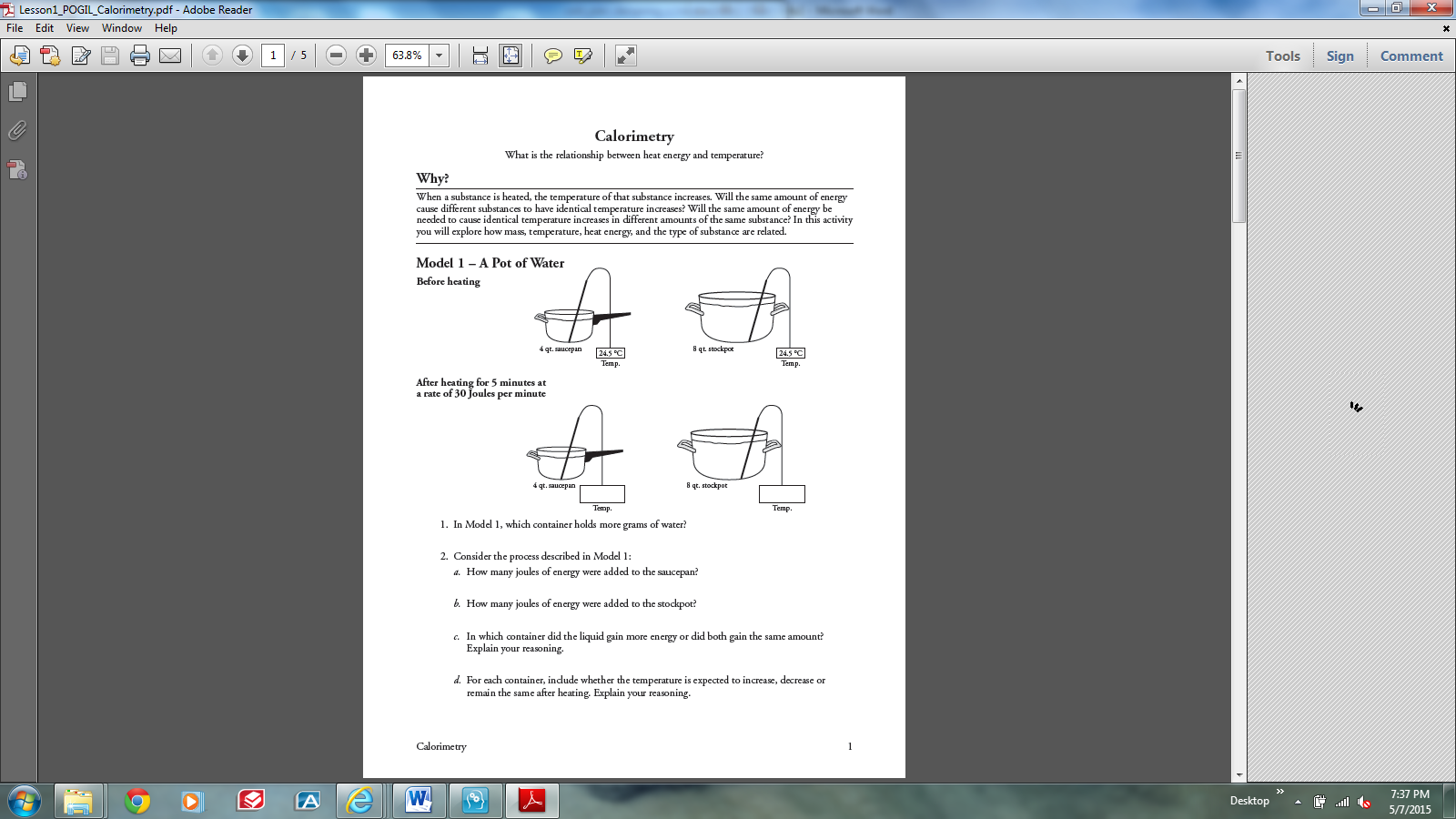
Students will be assembled into predesigned groups per teacher’s discretion. Each group will consist of at least one strong student, no more than one weak student, and two mid-level students. No team/group roles will be assigned at this time. Students will remain in these groups for the remainder of the unit.

1. **Introduction:**

* Give students pretest on prior knowledge of heat and heat transfer (10 min)
* Introduce the problem
* Provide students with a copy of a ‘letter’ from the school’s student store. Students should quietly read and mark the text for cues to what they already know (K) and what they need to know.
* As a class complete a KW chart

1. **Explore concept:**

* Distribute POGIL on calorimetry and have students complete in groups of 4



* **Sample questions to ask:**
  + Based on “Model 2”, what variables are the scientist controlling and how are the other variables responding?
  + What mathematical relationship do these data display?
  + Do you think other substances will demonstrate the same relationship between the variables? (eg, canola oil, alcohol, acetone?)

1. **Conclusion:**

* Students should understand the variables that affect temperature change in a sample of water
* Students should be able to describe the specific heat capacity of water and the units that it is measured/calculated

**Assessment:**

formative: pre-test, discussion of KEY (C:\Users\Addie\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.IE5\PBHXURGO\key-16457-large[1].png) ideas in POGIL activity.

summative: none.

