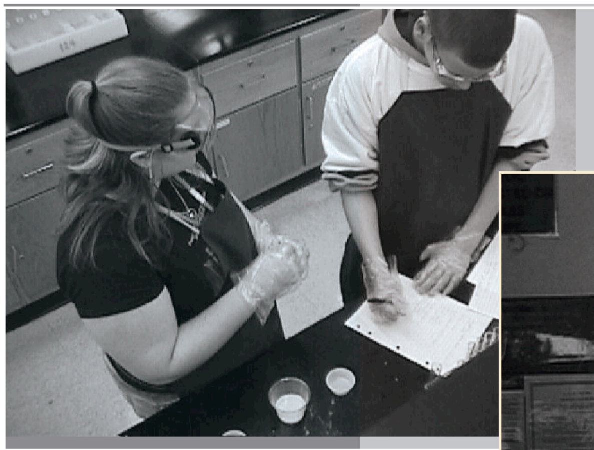
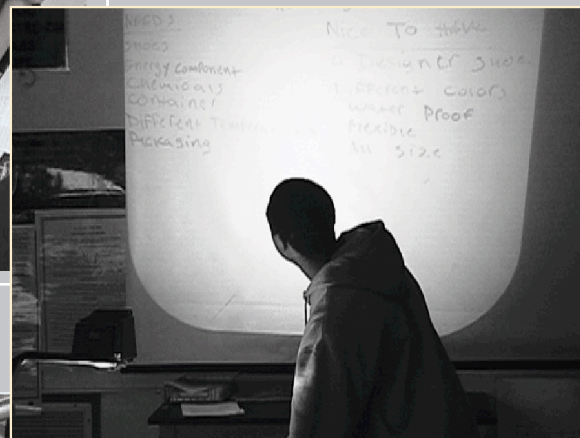
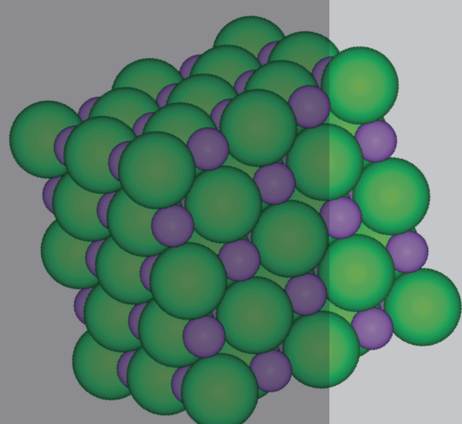
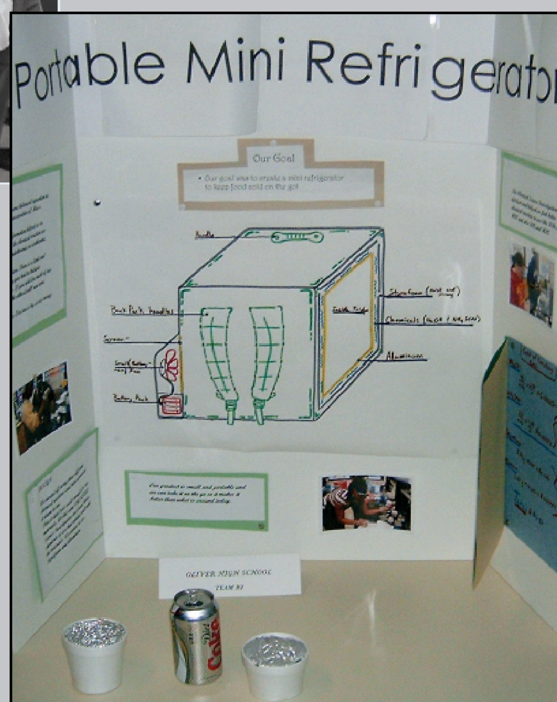
Team Guide









Designing a Heating/Cooling System

A Design-Based Immersion Unit

DRAFT VERSION 3 MARCH 2007

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NOW THAT YOU'VE THOUGHT ABOUT IT...

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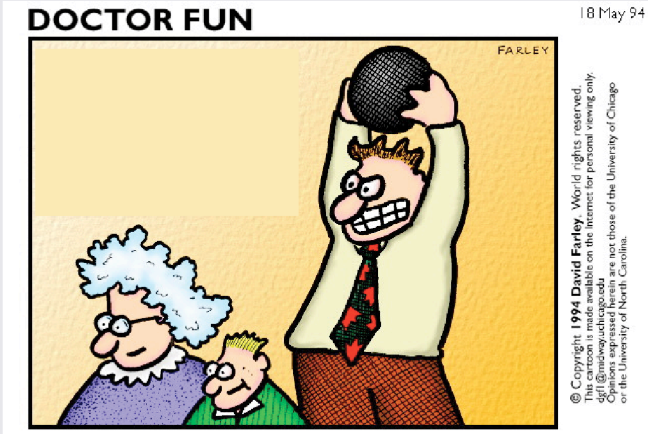
CHAPTER 1
Introduction

WHAT EXACTLY IS ENGINEERING?

Engineering is the practice of designing solutions for practical problems. Scientists may ask why a problem occurs and do experiments to answer their questions. Engineers try to find out how to solve a problem and create a solution. One way to think about the difference between engineers and scientists can be summarized as:

A scientist builds while learning,
but an engineer learns while building.

Over the next few weeks, you and your classmates will be working as chemical engineers to create a prototype of a heating/cooling system. Chemical engineers use their knowledge of chemistry, math, physics, and everyday things, to make new products and to solve real problems in safe and economical ways. Like an engineer, you will use what you know already to help you build a prototype of your heating/cooling system. In this process, you will learn many new ideas about chemistry that will help you improve your design.



CHAPTER 1
Working in Teams

Teamwork is a useful way to share ideas and to work towards solutions for problems. In this unit, you will be part of a team of engineers in charge of creating a heating/cooling system that solves a problem in your life. Below are a few suggestions to make the most of this teamwork experience.

LISTEN AND RESPECT

The two basic rules for successful teamwork are to listen to each other's ideas and to respect each other's ideas.

RECORD IDEAS

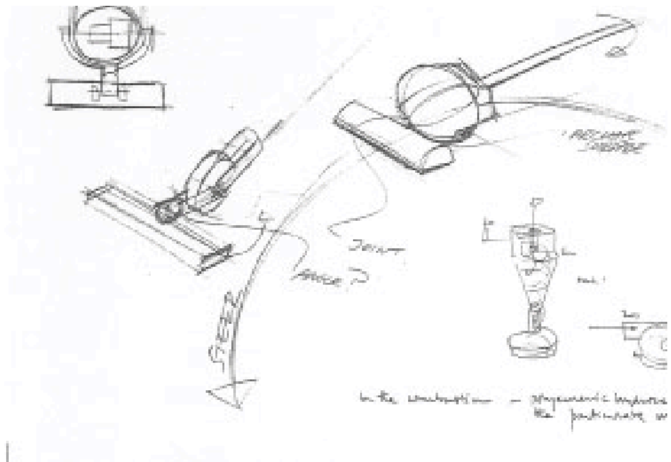
It is important that not one of your ideas is lost. Engineers and scientists use a lab notebook to record their ideas. To avoid losing your ideas, you should record them in your team guide.

REFLECT AND ASSESS

Learning includes reflection and assessment. You will think about what you have done (reflect) and evaluate how successful it was (assess) using this team guide.

Sweeping Up The Market

What is design and engineering all about? Do you have to be trained to be able to invent something and make money from your invention? These questions can be answered by looking at the story of one popular modern inventor, James Dyson.



DYSON THE INVENTOR

In his youth, James Dyson, the founder and chief executive of Dyson Ltd, was an avid long-distance runner and had aspirations of becoming an artist. Dyson studied design at the Royal College of Art, in London. While he was a student, he developed a boat called the Sea Truck. In 1979, after a short career with Rotork, the company responsible for manufacturing the Sea Truck, and a short stint running a company with a few friends, Dyson set out to pursue his own dreams.

One weekend while vacuuming his home, Dyson became increasingly frustrated with the lack of suction in his vacuum cleaner. He decided to pull the vacuum cleaner apart to figure out the cause of the problem. He assumed the loss of suction power was because the bag was full. He put a new bag in the vacuum cleaner and tried again. Still low suction power! He opened up the vacuum cleaner again. After looking more closely, he discovered that dust was clogging the paper bag's pores.

Dyson immediately began to experiment with alternative designs for the vacuum cleaner, using common household items like masking tape and the cardboard from cereal boxes. He wanted to see if he could create a better, and bagless, vacuum cleaner. Dyson spent the next several years building many prototypes of a bagless vacuum cleaner.

Dyson learned that a law of physics was the key to making his design work. The idea that particles passing around a curved surface accelerate rapidly was a physics concept that Dyson used to his advantage. Starting from this physics concept, Dyson was able to design a system that had a revolving cone-shaped cylinder. When air passed through this revolving cylinder, the dust clung to the sides, while the air escaped through a hole at the other end. This design proved successful. However, Dyson continued to refine his design until he created a machine that had two cylinders that he called 'cyclones'. The outer cylinder collected larger debris and the inner cylinder collected finer material. The dust and debris were trapped in a plastic bin that surrounded the two cylinders. When it was full, the bin could be emptied and fit back into place.

It took Dyson years, and literally thousands of prototypes to come up with his “dual cyclone” design. “I made hundreds of cyclones, then thousands of them,” Dyson stated. He hand-built 5,127 prototypes of the Dual Cyclone vacuum cleaner. Dyson obviously felt that all of this time was well spent and insists that the “Edisonian” process of invention is worthwhile: “When you develop a prototype, you have to change one thing at a time”. If you make several changes simultaneously, how do you know which change has improved the object and which hasn’t? You must be very patient, testing, and retesting and building a series of results.” Dyson remembers days where he thought his invention would never work, but by 1982 he had a working machine!

> “...you must be very patient, testing and retesting and building a series of results.”

The Dyson vacuum cleaner is sold in 37 countries and, at the end of 2004, sales had exceeded $757 million! Only three years after Dyson introduced his vacuum cleaner to the US market, it has become the country’s largest-selling vacuum cleaner brand. But this rise to the top took great endurance, perseverance, and determination by Dyson. He believes that his success is the result of the excellent design and the innate effectiveness of the machine. The Dyson Cyclone is now in the Twentieth Century Gallery of the Victoria and Albert Museum in London.

This article is has been adapted for this unit from:
Bentley, D. (2005). Cleaning up the market. Hemisphere Magazine, November, 86-90.

____

____

As you read the article, write three questions that you would like Dyson to answer in more depth.

While reading I wondered or wanted more information about...

1.

2.

3.

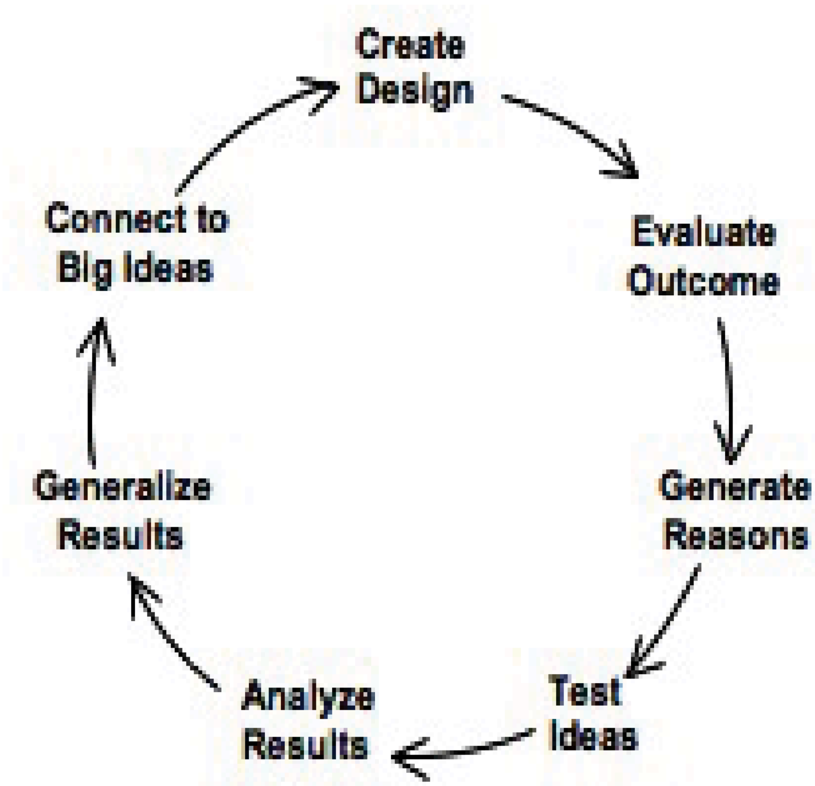
Discuss the questions below in your teams. Be prepared to share your ideas with the class.

1. What general steps did Dyson follow that helped him to design and refine his prototype?

2. What need was Dyson trying to solve when he started to design his vacuum cleaner?

3. Why do you think Dyson made so many prototypes?

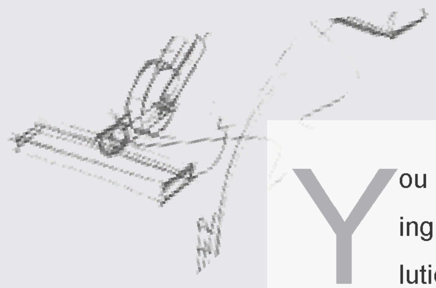
Date ____________________



A picture of this cycle is located on most of the pages in the team guide to help you think about ways to improve your design. The table below gives you more details about each step of the cycle.

STEP	IN THIS STEP OF CYCLE YOU WILL...
Create Design	Try to make a design based on your prior knowledge or experiences.
Evaluate Outcome	Determine whether your design did or did not work.
Generate Reasons	Think about reasons why your design did or did not work. Brainstorm all the possible reasons for why you thought your design did or did not work.
Test Ideas	Test systematically, one of the ideas that you brainstormed for why your design did or did not work.
Analyze Results	Summarize the data you collected to see whether the results do or do not support the idea(s) you tested.
Generalize Results	Determine whether the patterns that you noticed from the data you collected can be summarized to make a general statement about your idea.
Connect to Big Ideas	Think about how what you tested is related to a scientific theory and how you can use this information to improve your design.

CHAPTER 2
Planning Your Design

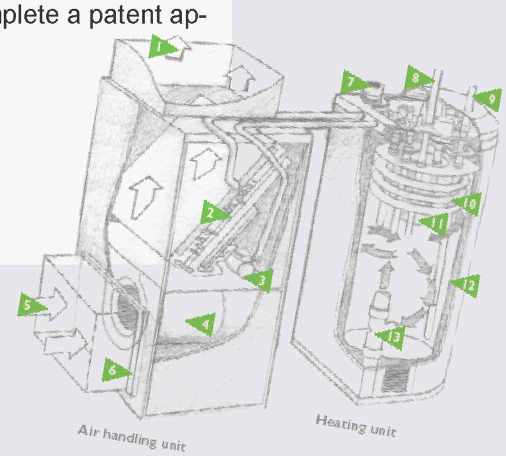


You will take the role of an engineer during this unit. You will determine a solution to a problem in your life that requires a heating or cooling system. Engineers think about needs when they design new products or improve existing products. A **need** can be thought of as a problem that requires a solution. You saw from the article that sometimes inventors improve existing products so that those products make their work easier or their life more comfortable.

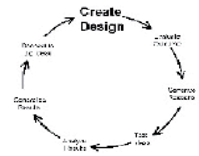
Need
A problem that requires a solution

You will design a system that solves a problem in your life. You can either improve an existing product or create a new product to accomplish your goals. The next few lessons will help you organize your ideas and think through your design.

You will have lots of ideas. You should record these ideas as you continue to develop the design for your heating/cooling system prototype. Keeping track of your ideas as you work will be important because at the end of this unit you will complete a patent application for your design.



Planning NEEDS & NEW IDEAS



As a team, examine your own needs for a heating/cooling system. Encourage everyone to share their ideas freely. Do not criticize others' suggestions. By the end of the class, you will need to determine the heating or cooling system you would like to design.

NEEDS: Describe situations in your life where a heating or cooling system would be useful.

NEW IDEAS: Create a list of heating/cooling systems that might meet your need. Explore as many ideas as you can. These ideas can include existing or new products.

OUR DECISION: Explain the need your team will meet and the new idea you have for a system that will meet that need.

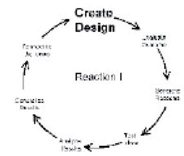
Our team's choice for a heating/cooling system is

____

(name of your team's product).

Planning **SKETCH DESIGN**

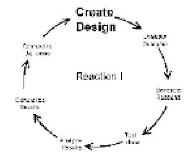
Choose an artist for your team. Sketch your design. Include ideas from all team members. Label each part of the design that you think is essential for making your design function.



Date ____________________

Planning ***USES / NEEDS***

In your teams, brainstorm a list of many heating and cooling systems. Describe why the systems are needed and the essential parts that are required for each system to operate. Be creative! Do not limit your ideas or thoughts to just one type of system. All of your ideas should be recorded no matter how crazy they may seem.



NAME OF SYSTEM	WHY IS IT NEEDED?	ESSENTIAL PARTS

What essential parts are the same among these systems?

What is different about these systems?

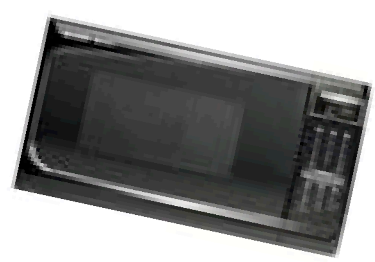
Date

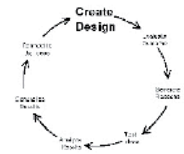
NOW THAT YOU'VE THOUGHT ABOUT IT...

We use heating/cooling systems in our daily lives to warm or cool objects or environments. An example of a heating system is a microwave. We need microwaves to heat our food very quickly.

Other heating/cooling systems keep a constant temperature in an environment. For example, air conditioners are used to lower the temperature in a closed space, and can be set to keep the temperature constant. Heaters are very similar to air conditioners, except that they are used to increase the temperature rather than decrease it.

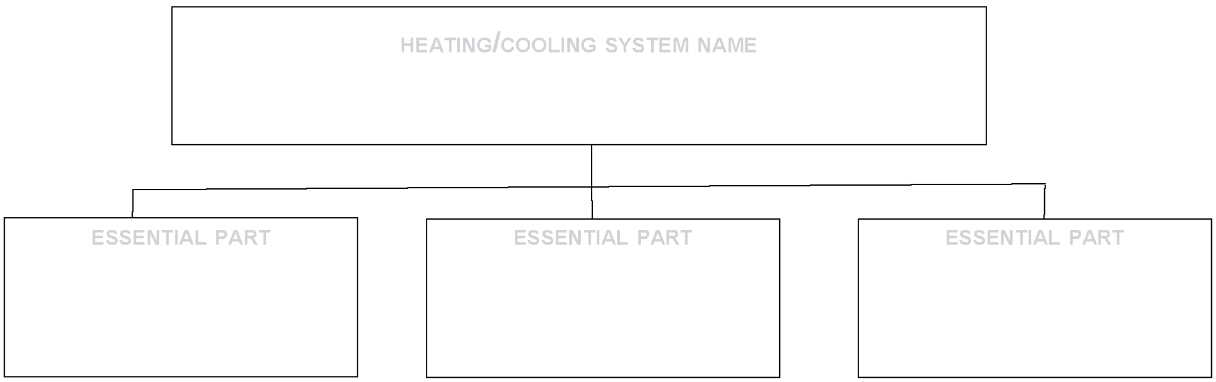
Individual heating/cooling systems may work differently, but one thing they have in common is that they work to increase or decrease the energy levels of the surrounding environment. A heating system increases the energy levels in the surrounding environment. A cooling system decreases energy levels.





Engineers use diagrams and models to help them think about systems. Diagrams and models are convenient ways to describe how a system works.

In the previous task, you identified essential parts of heating/cooling systmes. Use the system diagram below to define the parts that are necessary for your heating/cooling system to work. Add more boxes as needed. Be prepared to share your ideas with the class.



Definition

Subsystem is an essential part of a system that accomplishes one goal

SYSTEM FUNCTIONS

In your teams, place the name of each subsystem in your design. Write a description of the specific function for each subsystem. Make sure that each subsystem has only one function. You should think carefully about each function because the more you clarify the goal of each subsystem, the better your design will be.

SUBSYSTEM NAME	FUNCTION

Date

NOW THAT YOU'VE THOUGHT ABOUT IT...

SYSTEMS AND SUBSYSTEMS

To build your heating/cooling system according to the requirements you will generate, you will need to understand what a system is and how a system works.

WHAT IS A SYSTEM?

A system can be defined as several parts that are functioning together in order to achieve a desirable goal. All systems have a main goal, or purpose.

Instead of focusing on the entire design, engineers break it down into its subsystems. This strategy helps them tackle their task by focusing on one part of the prototype at a time. Subsystems can be thought of as the essential parts that are needed to operate the system. Each subsystem is designed to accomplish one goal, or function. Dividing a design into its subsystems and functions clarifies its goals.

CHEMICAL SYSTEMS

To create your heating/cooling system design you will use energy from a chemical system. Chemical energy depends on the structural arrangement of atoms or molecules. This arrangement may be the result of chemical bonds within a molecule. As the bonds undergo rearrangement, the chemical energy transfers into a new storage form called kinetic energy. Kinetic energy is responsible for the heating and cooling processess. For example, when a fuel is burned the chemical energy released goes into the kinetic energy storage form and we feel a temperature increase.

Now that you have thought about each subsystem and its function for your heating/cooling system, you should figure out what features are necessary for your design to work.

Each of your subsystems has requirements. There are two types of requirements. Must-have requirements are necessary for your design to work. Nice-to-have requirements are not necessary for your design to work, but they make it more attractive.

Definitions

Must-Have Requirements are features that are necessary for a design to work.

Nice-to-Have Requirements are unnecessary features that make the design more attractive.

Record your ideas about the requirements for your design. Decide which of these requirements are must-have and which are nice-to-have.

REQUIREMENTS	MUST-HAVE	NICE-TO-HAVE

Now that you have thought about fuctions and requirements, sketch your revised design in the space below. Include as much detail as possible so that others can understand how your design will work.

Below are some ideas you should discuss as a team. Be prepared to address these ideas during your presentations

Explain your need for this design and the design's requirements.

Use your sketch to describe how the design will function.

Describe what other information you will need to understand as you construct your design.

Date

Planning REFLECTION I

It is very important for chemical engineers to record their progress during product development. Throughout this unit you will practice this important skill using the Reflection Logs.

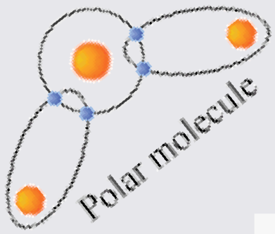
How did thinking about your needs and requirements help you plan your design?

Think about the comments from your peers about your design and the comments about your peers' designs. How could you improve your design based on any of these comments?

How do you think that your design might change once you begin to think about the chemical possibilities?