**Accommodations:** Students with writing impairments may have a scribe.

**Resources:**

1. **Lesson 1 PowerPoint**
2. **Letter from the Student Store**
3. ***“Calorimetry”. POGIL Activities for High School Chemistry.*Trout, L. ed. Batavia, IL: Flinn Scientific, 2012.**
4. **Answer Key to POGIL Activity *“Calorimetry”***

**EXPLORE THE PROBLEM**

**Lesson 2: Calorimetry: How to Measure Heat**

**“How can chemists determine heat quantities in chemical reactions?”**

**Problem Statement:**

How can calorimetry investigations help students learn what kind of chemicals make the best hand-warmer?

This lesson introduces students to the conducting a laboratory investigation in calorimetry. Before they conduct the experiment, students will work in their teams of 4 to write a flow-charted procedure as a way to prepare themselves for the work.

**Learning Objectives:**

* Students will clearly identify the necessary procedures to follow and data to collect while measuring the heat of solution of MgSO4.

**Materials:** (per team of 4)

* Lab Handout for “12 - Designing a Hand Warmer, AP7654” FLINN Scientific (1 per student)

**Lesson Preparation**

* Refer to the lab handout and ‘teachers’ instructions at the back of the packet.
* Read through the completed flow-chart for the procedure to ensure the students are constructing flow-charts of similar completeness.