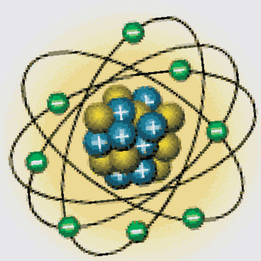
Date ____________________

CHAPTER 3
Creating Your Design



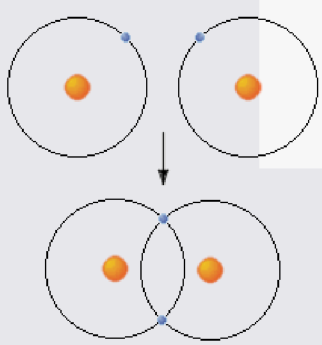
Now that you've thought about heating/cooling systems, why we need them, how they work, and the functions of their essential parts, it is time to think about the resources that you have available to create your design.

To create your design you will use chemical energy. Chemical engineers have lots of knowledge about how chemicals interact with each other. They use this knowledge to help them make good design choices.



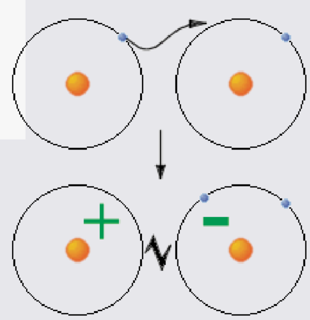
There are a number of chemistry concepts that you might use to understand what happens in your system and to improve your design. Many of these concepts will be explored as you test your ideas and analyze the results of those tests. Also, engineers use resources to help them make calculations. Many of these resources will be provided for you throughout the unit. This will be an important information for you to use as you build your knowledge and will help you to make better decisions about your design.

So let's begin....the Reaction Subsystem...



Covalent bond

$$NaCl_{(s)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

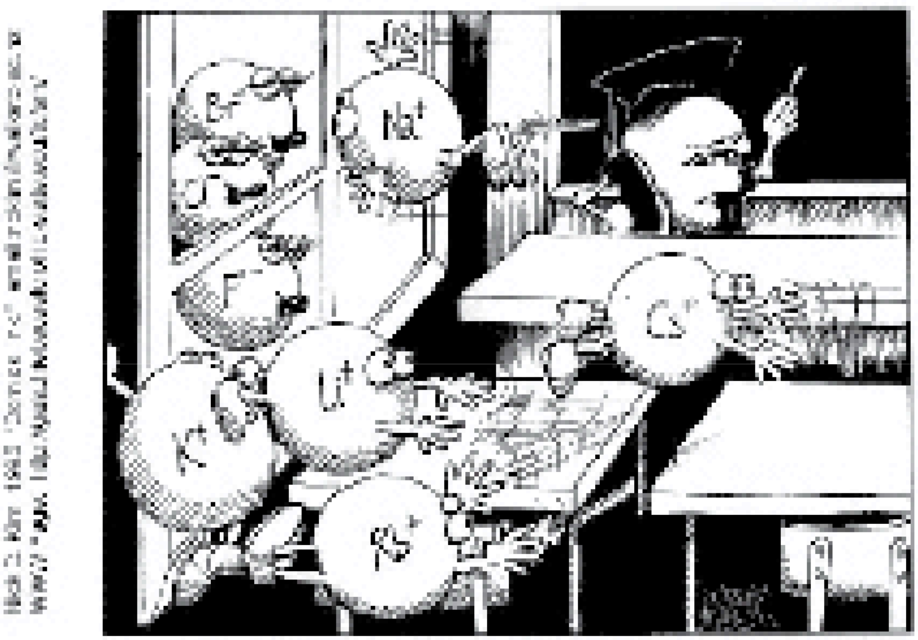


Ionic bond

The Reaction Subsystem

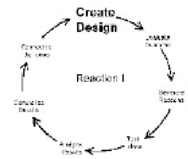
OBJECTIVE

- Explore the chemicals available to see how they can be used to meet your system requirements.
- Consider the particle nature of chemicals and how the properties of the chemicals impact your design.



"Perhaps one of you gentlemen would mind telling me just what it is outside the window that you find so attractive ...?"

Sort your chemical sheets into groups that seem similar (e.g., all chemicals include chlorine). Record the groups in the space below. Make as many groups as you can. You will use these groups to explore the chemical potential available to meet your energy requirements. Groups may also be based on visually inspecting the chemicals.



Group 1

These chemicals are similar because ______

____

____

List the chemicals in this group.

Group 2

These chemicals are similar because ________

____

____

List the chemicals in this group.

Group 3

These chemicals are similar because _______

____

____

List the chemicals in this group.

Group 4

These chemicals are similar because ________

____

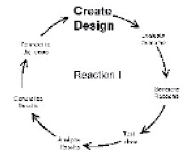
____

List the chemicals in this group.

Date ____________________

Reaction I CREATE DESIGN

Sort your chemical sheets into groups that seem similar (e.g., all chemicals include chlorine). Record the groups in the space below. Make as many groups as you can. You will use these groups to explore the chemical potential available to meet your energy requirements. Groups may also be based on visually inspecting the chemicals.



Group 5

These chemicals are similar because ________

____

____

List the chemicals in this group.

Group 6

These chemicals are similar because ________

____

____

List the chemicals in this group.

Group 7

These chemicals are similar because _______

____

____

List the chemicals in this group.

Group 8

These chemicals are similar because ________

____

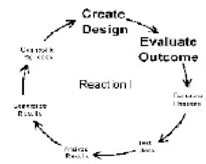
____

List the chemicals in this group.

Date ________________

Reaction I ***CREATE DESIGN***

Now that you have categorized your chemicals, it is time to do some trials to see if your groupings were appropriate. Select two groups that you think may help you meet your energy requirement. Record all of the combinations that you try and your observations. Try each chemical with water.



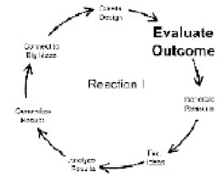
What requirement is your team trying to meet?

	CHEMICAL COMBINATION *(e.g. sodium chloride + water)*	OBSERVATIONS
Group A		
Group B		

Date

Reaction I EVALUATE OUTCOME

As a team, think about the results from your categorization trials. Follow the instructions below. Be prepared to participate in the class discussion.



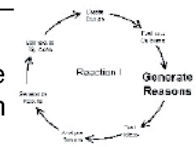
List your teams results in terms of the requirement you were trying to meet.

During the class discussion, record other teams’ outcomes. These outcomes may help you meet a requirement for your design.

Date

INDIVIDUAL THINK TIME

Think about your outcomes. List at least three reasons why you were or were not able to meet your requirement. Justify your reasons with evidence from your observations.



What requirement were you trying to meet?

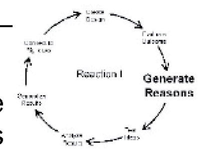
List at least three reasons why you were or were not able to meet your requirement.

1.

2.

3.

Date



CLASS THINK TIME

What variables seem to affect the requirement you were trying to meet? Share the evidence that supports your reasons with the class. Record other students ideas in the space below. These ideas may be useful for improving your design.

REASON FOR OUTCOME	VARIABLE TO TEST

Date ____________

NOW THAT YOU'VE THOUGHT ABOUT IT...

CHEMICAL REACTIONS

Chemical reactions involve transfers of energy between the reactants and the products. This transfer of energy occurs during two theoretical steps: breaking the bonds of the reactants and forming the bonds of the products. Energy is required to break the bonds of the reactants. Energy is released when new bonds are formed to make the product. Chemical reactions can be described as endothermic or exothermic dependent on the amount of energy that is absorbed or released as heat during the reaction.

ENDOTHERMIC AND EXOTHERMIC REACTIONS

Endothermic reactions have less energy in the bonds of their reactants than in the bonds of their products. Because more energy is needed for the rearrangement to occur, these reactions absorb energy from the surroundings. **Endothermic reactions are measured by a decrease in the temperature of the system.**

Exothermic reactions have more energy in the bonds of their reactants than the bonds of their products. Because less energy is needed for the rearrangement to occur, these reactions release energy to the surroundings. **Exothermic reactions are measured by an increase in the temperature of the system.**

INSERT ENERGY DIAGRAMS HERE

Reaction I TEST IDEAS

What idea did you test?

Variables

What variables did you use to test your idea?

Independent (IV) (what did you change?)

Dependent (DV) (what did you measure?)

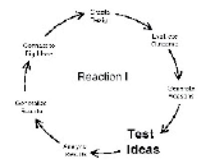
Constants (what did you keep the same?)

Chemical Equation

Hint: Write a word equation to describe your chemical combination. Include the heat lost or gained.

Step-by-Step Procedure and Calculations

Hint: Molecular weight tells you how many grams are in 1 mole



Predictions

(Hint: What will happern to the DV as the IV changes?)

Data Chart

Reactant Name	Independent Variable	Dependent Variable	Initial Temp (°C).(Solvent)	Final Temp. (°C) (Solution)	Observations

Date

NOW THAT YOU'VE THOUGHT ABOUT IT...

BALANCED CHEMICAL EQUATIONS

Particles rearrange during chemical reactions. Chemists use a short hand notation to express what happens in a chemical reaction. This notation is called a **chemical equation.**

Chemical equations list the chemical formulas of the starting substances on the left side. They include an arrow to point to the chemical formulas of the substances created on the right. The starting substances are called reactants. The new substances are called products. The chemical formula is an expression that shows the number and kind of atoms in a molecule. For example:

$$H_2(g) + O_2(g) \rightarrow H_2O(l)$$

This equation reads "gaseous hydrogen plus gaseous oxygen makes liquid water." The chemical equation tells us that under the right conditions, hydrogen and oxygen will react to produce water. The way it is written, the equation does not tell us how much of each reactant (that is molar amounts) is needed. This equation is similar to the list of ingredients in a cooking recipe without the measurements.

The **Law of Conservation of Matter** states that particles cannot be created or destroyed in a chemical reaction. This means that the chemical equation must have the same number of each type of particle on each side of the arrow. When the same number of particles is on the left and the right sides of the arrow, then the equation is balanced.

Changing the subscripts of the chemical formulas would change the type of compound, much like adding letter to the spelling of a name would change the name. This means that equations are balanced by describing how many particles of each type of compound are used or produced. To do this, a number, called the **stoichiometric coefficient**, is placed in front of the chemical formula.

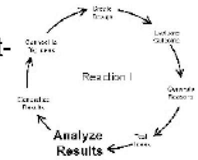
If we balance the equation for the formation of water, it looks like this:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) + \text{heat}$$

What is different about this reaction equation and the previous one for the formation of water?

> *Chemists use symbols to represent the materials involved in chemical reactions. The substances on the left of the arrow are called the reactants. The substances on the right of the arrow are products of the reaction. The small letters in parenthesis show the physical state of the chemicals: g = gas; s = solid; l = liquid; aq = aqueous or dissolved in water.*

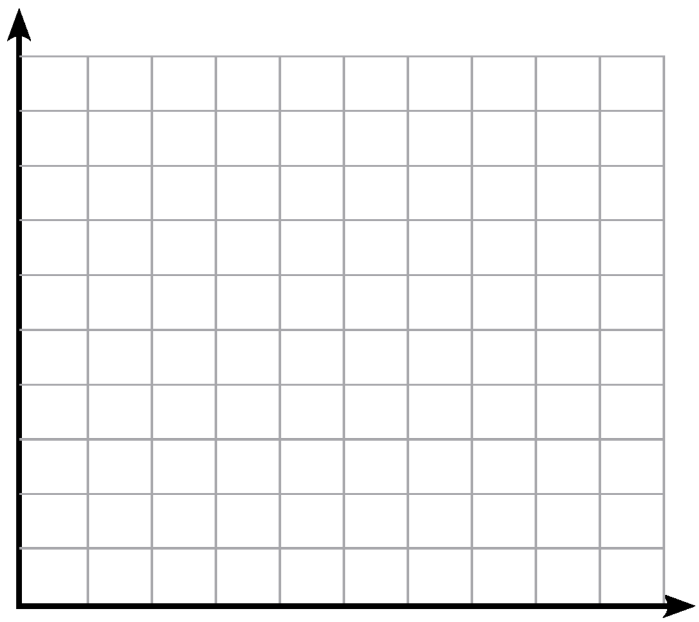
Reaction I **ANALYZE RESULTS**



Analyzing your data will help you identify patterns that will allow you to predict outcomes.