**Time Required:** 50 minutes: 1 class period + HW time for students who need time to finish

**Grouping of students for instruction:**

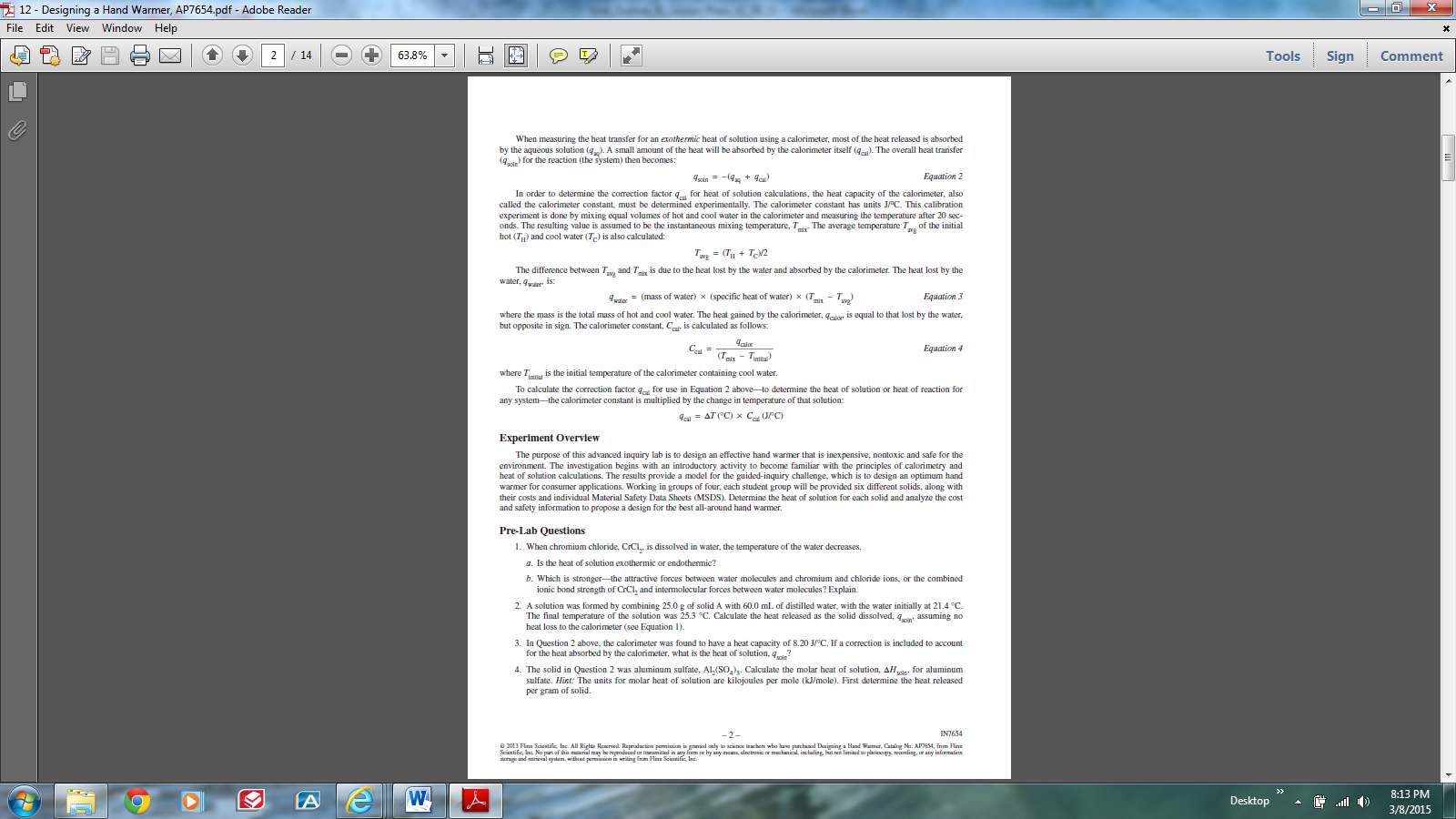
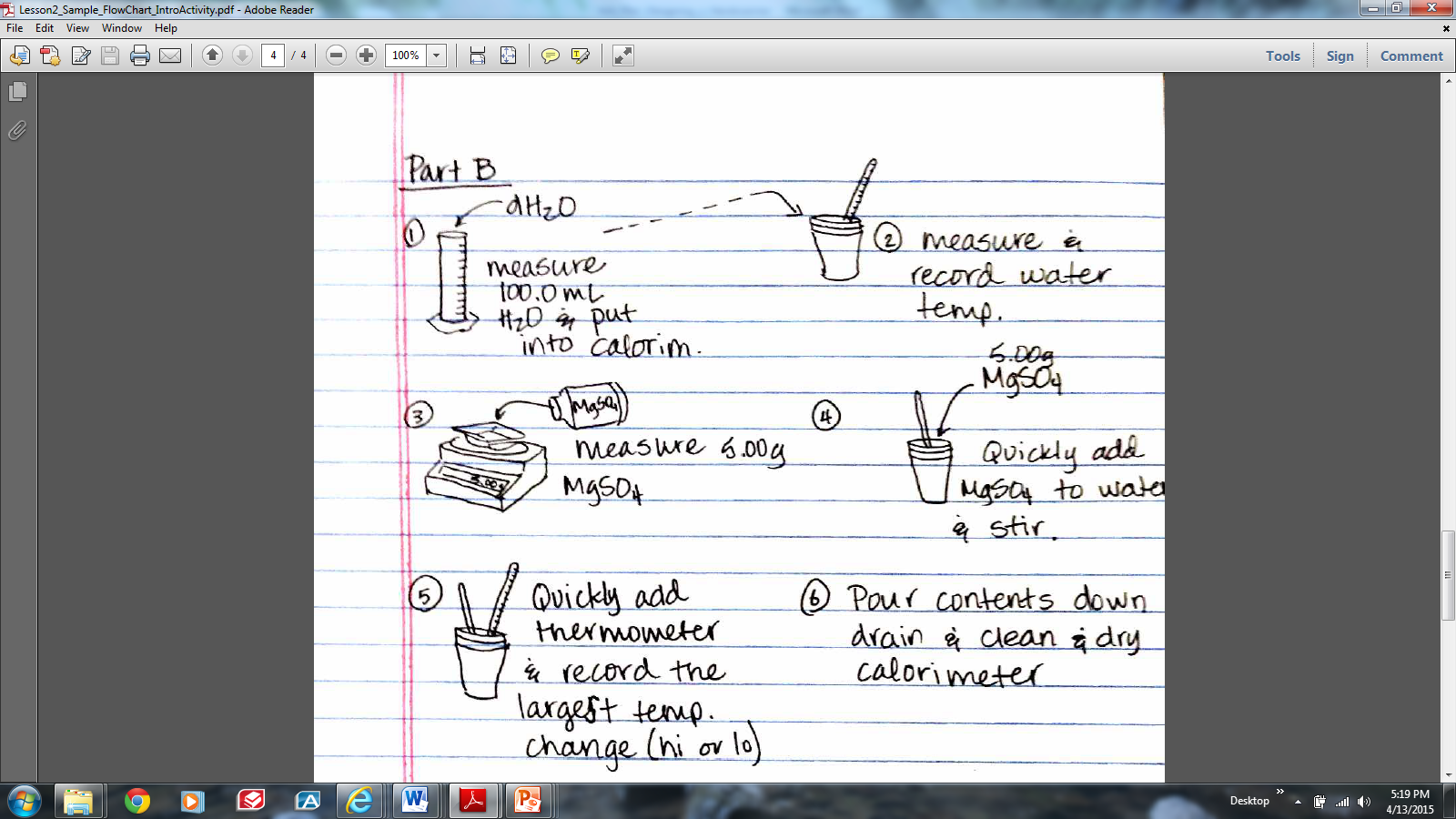
Students will be assembled into predesigned groups per teacher’s discretion. Each group will consist of at least one strong student, no more than one weak student, and two mid-level students. No team/group roles will be assigned at this time. Students will remain in these groups for the remainder of the unit.