Bar Graph

Use the results from your data chart (averaged data from the previous page) to construct the graph.

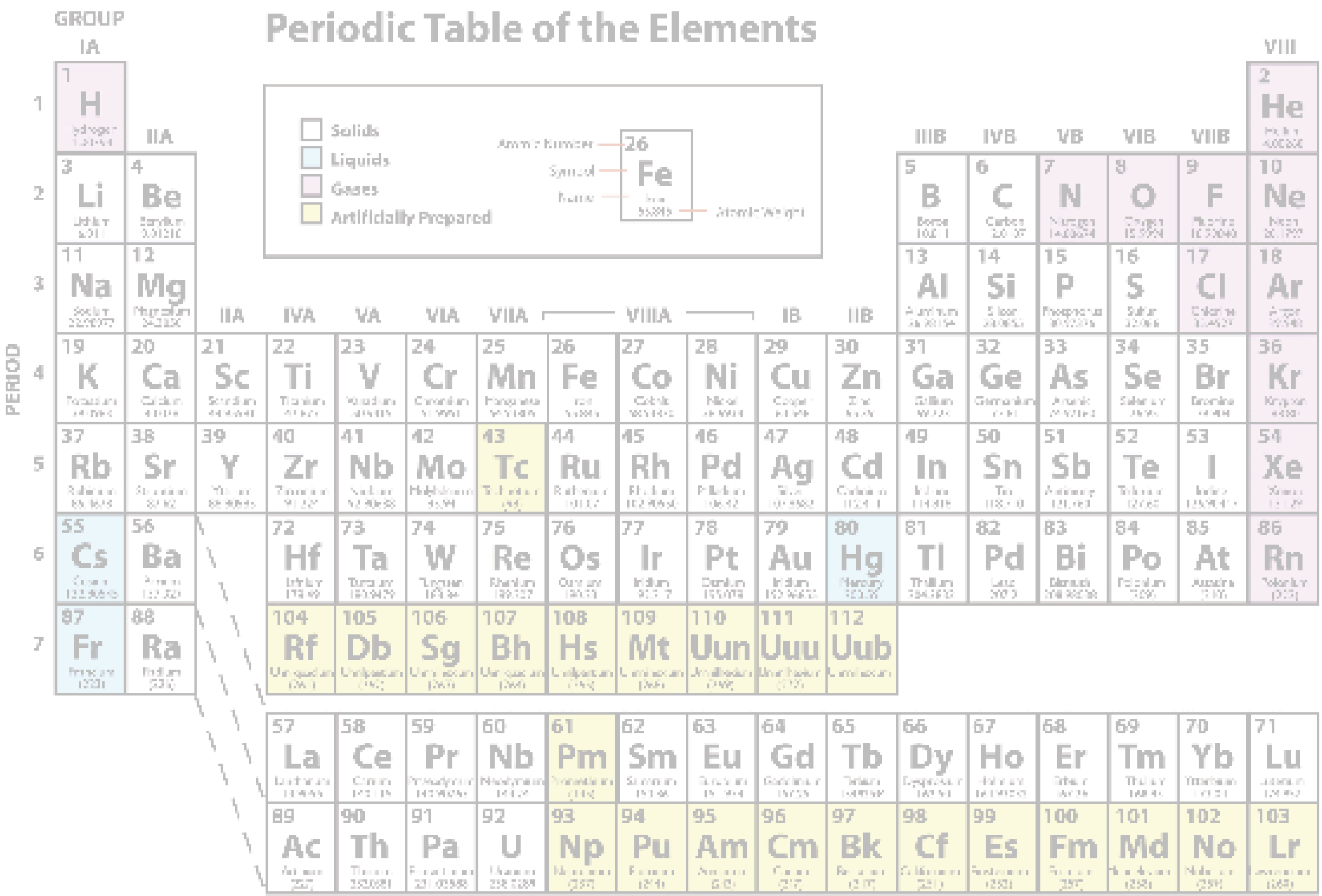


Plot your data on the periodic table. What trends or patterns do you notice?

Rubidium chloride (RbCl) and cesium chloride (CsCl) are ionic compounds like the ones you have tested. Considering the patterns you observed in your data, extend the graph to include your prediction about whether rubidium chloride (RbCl) and cesium chloride (CsCl) will be endothermic or exothermic. Draw where you think these data points will fall on your graph. Assume the IV, DV, and constants are the same as your previous trials.

Do your data support your idea? Explain why or why not.

Date

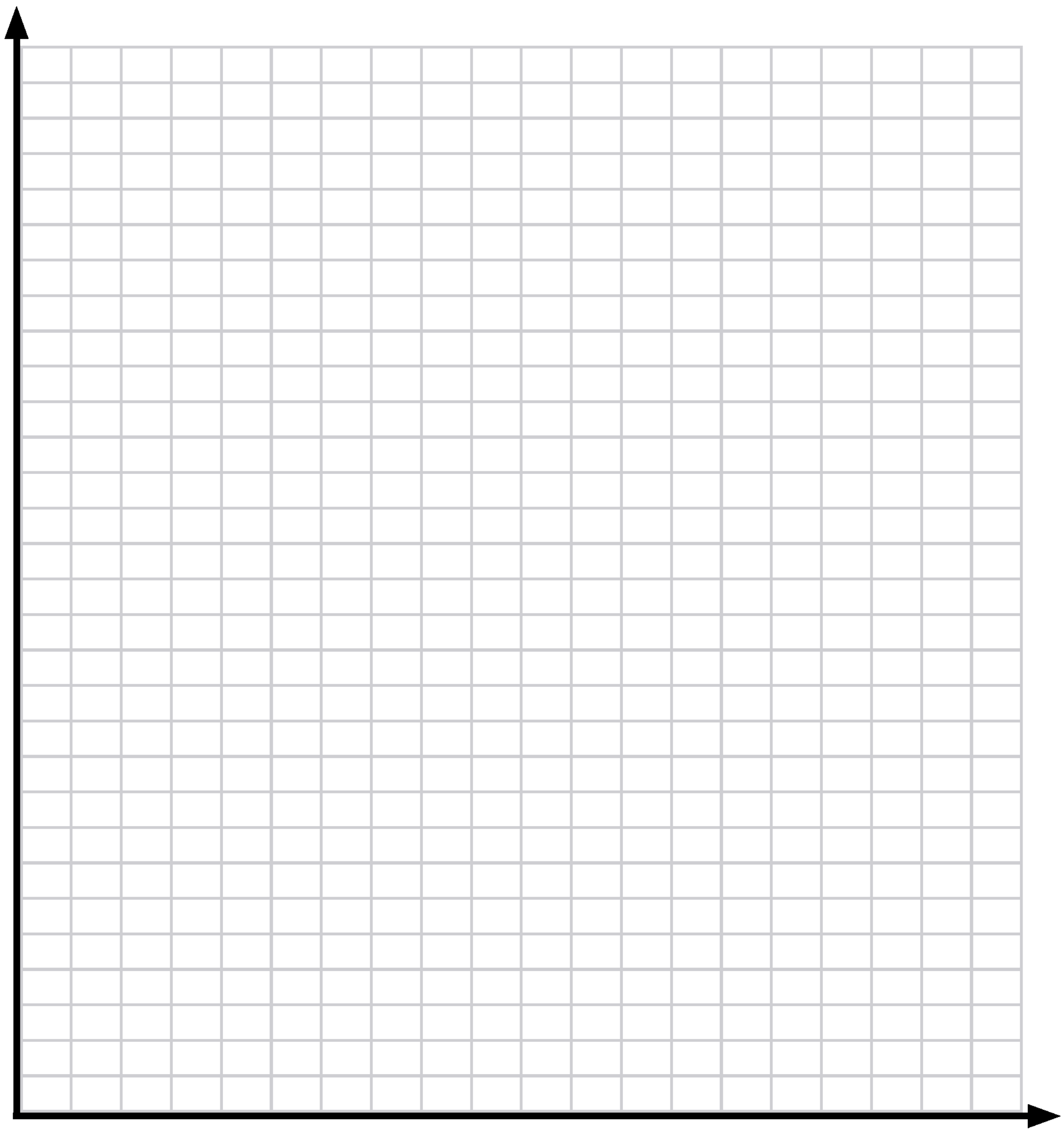


Periodic Table of the Elements
GROUP
PERIOD
Solids
Liquids
Gases
Artificially Prepared
Atomic Number
Symbol
Name
Atomic Weight
IA IIA IIIA IVA VA VIA VIIA VIIIA IB IIB IIIB IVB VB VIB VIIB VIII
1 H 2 He
3 Li 4 Be 5 B 6 C 7 N 8 O 9 F 10 Ne
11 Na 12 Mg 13 Al 14 Si 15 P 16 S 17 Cl 18 Ar
19 K 20 Ca 21 Sc 22 Ti 23 V 24 Cr 25 Mn 26 Fe 27 Co 28 Ni 29 Cu 30 Zn 31 Ga 32 Ge 33 As 34 Se 35 Br 36 Kr
37 Rb 38 Sr 39 Y 40 Zr 41 Nb 42 Mo 43 Tc 44 Ru 45 Rh 46 Pd 47 Ag 48 Cd 49 In 50 Sn 51 Sb 52 Te 53 I 54 Xe
55 Cs 56 Ba 72 Hf 73 Ta 74 W 75 Re 76 Os 77 Ir 78 Pt 79 Au 80 Hg 81 Tl 82 Pd 83 Bi 84 Po 85 At 86 Rn
87 Fr 88 Ra 104 Rf 105 Db 106 Sg 107 Bh 108 Hs 109 Mt 110 Uun 111 Uuu 112 Uub
57 La 58 Ce 59 Pr 60 Nb 61 Pm 62 Sm 63 Eu 64 Gd 65 Tb 66 Dy 67 Ho 68 Er 69 Tm 70 Yb 71 Lu
89 Ac 90 Th 91 Pa 92 U 93 Np 94 Pu 95 Am 96 Cm 97 Bk 98 Cf 99 Es 100 Fm 101 Md 102 No 103 Lr

Reaction I ANALYZE RESULTS

Use this tranparency to graph the data from your CSI. Include the extension data on this graph. As a team, discuss the graph and be prepared to share your graph with the class. Use your periodic table as a reference.

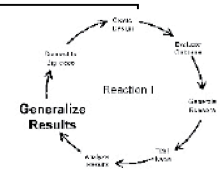
The chemicals we tested were:



Reaction I GENERALIZE RESULTS

CLASS THINK TIME

What general statements can you make about the ideas you tested as a class? Share your evidence. In the space below, record other teams' results and the ideas that were discussed in your class. This information may be useful for improving your design.



GENERAL STATEMENTS	EVIDENCE

Date

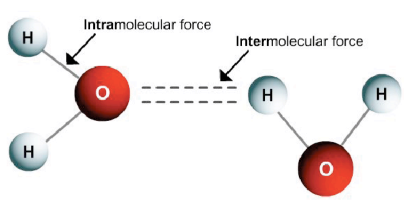
NOW THAT YOU'VE THOUGHT ABOUT IT...

ATTRACTIVE FORCES

There are many forces that hold particles (atoms, ions, or molecules) together. Intra-molecular forces hold together the particles within a molecule. Inter-molecular forces hold together the particles between molecules. Both forces are involved in chemical reactions, but some chemical reactions depend more on either intra-molecular or inter-molecular forces. These forces hold the particles together based on the attraction of a positive charge to a negative charge.

The strength of these forces influences the properties of substances. The strength of intra-molecular forces is related to the rearrangements that occur in chemical reactions. The strength of the inter-molecular forces in a substance determines many of its observable properties, including melting point, boiling point, and solubility.

Just as an interstate highway runs between states, **intermolecular** forces are attractions between molecules. In contrast, **intramolecular** forces occur within a molecule and include covalent bonds between atoms.



From www.wwnorton.com/chemistry/overview

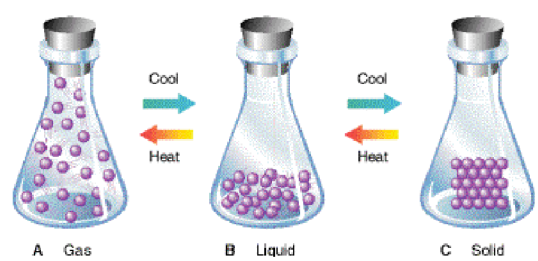
PARTICLE INTERACTIONS IN MATTER

When many particles are held closely together, then they may form liquids or solids. In solids, the particles are close to each other and have only limited motion. In liquids, the particles (atoms, ions, or molecules) can move freely, but remain close to the other particles. In gases, the particles move freely and independently; that is, gas particles are not attached to other particles.

Solids - lowest energy because the particles are packed closely together restricting movement

Liquids - more energy because the particles are not so close and movement is not restricted

Gases - highest energy state because particles ar spaced far apart allowing lots of movement



EXAMPLE OF A PARTICLE DRAWING

In an aqueous solution, there is a mixture of substances, a solid, liquid, or gas that are dissolved in water (or some other solvent). This particle model would show two types of matter.

ENERGY AND COLLIDING PARTICLES

Scientists use a theory of particle behavior to explain how chemical reactions occur. Two particles can react only if they collide with each other. For a chemical reaction to occur, particles have to:

- Collide the correct way, with the correct orientation.
- Collide with enough energy to overcome the attractive forces.
- Energy is transferred when these conditions are met.

BOND ENERGIES

For any chemical attraction (called a bond), the amount of energy necessary to break that bond is exactly the same as the amount of energy released when the bond is formed. This value is called the **bond energy**. The following table includes the average bond energies for a variety of bonds in units of kcal/mole.

The bond energies of ion-ion attractions (ionic bonds) are called **lattice energies.** These bond energies are relatively large. The ionic bonds of opposite charged ions are strongest when the ions are small. When the ions are small, then the bond length is shorter.

Lattice Energies (kJ/mol)

	F^{-1}	Cl^{-1}	Br^{-1}	I^{-1}
Li^{+1}	1036	853	807	757
Na^{+1}	923	787	747	704
K^{+1}	821	715	682	649
Rb^{+1}	785	689	660	630
Cs^{+1}	740	659	631	604

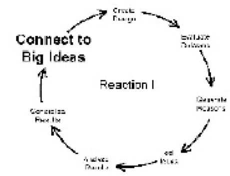
The ionic bond becomes stronger as the charge of the ions becomes larger. The data in the table below show that the lattice energies for salts of the OH^{-1} and O^{-2} ions increase rapidly as the charge on the ion becomes larger.

Lattice Energies (kJ/mol)

	OH^{-1}	O^{-2}
Na+	900	2,481
Mg^{+2}	3,006	3,791
Al^{+3}	5,627	15,916

Reaction I CONNECT TO BIG IDEA

Apply what you have learned about atomic structure, periodic trends, and bond energy to make predictions about whether the transformation will be endothermic or exothermic. Write the reasons for the predictions that you make. Place a check by the transformations you want to test.



√	TRANSFORMATION *(Write chemical equation for each transformation)*	PREDICTION (ENDO OR EXO)	EXPLANATION FOR PREDICTION
	$Na_2CO_3(s) + H_20(l) \rightarrow Na^{+1}(aq) + CO_3^{-2}(aq)$		
	$Na_2CO_3(s) + HCl(aq) \rightarrow NaHCO_3(aq) + NaOH(aq)$		
	$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$		
	$NaOH(s) + HCl(aq) \rightarrow H_2O(l) + NaCl(aq)$		

Date ____________________

NOW THAT YOU'VE THOUGHT ABOUT IT...

THEORECTICAL HEATS OF FORMATION

All chemical compounds are created by chemical reactions. The Heat of Formation is a measure of the amount of energy change that happens when one mole of a substance is formed from its constituent elements. This is represented as ΔH_f (called 'delta-H of formation').

For example, the combustion of 1 mole of hydrogen gas (2 grams/mole) with a half of a mole of oxygen gas (16 grams/mole) forms 1 mole of water (18 grams/mole) and release heat.

The balanced thermo-chemical equation for the formation of water is:

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l); \quad \Delta H = -571.6$ kJ/mol

We can measure the amount of heat released during this reaction. It is 571.6 kJ of energy for every 2 moles of water produced.

The thermo-chemical equation is the balanced equation that specifies the amount of heat released (negative) or absorbed (positive number) for the molar amounts of reactants to produce the molar amounts of products.

ENTHALPY CHANGES IN REACTIONS

Scientists measure the amount of heat released or absorbed by reactions. This measurement is called Enthalpy (H). Enthalpy is often reported in units of kJ/mole (reads "kilojoules per mole"). Changes in enthalpy for reactions are written as $\Delta H_{reaction}$.

$$\Delta H_{reaction} = \Delta H_{products} - \Delta H_{reactants}$$

Chemists use this equation to determine whether a reaction will be exothermic or endothermic. If $\Delta H_{reaction}$ is negative, then the reaction will be exothermic. If $\Delta H_{reaction}$ is positive, then the reaction will be endothermic

$\Delta H_{reaction} > 0$, the reaction is endothermic

$\Delta H_{reaction} < 0$, the reaction is exothermic

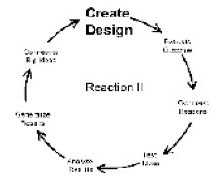
As a class, you generated a number of possible reasons why the temperature changed in your trials. How has your thinking about what caused these temperature changes changed as you collected more data? Explain your answers fully and cite evidence from your experiences so far to support your claims.

How did the cycle help you think about refining your design?

Date ______________________

Reaction II CREATE DESIGN

What requirement are you trying to meet?



Chemical Equation

List the chemical transformations you want to try. Include the chemical equation for each trial. Justify your choices in terms of concepts you have discussed.

Data Chart

(Hint: Record the average data on this chart)

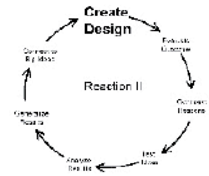
Reactant Name	Independent Variable	Dependent Variable	Final Temp. of Each Trial (°C)	Average Initial Temp. (°C) (solvent)	Average Final Temp. (°C) (solution)	Observations
			1			
			2			
			3			
			4			
			1			
			2			
			3			
			4			
			1			
			2			
			3			
			4			
			1			
			2			
			3			
			4			

Teacher approval ____________________

Date ____________________

Reaction II *CREATE DESIGN*

What requirement are you trying to meet?



Chemical Equation

List the chemical transformations you want to try. Include the chemical equation for each trial. Justify your choices in terms of concepts you have discussed.

Data Chart

(Hint: Record the average data on this chart)

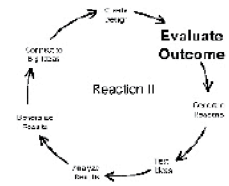
Reactant Name	Independent Variable	Dependent Variable	Final Temp. of Each Trial (°C)	Average Initial Temp. (°C) (solvent)	Average Final Temp. (°C) (solution)	Observations
			1			
			2			
			3			
			4			
			1			
			2			
			3			
			4			
			1			
			2			
			3			
			4			
			1			
			2			
			3			
			4			

Teacher approval ____________________

Date

Reaction II EVALUATE OUTCOME

As a team, think about the results from your trials. Follow the instructions below and be prepared to participate in the class discussion.

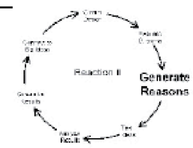


Summarize your team's results in terms of the requirement your were trying to meet.	Did you meet your requirement?
During the class discussion, record other teams' outcomes. These outcomes may help you meet a requirement for your design.	

Date

INDIVIDUAL THINK TIME

Think about your outcome. List at least three reasons why you were or were not able to meet your requirement. Justify your reasons with evidence from your observations.



What requirement were you trying to meet?

List at least three reasons why you were or were not able to meet your requirement.

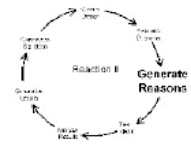
1.

2.

3.

Date

CLASS THINK TIME



What variables seem to affect the requirement you were trying to meet? Share the evidence that supports your reason(s) with the class. Record other students ideas in the space below. These ideas may be useful for improving your prototype.

REASON FOR OUTCOME	VARIABLES TO TEST

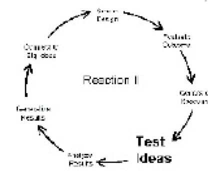
Date

Reaction II TEST IDEAS

What idea did you test?

Chemical Equation

Hint: Write a word equation to describe your chemical combination



Variables

What variables did you use to test your idea?

Independent (IV) (What did you change?)

Dependent (DV) (What did you measure?)

Constants (What did you keep the same?)

Calculations (Converting moles to grams)

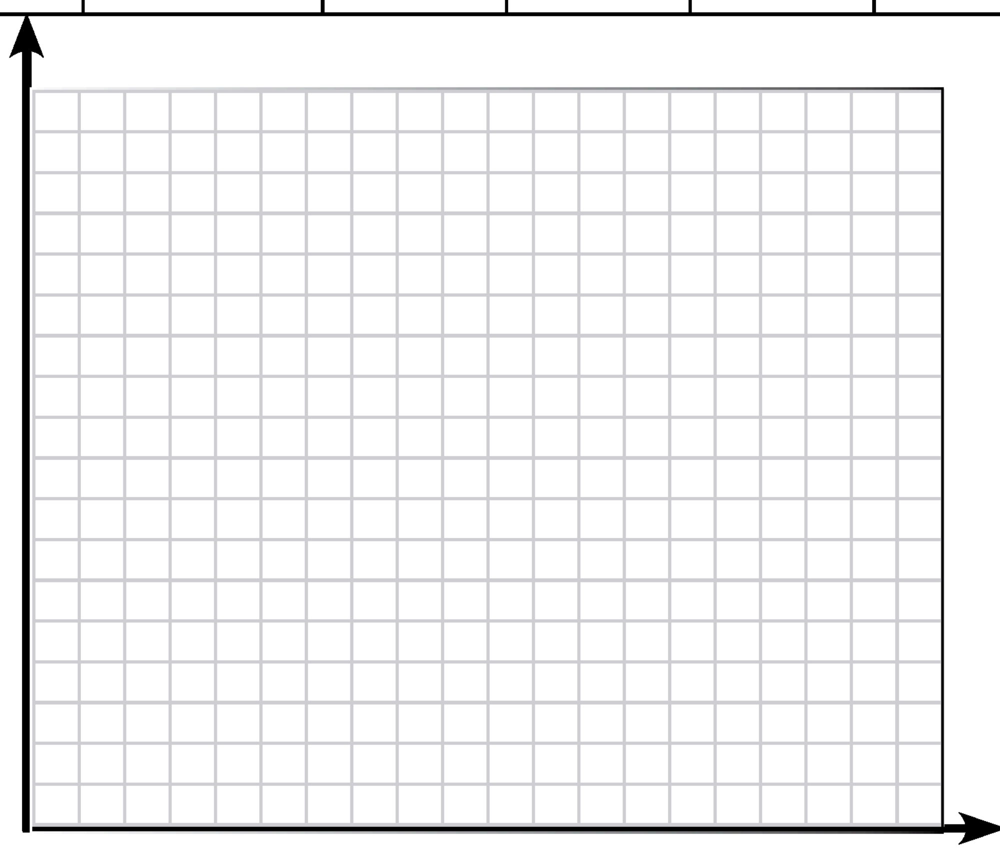
Hint: Molecular weight tells you how many grams are in one mole

Date

Data Chart

Hint: Be sure to record the initial temperature of the liquid before adding the solid.