1. **Introduction:**

* Distribute the Lab handout “Designing a Hand Warmer” AP\* Chemistry Big Idea 5, Investigation 12 - An Advanced Inquiry Lab
* Have students read & mark the text for the “Introduction” & “Background” sections (10 min). As they mark the text they should follow these guidelines:
  + Underline key ideas - Have them identify the purpose for the activity and put a box around it.
  + Circle key terms or new terms
  + Put “**?**” beside any content or concept that is confusing to them or they have questions about.
* Have students share out in their teams of four the markings they have on their handout. Identify any common sources of comment or question in the group. (5 min)
* Share out as a whole-class the new terms, key ideas, and the common questions had among team members. (5 min)

1. **Explore:**

* Explain today’s task: Today students will work in their teams of 4 to read through the “introductory activity”, and complete a prelab assignment and flow-charted procedure for the “introductory activity” parts A & B. (5 min)
* Students have the remaining class time to work in their teams to complete the prelab assignment, prelab questions, materials list, and the flow-charted procedure for parts A & B of the “introductory activity”.
* A sample prelab assignment and flow-charted procedure is in the Teacher Resources folder for this unit.

1. **Conclusion:**

* Students should understand the procedure for the introductory part of the lab tomorrow.
* Students should be able to discuss the pre-lab questions and how they relate to the introductory lab tomorrow including concepts of edo-/exothermicity, attractive forces, and calculating q.

1. **Assessment:**

formative: none.

summative: none.

1. **Accommodations:** Students with writing impairments may have a scribe or they may use a computer program to make the flowchart.

**Resources:**

1. **Lesson 2 PowerPoint**
2. **Lesson 2 Sample FlowChart**
3. **FLINN Scientifics, *“Designing a Hand Warmer”* - Advanced Inquiry Laboratory Kit AP7654. AP Chemistry Big Idea 5, Investigation 12.**

**Lesson 3: Calorimetry: How to Measure Heat**

**“How can chemists determine heat quantities in chemical reactions?”**

**Problem Statement:**

How can calorimetry investigations help students learn what kind of chemicals make the best hand-warmer?

This lesson introduces students to the conducting a laboratory investigation in calorimetry. Students will carry out an investigation on the heat of solution of MgSO4. Then, they will use this common experience to develop a procedure for collecting calorimetry data for 3 new substances in lesson 3.

**Learning Objectives:**

* Students will identify what information is needed in order to collect data on calorimetry based on the completion of a POGIL activity.

**Materials:**

* Prelab Quiz (1 per student)

(per team of 4)

* Set up eight stations – one per team. Each station should include the following materials:
* Calorimeter (two nested polystyrene cups)
* Graduated cylinder, 100-mL
* Heat-resistant gloves
* Hot plate
* Stirring rod
* Paper towels
* Magnesium sulfate, anhydrous, MgSO4, 5g
* Support stand and ring clamp
* Water, deionized or distilled
* Thermometer, digital
* Balance, 0.01-g precision (shared)
* Timer or stopwatch
* Beaker, 250-mL
* Weighing dishes
* Goggles – 4
* Aprons - 4
* *Safety Alert! Magnesium sulfate is a body tissue irritant.*