Name of the reactant being tested			Name of the solvent being used		
Reactant Moles (grams/mole)	Reactant Mass, grams *(From Calculations)*	Liquid Volume (ml)	Initial Temp. (°C)	Final Temp. (max.) (°C)	Temperature Change, ΔT (°c)



Reaction II **TEST IDEAS**

What idea did you test?

Variables

What variables did you use to test your idea?

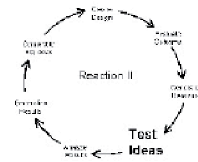
Independent (IV) (What did you change?)

Dependent (DV) (What did you measure?)

Constants (What did you keep the same?)

Chemical Equation

Hint: Write a word equation to describe your chemical combination



Calculations

Hiint: Molecular weight tells you how many grams are in one mole

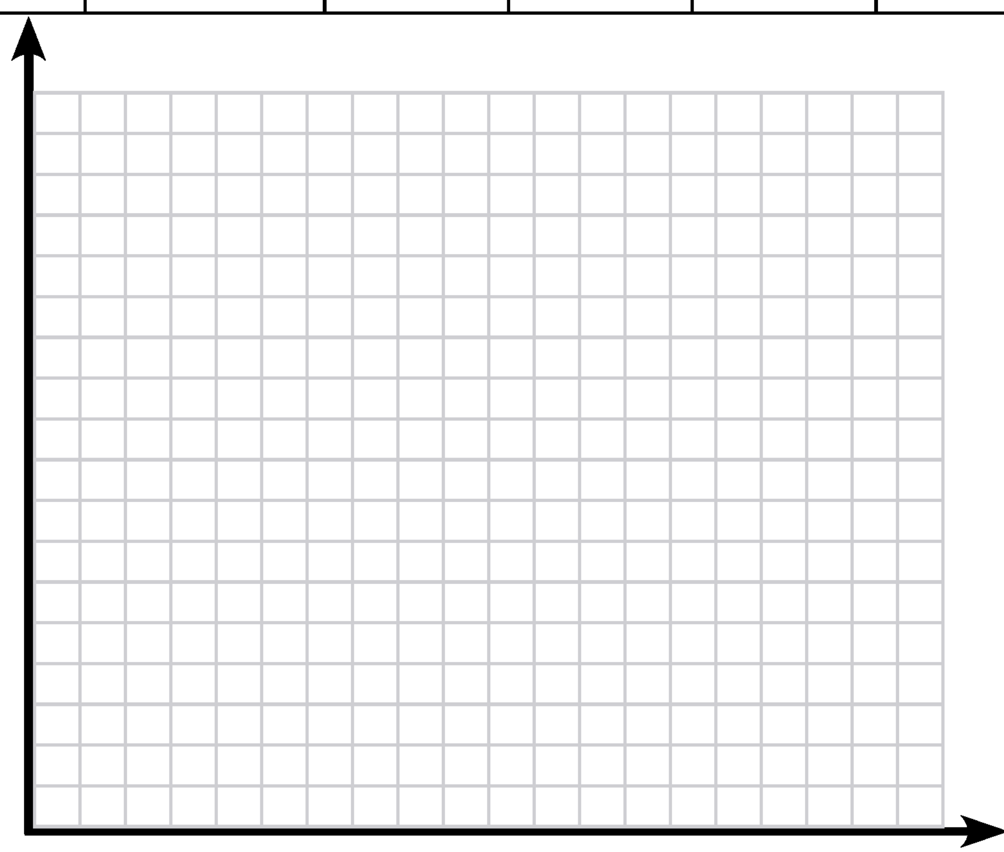
Date ____________________

COLLECTING YOUR VOLUME DATA

Data Chart

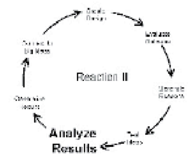
Hint: Be sure to record the initial temperature of the liquid before adding the solid.

Name of the reactant being tested			Name of the solvent being used		
Reactant Moles (grams/mole)	Reactant Mass, grams *(From Calculations)*	Liquid Volume (ml)	Initial Temp. (°C)	Final Temp. (max.) (°C)	Temperature Change, Δt (°C)



ANALYZING YOUR MASS DATA

Reaction II **ANALYZE RESULTS**



Do your data support your idea? Explain why or why not.

What does the direction of the slope indicate about the trend you observed? Explain what happens in the system when the slope increases or decreases. When the slope plateaus?

If you doubled the mass at the maximum temperature, then would you expect the temperature to double too? Why or why not? Does this prediction support the idea you were testing? How?

How does what you learned about particle interactions apply to the new data? Draw two particle diagrams representing the system before and after increasing the mass.

Date ______________________

Reaction II **ANALYZE RESULTS**

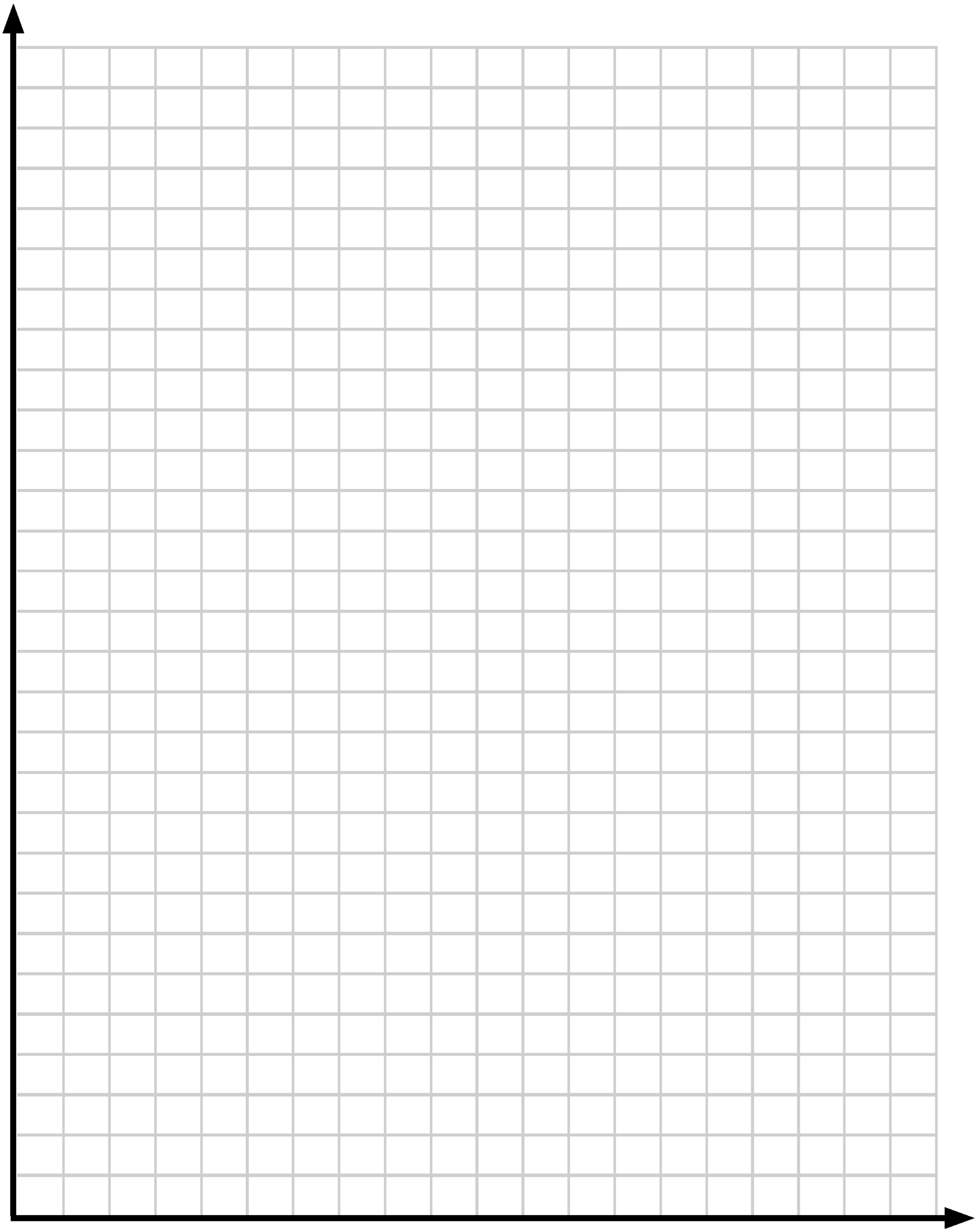
Do your data support your idea? Explain why or why not.

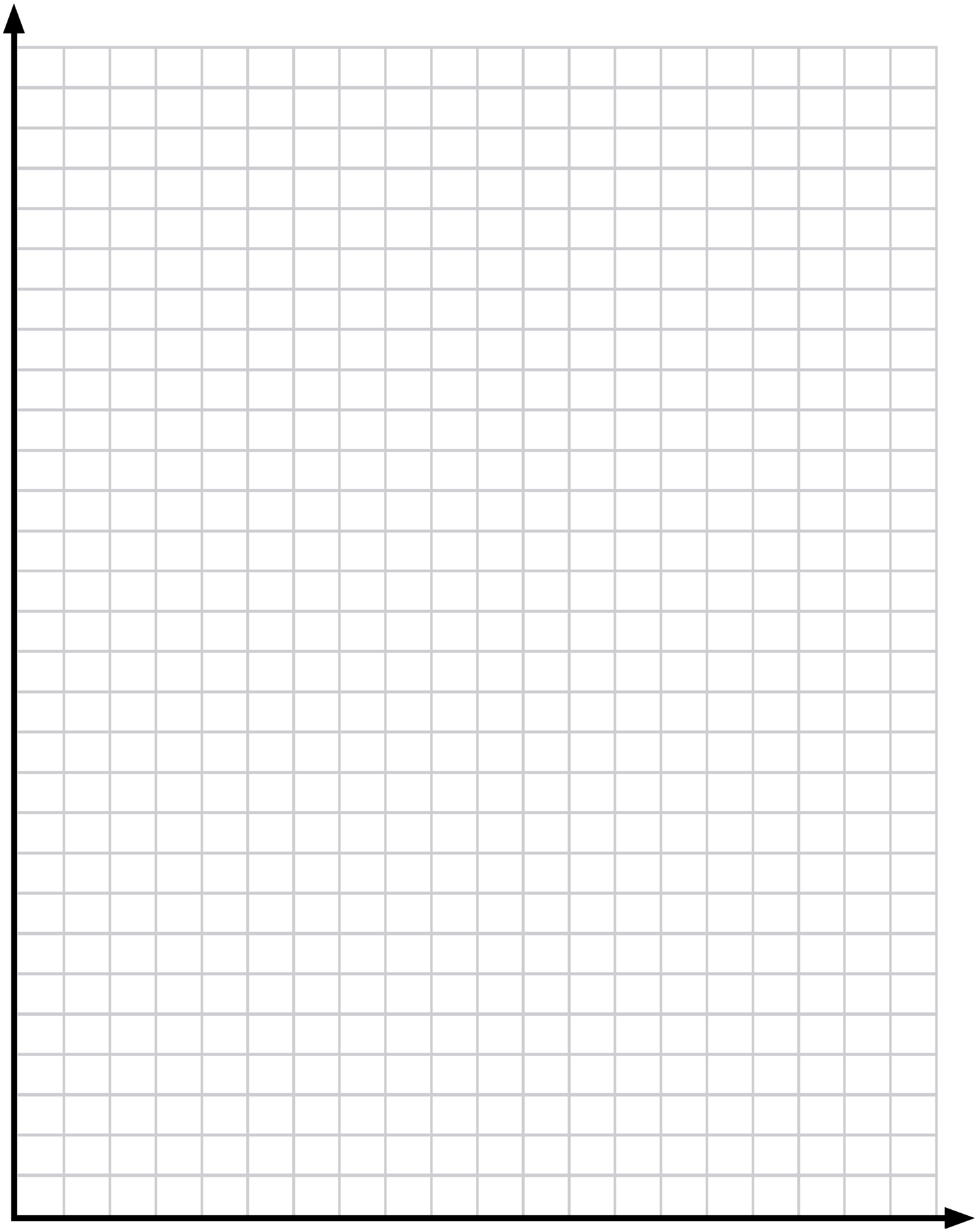
What does the direction of the slope indicate about the trend you observed? Explain what happens in the system when the slope increases or decreases. When the slope plateaus?