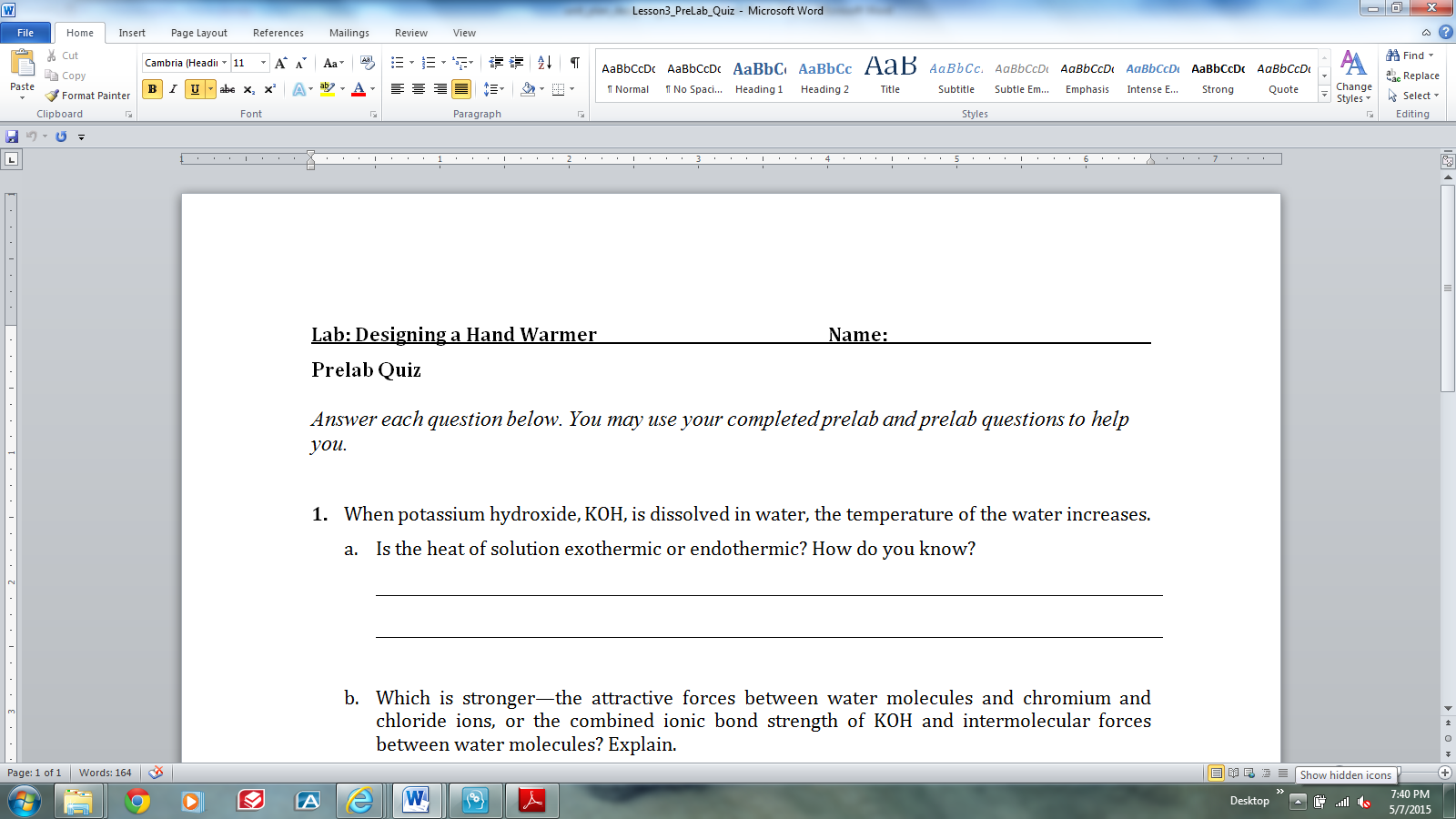
**Lesson Preparation:**

* Have copies of the intro activity quiz ready for students to complete as they enter. Students may use their prelab work on the quiz.
* Have ready all of the lab equipment above for students to easily obtain.
* Review safety precautions for working with glassware, hot-plates, and MgSO4.

**Time Required:** 50 minutes: 1 class period

1. **Introduction:**

* Have students complete the prelab quiz as they enter the room. (10 min) Remind students they are allowed to use their prelab questions on this quiz. Collect when the 10 minutes are done.



* Briefly discuss the lab procedure drawing student’s attention to the safety protocols and equipment use. Remind students of
  + The irritation caused by handling magnesium sulfate crystals.
  + Exercising care when handling glassware & hot plates.
* Ask students if there are any concerns or comments or procedural steps they are unsure of before you begin the lab.

1. **Explore concept:** (1 hr, 15 min)

* Monitor students and teams for following procedures, questions they may have, or safety considerations.
* Be mindful of the time. If your school schedule has 55-minute or less class lengths, allow 6-7 minutes at the end of the time for students to stop their work, and carefully clean up.
* These kinds of bell schedules should plan to do part A of the Introductory Activity on Day #1, and part B of the Introductory Activity on Day #2.
* As teams of students complete the introductory Activity, have them work together to answer question 7 from part B. Remind them to show their work in their notebooks.

1. **Conclusion:** (15 min) – Whole Class Discussion

* Lead the class in a whole-class discussion to clarify and explain certain procedures and calculations in the Introductory Activity.
  + Why did you need to calibrate your calorimeters?
  + What did value did you calculate for your calorimeter constants?
  + Was the reaction in part B endo- or exothermic? How do you know?
  + What did you calculate as the molar heat of solution for MgSO4? (take volunteer teams to share their calculations)

1. **Assessment:**

formative: pre-lab assessment,

summative: none.

1. **Accommodations:** Students who do not come prepared will have to work in the classroom to finish their prelab assignment. Not having this work finished on time is a safety concern. Any student with a mobility disability should work as they are able in their team. Lab facilities that are not ADA approved should not have students in wheelchairs using them. These labs are safe enough to do in a classroom on a flat surface; students needing this option should work with at least one other person. Students with writing impairments may have a scribe.

**Resources:**

1. **Lesson 3 PowerPoint**
2. **Lesson 3 Prelab Quiz**
3. **Lesson 3 Prelab Quiz Key**
4. **FLINN Scientifics, *“Designing a Hand Warmer”* - Advanced Inquiry Laboratory Kit AP7654. AP Chemistry Big Idea 5, Investigation 12.**

**Lesson 4: Chemical Safety and the MSDS**

**“What is an MSDS and What Information Does it Provide?”**

**Problem Statement:**

How do you read an MSDS to find information that can prepare you for an inquiry investigation in Chemistry?

This lesson introduces students to using an MSDS to find information. It is likely that students in high school have not had direct experience using an MSDS as a resource for laboratory/chemical safety

**Learning Objectives:**

* Students will learn how to read an MSDS by researching the six compounds that will be tested in the inquiry investigation component of their activity.

**Materials:** (per team of 4)

* 2 copies of the Lesson 4 “MSDS Activity”
* MSDS pages – 1 copy of each MSDS per group (CaCl2, NaCl, Na2CO3, NaC2H3O2, NH4Cl, LiCl)
* MSDS page for MgSO4 – 1 per student

**Lesson Preparation:**

* Place 4 copies of the MSDS for MgSO4 at each table for the introductory activity.
* Have sets of MSDS for other 6 compounds and MSDS activity pages in separate stacks ready to distribute when needed.

**Time Required:** 50 minutes: 1 class period

1. **Introduction:** (10 min)

* As students enter the room, have the following task posted on the board: “Five Minute Brain Storm: If MgSO4 is a potential hand-warmer compound, what information would you need to know about it to consider it as a possible selection?” (5 min)
  + Students should write their responses in their notebooks.
* Have students share their responses in their teams.
* Discuss as a class what criteria are important in your selection process? (make list on the board. Keep this list as you will return to it in lesson 7)

1. **Explore concept:** (30 min)

* Team Jigsaw: Student teams will divide into pairs. Each pair will receive copies of the MSDS for 3 of the 6 compounds that will be tested in the “Inquiry Activity”. Student Pair-Teams should complete the MSDS Information Page for their team and report back at the end of the period.
* Student Pairs can be directed to read the MSDS and ‘mark the text’ with highlighters or markers as a way to interact with the text and retrieve the relevant information for their research.
* Teacher should walk around the room and monitor teams for any questions that may arise.

1. **Conclusion:** (5 min) – Closing Discussion

* Teacher Says: “MSDS are standard forms. They may not all look the same, but they all have to contain certain information and it has to be organized in a particular way. Can you think of any jobs/careers where you may need to know how to read and obtain information from an MSDS?”
* Possible answers can include:
  + Chemist
  + Pharmacist
  + Firefighter
  + Hardware store employee
  + Hospital worker
  + Janitor

1. **Assessment:**

formative: none.

summative: none.

1. **Accommodations:** Students with writing impairments may have a scribe..

**Resources:**

1. **Lesson 4 PowerPoint**
2. **Lesson 4 MSDS Activity**
3. **FLINN Scientifics SDS Pages for Laboratory Grade Compounds: CaCl2, NaCl, Na2CO3, NaC2H3O2, NH4Cl, LiCl**

**Lesson Five: Planning Data Collection**

**How do we collect data about which substance will make the most effective hand warmer?**

**Problem Statement: Designing an effective hand warmer.** Today’s lesson has students create and flowchart their procedures so they can collect data on their substances.

**Standards:**

CCSS-M

MP.1 Make sense of problems and persevere in solving them.

MP.6 Attend to precision.

NGSS

HS-PS3-4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

**Learning Objectives:**

* Students will write a procedure for testing substances using calorimetry.

**Materials:**

* Procedure, data, and calculations from lesson 3 (introductory lab activity)
* Paper and pencil

**Lesson Preparation:**

* Organize substance assignments for students. There are two sets of three substances. Each group of 4 will test all 6 substances over the span of two days.
  + Set A = ammonium chloride, calcium chloride, sodium acetate
  + Set B = lithium chloride, sodium chloride, sodium carbonate

**Time Required:**

* 50-minute period

**introduction:**

* How can we take what we've learned so far and apply it so that we can test new substances?

**Exploration:**

* Students will write lab procedures (hopefully they will come to the realization that this is they need the same data that they collected in part b of lesson 3, so the procedure will be very similar to the previous procedure)
* Once students have an approved procedure, they will convert their written procedure into a visual flowchart
* Students should also create a data table to hold the data the need for the lab

**Conclusion:**

* By the end of the period all students will have a procedure. If they do not finish the flowchart in class, it must be finished before the next class period so they may participate in the lab

**Assessment:**

formative: student-generated procedures and flow charts

summative: none

**Accommodations:** Students with writing impairments may have a scribe. Students who do not come prepared will have to work in the classroom to finish their prelab assignment. Not having this work finished on time is a safety concern. Any student with a mobility disability should work as they are able in their team. Lab facilities that are not ADA approved should not have students in wheelchairs using them. These labs are safe enough to do in a classroom on a flat surface; students needing this option should work with at least one other person.

**Extensions:** Have students write a second procedure to test the same compounds but using different equipment/materials? Students could research more technical equipment they could use to collect more consistent/better data.

**Resources:**

1. **Lesson 5 PowerPoint**
2. **FLINN Scientifics, *“Designing a Hand Warmer”* - Advanced Inquiry Laboratory Kit AP7654. AP Chemistry Big Idea 5, Investigation 12.**

**RESOLVE THE PROBLEM**

**Lesson Six: Collect the Data**

**Which substance will make the most effective hand warmer?**

**Problem Statement: Design an effective hand warmer.** Today’s lesson has students using the procedures and flow charts they created in the previous lesson to collect data on their three assigned substances.

**Standards:**

CCSS-M

MP.1 Make sense of problems and persevere in solving them.

MP.6 Attend to precision.