If you reduced the volume by half at the maximum temperature, then would you expect the temperature to double too? Why or why not? Does this prediction support the idea you were testing? How?

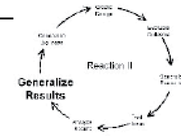
How does what you learned about particle interactions apply to the new data? Draw two particle diagrams representing the system before and after increasing the mass.

Date ____________________





Reaction II GENERALIZE RESULTS



CLASS THINK TIME

What general statements can you make about the ideas you tested as a class? Share your evidence. In the space below, record other teams' results and the ideas that were disscussed in your class. This information may be useful for improving your design.

GENERAL STATEMENTS	EVIDENCE

Date ____________________

NOW THAT YOU'VE THOUGHT ABOUT IT...

You have been experimenting with the effect of mass on the heat of reaction of your system as observed by the changes in temperature. When you analyzed your results, you saw that the temperature change of your solution depended on the mass of the reactants. Both the temperature change and the mass of the reactants are related to the amount of enery released in absorbed.

SPECIFIC HEAT

You can measure the amount of energy input needed to raise the temperature of a mass of a specific substance by 1°C. This measurement is called the **specific heat** of the material. It is different for all substances. You can calculate specific heat by this equation:

$$q = mc\Delta T$$

The equation reads "Heat change = (mass in grams) x (specific heat per gram of substance) x (change in temperature)".

In this equation:

q = the heat change

m = the mass (in grams)

c = specific heat per gram

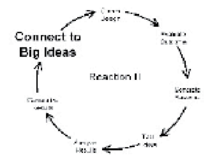
ΔT = the change in temperature

Water has a specific heat per gram of 4.184 J/g °C. This is higher than any other common substance. Below is a table of the specific heat of some common substances.

Specific Heat of Common Substances

Substance	Specific Heat (J/g °C)
Air (50 °C)	1.05
Aluminum	0.90
Ammonia (liquid)	4.70
Copper	0.40
Glass	0.84
Gold	0.13
Plastic (HD)	1.9
Sand	0.29
Soil (typical)	1.05
Styrofoam	.3
Tin	0.23
Water	4.18
Wood (typical)	1.69

Reaction II CONNECT TO BIG IDEA



1. If the reaction of aluminum and NaOH is used to heat up 1 cup of H_2O(250 ml) from 20°C to 95°C, according to the following equation:

   $2\ Al + 6\ H_2O \rightarrow 2\ Al(OH)_3 + 3\ H_2$

   $Al(OH)_3 + NaOH \rightarrow Na^{+1} + [Al(OH)_4]^{-1}$

   How much energy is needed?
   Assume the density of water is 1.0 g/ml and the specific heat of the solution is 4.184 J/g °C.

2. When a 5 gram sample of NaOH is dissolved in 10 ml of H_2O, then the temperature rises from 23°C to 60°C. Write an equation to describe the process.
   Is this an exothermic or endothermic process?
   Calculate the heat change of this reaction, q.

3. How much energy is needed to heat 500 ml of H_2O from 20 °C to 80 °C? Specific heat capacity of water is 4.184 J/g °C and the density of water is 1.0 g/ml.

4. 20 g of NH_4NO_3 is added to 50 ml of H_2O at 20 °C and dissolves.
   Calculate the amount of energy needed for the ammonium nitrate to dissolve.
   If the energy for this process is provided by the cooling of the water, determine the temperature change for the water.

5. When mixed with 25 ml of H_2O, 10 g of ammonium chloride solution cools from room temperature to 10 °C. How much energy does it absorb from the surroundings?

Questions created by Sally Martin- Allderdice HIgh School

Reaction II REFLECTION III

Some chemical reactions absorb energy. What are these reactions called?

What properties cause these reactions to absorb energy?

Where does the energy come from?

Where does the energy go when it is absorbed?

Date ____________________

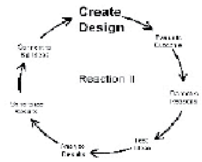
Reaction II CREATE DESIGN

What requirement are you trying to meet?

Chemical Equation

List the chemical transformations you want to try. Include the chemical equation for each transformation.

Procedure



Write a procedure explaining how you will conduct your trials. Include IV, DV, and constants, the amounts used of each reactant.

Our independent variable is:

Our dependent variable is:

Our constant variables are:

DATA CHART

Reactant Name	Independent Variable	Dependent Variable	Initial Temp. (Solvent)	Final Temp. (°C) (Solution)	Observations

Teacher approval ____________________ Date ____________________

Reaction II CREATE DESIGN

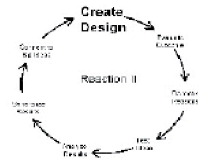
What requirement are you trying to meet?

Chemical Equation

List the chemical transformations you want to try. Include the chemical equation for each transformation.

Procedure

Write a procedure explaining how you will conduct your trials. Include IV, DV, and constants, the amounts used of each reactant.



Our independent variable is:

Our dependent variable is:

Our constant variables are:

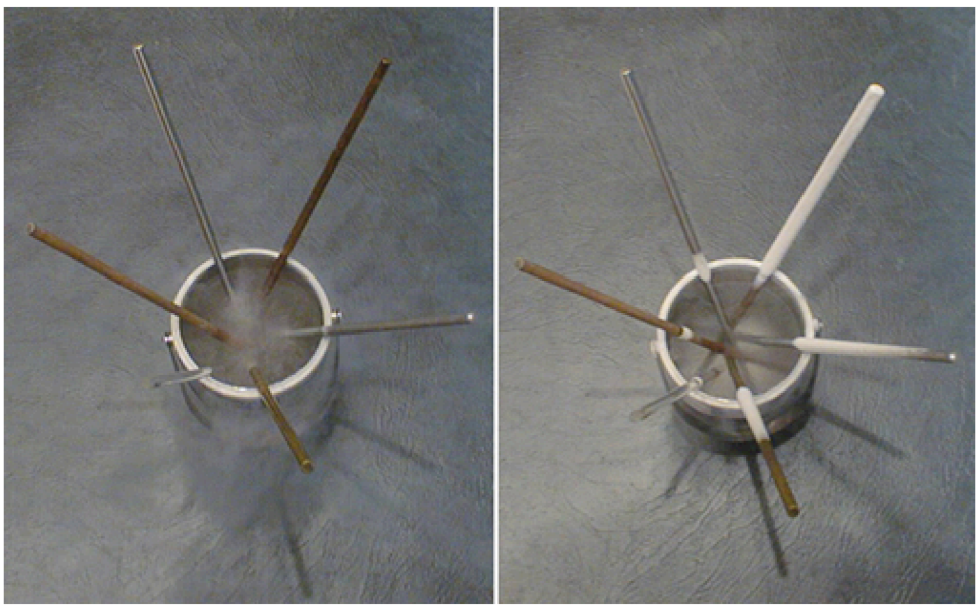
Data Chart

Reactant Name	Independent Variable	Dependent Variable	Initial Temp. (Solvent)	Final Temp. (°C) (Solution)	Observations

Teacher approval ___________________ Date ___________________

OBJECTIVES

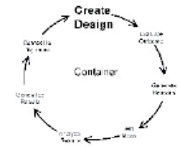
- Recognize that the container materials are also made up of particles that determine their properties.
- Understand how your container materials affect the transfer of energy from your reaction subsystem to the object you want to heat or cool.
- Consider how the flow of energy from regions of high energy to regions of low energy will affect your design.



(photo http://demo.physics.uiuc.edu/LectDemo/scripts/demo_descript.c?))DemoID=43scripts/demo_descript.idc?DemoID=43)

Rods of different materials are cooled in a dewar of liquid nitrogen to demonstrate different rates of thermal conductivity. The rods are left in the dewar for equal amounts of time. To check which ones conduct faster, look at the frost that develops on the rods

Sort your material cards into groups that seem similar (e.g., all contain metallic bonding). Record the groups in the space below. Make as many groups as you can. You will use these groups to explore the material potential available to meet your container requirements.



Group 1

These container are similar because______

____

____

List the containers in this group.

Group 2

These container are similar because__________

____

____

List the containers in this group.

Group 3

These container are similar because_______

____

____

List the containers in this group.

Group 4

These container are similar because__________

____

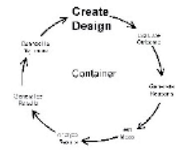
____

List the containers in this group.

Date ________________

Container CREATE DESIGN

Sort your material cards into groups that seem similar (e.g., all contain metallic bonding). Record the groups in the space below. Make as many groups as you can. You will use these groups to explore the material potential available to meet your container requirements.



Group 5

These container are similar because______

____

____

List the containers in this group.

Group 6

These container are similar because_________

____

____

List the containers in this group.

Group 7

These container are similar because_______

____

____

List the containers in this group.

Group 8

These container are similar because_________

____

____

List the containers in this group.

Date ____________________

Container I **CREATE DESIGN**

What idea did you test?

Variables

What variables did you use to test your idea?

Independent (IV) (What did you change?)

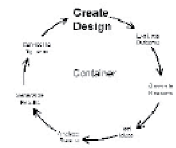
Dependent (DV) (What did you measure?)

Constants (What did you keep the same?)

Your Packaging and Your Chemical Equation

Step-by-Step Procedure and Calculations

Hint: Molecular weight tells you how many grams are in 1 mole



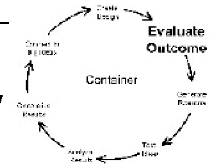
Predictions

(Hint: What will happen to the DV as the IV changes?)

Data Chart

Date

Container EVALUATE OUTCOME



TEAM THINK TIME

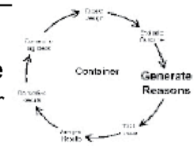
As a team, think about the results of your trials. Follow the instructions below and be prepared to particiapate in the class discussion.

Summarize your team’s results.	Did you meet your requirement?
During the class discussion, record other teams’ outcomes. These outcomes may help you meet a requirement for your design.	

Date ____________

INDIVIDUAL THINK TIME

Think about your outcomes. List at least three reasons why you were or were not able to meet your requirement. Justify your reasons with evidence from your observations.



What requirement were you trying to meet?

List at least three reasons why you were or were not able to meet your requirement.

1.

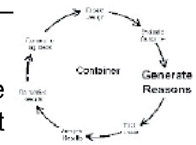
2.

3.

Date ____________________

CLASS THINK TIME

What variables seem to affect the requirement you were trying to meet? Share the evidence that supports your reason(s) with the class. Record the ideas that your class decided to explore more closely. These ideas may be useful for improving your design



REASON FOR OUTCOME	VARIABLES TO TEST

Date

What idea did you test?

Variables

What variables did you use to test your idea?

Independent (IV)

Dependent (DV)

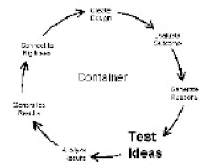
Constants

Predictions

Hint: Based on the atomic structure of the metals, what will happern to the DV as the IV changes?