NGSS

HS-PS3-4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

**Learning Objectives:**

* Collect data on substances

**Materials (per group):**

* 3 substances to test (15 g of each)
  + Set A = ammonium chloride, calcium chloride, sodium acetate
  + Set B = lithium chloride, sodium chloride, sodium carbonate
* 2 styrofoam cups
* Digital thermometer
* Distilled water
* Electronic balance with weigh boats (balances can be shared across multiple groups)
* Ring stand with ring
* Stir rod
* Safety goggles for each group member

**Lesson Preparation:**

* Laboratories should be set up and ready for students to use. Group procedures may vary slightly, so materials should be available according to the procedures that students have written

**Time Required:**

* 2 50-55 minute periods

**Procedure:**

**introduction:**

* Review lab procedures and flowcharts
  + Ensure each student has completed a flowchart and that all procedures are safe for students to be performing

**Exploration:**

* Students follow lab procedure to conduct lab day 1 and 2
* Students will test all six of the substances in their set – on day 1, half of the groups will test Set A and the other half will test Set B. On day 2, the groups will switch.

**Conclusion:**

* Each group will have data collected. Analysis of data of will occur in later lessons.
* Two full days might be more time than needed. If time is available at the end of day 2, lesson 7 can be started (students should be able to get started with calculations using their lesson 3 work as a guide).

**Assessment:**

formative: Students performance on lab will serve as formative assessment

summative: none

**Accommodations:** Students with certain motor or visual impairments may struggle with this lab. A supportive group will allow these students to fully participate and to learn. If students do not have pre-lab work done, they will remain in the classroom finishing the pre-lab work before rejoining their group in the lab.

**Extensions:** Students can do their own research on other substances or other applications of the substances used.

**Resources:**

1. **Lesson 6 PowerPoint**
2. **FLINN Scientifics, *“Designing a Hand Warmer”* - Advanced Inquiry Laboratory Kit AP7654. AP Chemistry Big Idea 5, Investigation 12.**

**Lesson Seven: Analyze Data and Report Results**

**What does our data mean? Which substance should we choose?**

**Problem Statement: Design an effective hand warmer.** Students will have 3 days after their lab experiments are complete to analyze their data, write a persuasive letter, and create their poster to communicate their result.

**Standards:**

CCSS-M

MP.1 Make sense of problems and persevere in solving them. MP.2 Reason abstractly and quantitatively.

MP.3 Make a viable argument and critique the reasoning of others.

MP.4 Model with mathematics.

MP.6 Attend to precision.

HSN.Q.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

HSA.CED.1 Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

HSA.REI.3 Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

NGSS

HS-PS1-2 Construct and revise 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.

HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

HS-PS3-4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

**Learning Objectives:**

* Use raw lab data to calculate relevant information in order to choose a best option according student-chosen criteria
* Write a persuasive letter to the student store describing why their choice is best
* Create a poster to communicate information about choice in a compelling, visual way

**Materials (per group):**

* Pencil and paper
* Access to MSDS information for all substances
* Price data for all substances
* Posters, markers
* Computers to type persuasive letters? Can also be hand-written

**Lesson Preparation:**

* Prior to this lessons students need to have collected their data and will have completed calculations for the introductory activity. Students will need to bring that data and their prior calculations, which will serve as the template for their analysis today.

**Time Required:**

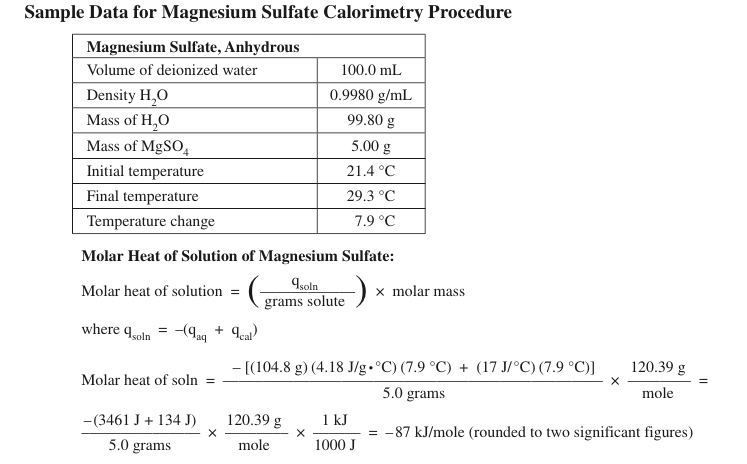
* (3) 50-55 minute periods

**Procedure:**

**introduction:**

* **Data Analysis**
  + Students will use their data from lesson 6 to complete calculations so they can find the heat of solution for each of their substances. They should be guided through the first of these calculations, and reminded that these calculations match what they did in lesson 4.
  + Students can then work in their small groups to complete the rest of the calculations. They should share the work load across group members.

*Figure: calculation process for finding heat of solution from data (including calorimetry constant data calculated in lesson 3) Image from original Flinn lab.*

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**Exploration:**

* Data Analysis
  + Students now have a quantitative way to compare efficiency of the substances. They should combine this lab data with pricing data and MSDS information to make an informed decision on the best substance to use for their hand warmers
  + Students will complete a Pugh Chart at this step as a decision matrix
    - [Insert Kim's Pugh chart stuff here]

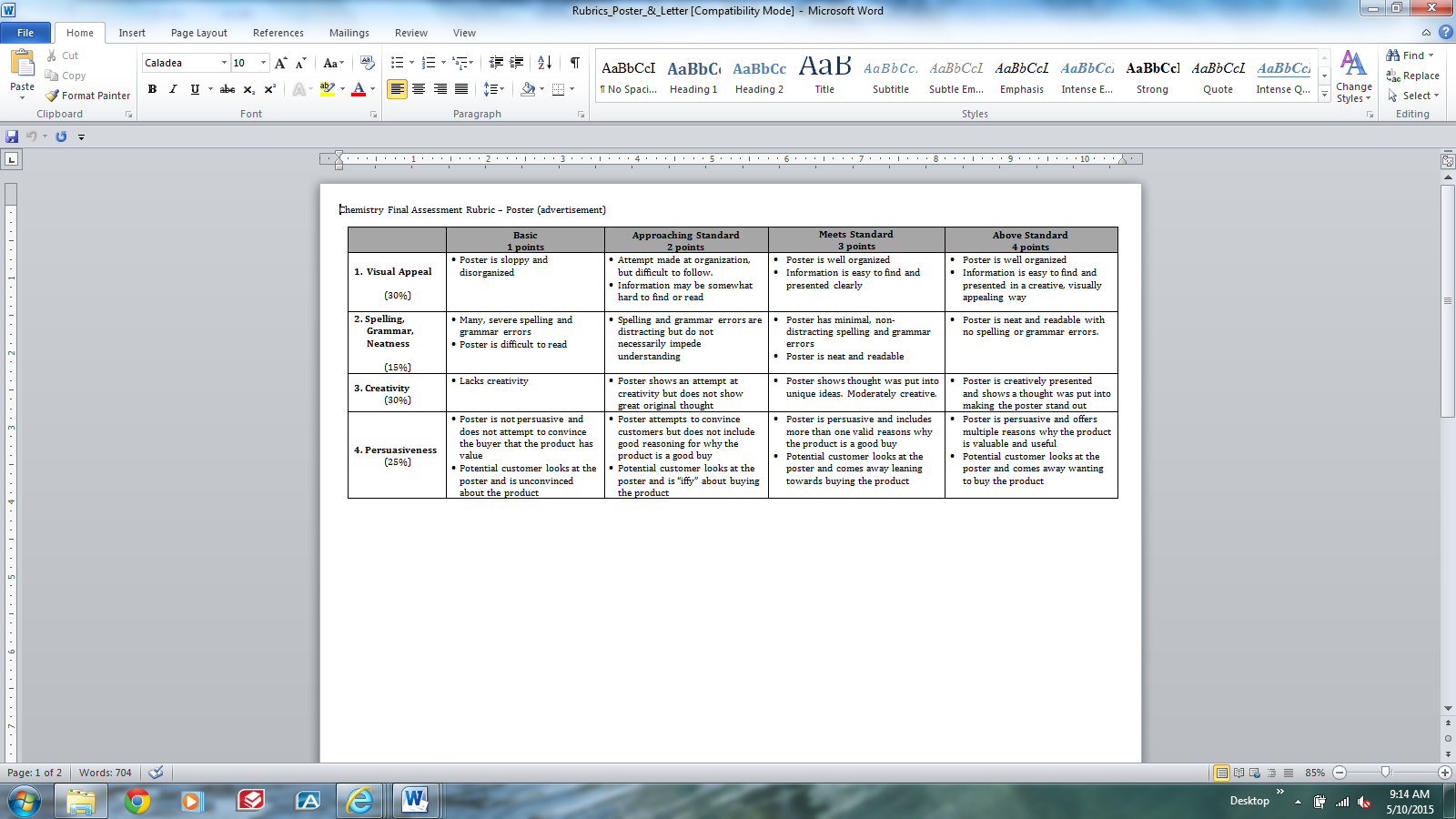
**Conclusion:**

* Persuasive letter
  + Students will write a persuasive letter to the student store explaining both the benefits of their choice and the relative downfalls of the other options
  + The letter should include information about heat of solution, price, and safety aspects of the materials being analyzed
* Poster creation
  + Students will create a poster to visually display the information they have discovered throughout this unit
  + Poster should include substance chosen, benefits, and detriments of the other substances

**Assessment:**

formative: Students' calculations (and Pugh charts) serve as an intermediate step on the way to their final products. These can be used as a formative assessment of students' understanding of the quantitative aspects of this project.

summative: This lesson includes the final product creation. A scoring rubric for the poster is provided in the resources for this project. Students are writing a letter and creating a poster that will include all the information learned throughout the unit and their conclusions.



**Extensions:** Students can do their own research on other substances or other applications of the substances used. Students may also want to research containers for hand warmers – what kind of materials can we use to hold the chemicals chosen in this unit?

Instant ‘endothermic’ reactions are just as important to consumers as exothermic reactions. A possible extension/modification to this activity would be to have students design effective “cold packs” for the sports medicine program at their school.

**Resources:**

1. **Lesson 7 PowerPoint**
2. **Lesson 7 Poster Scoring Rubric**
3. **Lesson 7 Student Response Letter Scoring Rubric**
4. **FLINN Scientifics, *“Designing a Hand Warmer”* - Advanced Inquiry Laboratory Kit AP7654. AP Chemistry Big Idea 5, Investigation 12.**