Calculations

Relative Thermal Conductivity

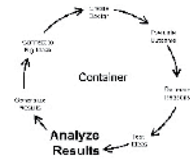


Data Chart

PART II	Aluminum	Brass	Steel	Nickel	Copper
Time					

Date

Container I ANALYZE RESULTS



Graph

Use the results from the data chart to construct the graph.

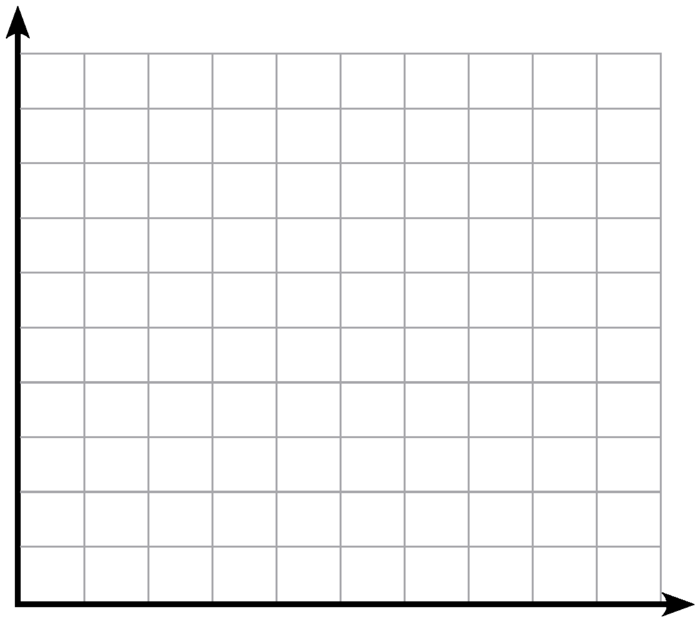


Chart your data on the periodic table.

Explain the trend you observed. What does the time for each pariffin ball to melt indicate about the energy transfer?

What is the signifigance of using relative thermal conductivities?

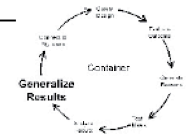
How does what you learned about particle interactions apply to the new data?

Date ____________________

Container GENERALIZE RESULTS

CLASS THINK TIME

What general statements can you make about the ideas you tested as a class? Share your evidence. In the space below, record other teams' results and the ideas that were disscussed in your class. This information may be useful for improving your design.



GENERAL STATEMENTS	EVIDENCE

Date

NOW THAT YOU'VE THOUGHT ABOUT IT...

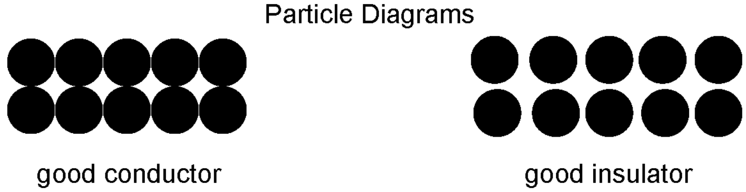
CONDUCTION

Heat can be transferred three ways -- by conduction, convection and radiation. Conduction is heat transfer by direct contact between objects. If you place a metal rod against a heated object, the vibrating atoms in the heated object will strike the atoms in the rod and cause them to vibrate with more motion. The atoms at the end of the rod will strike other atoms in the rod and they too will start to vibrate with more motion. Eventually, the entire rod will heat up.

If the same rod is placed on an ice cube, then the low-energy molecules of the ice will absorb some energy from the rod and slow down the vibration of the atoms that are touching the ice. The atoms in the warmer section of the rod will supply some of their energy to the less energetic atoms at the end touching the ice. The atoms supplying the energy to the colder end will become less energetic. The process of supplying energy from the warmer section of the rod to the cooler section will continue until the entire rod cools.

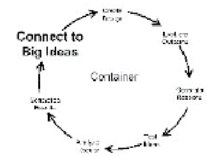
The atomic mass and structure of a substance affect its ability to transfer energy between adjoining atoms. Substances that transfer heat energy quickly are called **conductors**. Substances that transfer heat energy slowly are called **insulators.** Your *Material Sheet* lists the thermal conductivity rates for different types of materials. The thermal conductivity rate indicates how quickly a material transfers heat. Materials with high thermal conductivity values conduct heat better than materials with low thermal conductivity values.

Particle Diagrams



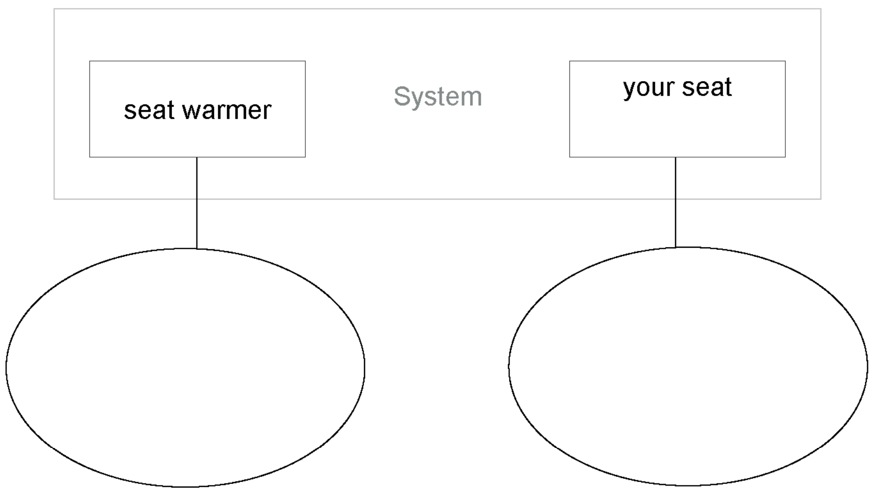
Text adapted from the NEED Project *Energy Works*

Container CONNECT TO BIG IDEA

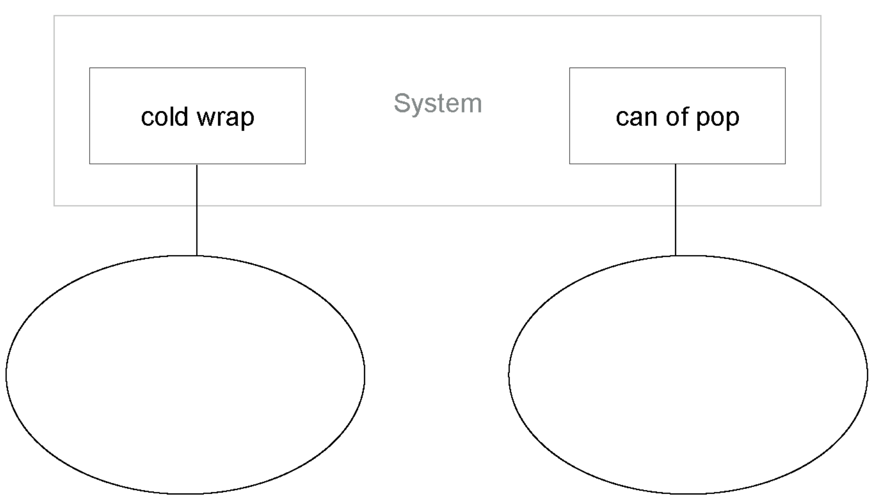


Look at the two systems below. Notice that the boundaries of the systems are defined by the box.

System A: You are a fan of your high school's football team. On cold days, the stadium bleachers are very cold and you hate to sit on them during the games. You have decided to make a seat warmer to sit on when you attend the games. When you are ready to warm your seat, you smack the seat warmer to initiate the interaction between the chemicals contained in the seat warmer. During the interaction, the seat warmer heats up to 70 ºC. Use the diagram below to show how the seat warmer warms your seat. In the ovals, describe the changes that occur in each part of the system (initially and over time). Draw an arrow showing the direction(s) that energy flows in the system

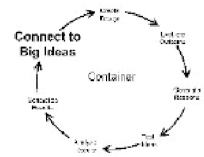


System B: You enjoy drinking cold pop at the beach on hot days. You always carry a case of pop in your trunk but you do not carry ice. You have decided to make a cooling wrap that will cool your can of pop while you are on the beach. When you are ready to cool your pop, you smack the cold wrap to initiate the interaction between the chemicals contained in the cold wrap. During the interaction, the cold wrap cools to 5 ºC. Use the diagram below to show how the cold wrap cools your pop. In the ovals, describe the changes that occur in each part of the system (initially and over time). Draw an arrow showing the direction(s) that energy flows in the system.



Date ________________

Container **CONNECT TO BIG IDEA**



What is the same about these systems?

What is different about these systems?

Write one general rule that explains how energy flows in both systems.

Date

CHAPTER 4
Presenting and Protecting Your Design

Now that you have created your best design, it is time for you to present your ideas to your class. Engineers present their design to their co-workers before the company agrees to produce it. Presenting your design to your class will be a great way for you to get feedback about what you have created.

After you give your presentation, you will complete a patent application. It can take a long time for designs to be ready to sell. Once scientists, engineers, or companies have developed a successful prototype they apply for a patent. A patent insures that no one else will be able to develop that particular product. In this way, companies and individuals are able to earn money on a product that they spent many hours and dollars developing. A patent guarantees that the scientist or engineer (or the company that he or she works for) is the legal owner of the design.

It is important to fully describe everything that your design can do. These are called your claims. For example, if you are cooling a beverage, then you may claim that your design can cool a 12 oz. can of soda from 10°C to 5°C.

The U.S. Patent Office has awarded over one million patents. Thomas Edison has often been called 'America's Great Inventor.' He has 1,093 patents for products like the light bulb and the phonograph (the century-old precursor to the MP3 player). IBM has the most patents of any company. Their top patent holder is Ravi Arimilli. At age 42, he has been awarded more than 300 patents, 78 of them during 2002 alone! That's three patents every two weeks!

GALLERY WALK

BEFORE THE GALLERY WALK . . .

Assemble a model of your design and prepare your team's poster. Be ready to explain what you did during this unit. You should talk about the parts of your design that were successful and the parts that were not as successful. Also, be ready to tell people about the changes you made along the way. Expect to get lots of questions.

OUR GALLERY WALK POSTER SHOULD INCLUDE . . .

- The name of your design.
- Your team members.
- The needs and new ideas that you discussed at the beginning.
- The requirements for your design.
- How you did or did not meet each of your requirements.
- The function for each of the subsystems.
- Sketch the design and describe how the it works.
- When and where the design should be used.
- The various tests and experiments that you ran while developing your design.
- What steps could be taken to improve the design.

DURING THE GALLERY WALK

Visit the posters for two groups in your class. Ask lots of questions so that you learn many details about how each team developed and created their design. To complete your evaluation sheets, you will need to summarize the design, identify at least one strength and one weakness of the design, and make recommendations for improving the design.

Date ____________________

Be sure to include the following ideas in your patent application.

ABSTRACT

Describe how your design works.

BACKGROUND INFORMATION

- Name of design.
- List of inventors.
- Date of application.
- Background information about the design.
- Describe the problem that your design solves.

YOUR CLAIMS

- Describe the situations where your design is most useful.
- Specifications for your design.
- Functions of your design.

Reaction Subsytem

- Report your balanced chemical equation.
- Describe how much of each chemical will be needed.
- Describe how the chemical reaction makes your design work.
- Describe how the atoms rearrange during your transformation.
- Describe how the rearrangement of atoms in your reactants is related to the temperature changes in the object your design is supposed to heat or cool.

Container Subsystem

- Describe your container materials.
- Describe how your container influences the energy transfer in your design.

Date ____________

PATENT APPLICATION

Write a 1-3 paragraph abstract describing your design.
Background of the design.

Date ____________________

What are your claims about this design?