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Thermochemistry/Medical Application

Next Generation Science Standards (NGSS)

and the Common Core State Standards (CCSS)

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NGSS Performance Expectations(s)

HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*

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

Background Information / Teacher Notes

Prior chemistry knowledge: Students should know how to take measurements with a thermometer and scale. It is not necessary that they understand moles or be able to calculate a molar mass. However, the labs are easy to extend to moles and molar mass. The lab activities will be written in both formats, with and without moles. Conversions between moles and grams is essential since all work at the lab bench is in mass. This unit incorporates all Science and Engineering Practices and about half of the Cross Cutting Practices. Day by Day Calendar

Lab Materials:

- Safety goggles
- Vienna Sausages (one per lab group)
- Sandwich sized sealable plastic bags
- Digital thermometers
- Balances
- Graduated cylinders
- Hot plates
- Styrofoam cups
- Paper cups with lids
- Insulating materials: bubble wrap, aluminum foil, insulating foam, cotton wrap, etc.
- Endothermic chemicals: Urea,$(NH_2)_2CO$, Potassium Chloride, KCl, Ammonium Nitrate, NH_4NO_3, and Ammonium Chloride, NH_4Cl. (not necessary to have all of them but at least three would allow for student choice)

		• Exothermic chemical: Calcium chloride, $CaCl_2$

SEP	Disciplinary Core Ideas	Crosscutting Concepts
Design a medical transport device that maintains a constant cold temperature for dismembered finger or organ transplant. **Constructing Explanations and Designing Solutions** to optimize the transport device and design a cold pack that absorbs enough energy to cool the finger or organ. **Planning and Carrying Out Investigations** make up 75% of this 5E thermochemistry unit.	**PS3.A: Definitions of Energy** ● Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. **PS3.B: Conservation of Energy and Energy Transfer** ● Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). PS3.D: Energy in Chemical Processes ● Although energy cannot be destroyed, it can be converted to less useful forms — for example, to thermal energy in the surrounding environment.	**Energy and Matter** is explored as students design a calorimeter to conserve energy and then make a cold pack with matter to produce an energy change within a system. **Scale, Proportion and Quantity a**re applied as students determine correct amounts of chemical to design the cold packs. **Systems and system models a**re explored and ultimately understood as students sketch energy flow throughout a system. Extending to mathematical models and equations is the goal. **Cause and Effect** students realize that when a solution is formed from dissolving a solid into a liquid energy is absorbed that has an effect on its surroundings. -

Anchoring Phenomenon for Unit

Phenomena Resources

Phenomenon: Students will watch 2 minute video: Accidental finger dismemberment due to fireworks. Other short video clips about finger reattachment issues and an article about finger reattachment, are included to maintain a real world connection as the unit progresses. While reading they will take notes on first aid procedures, pros and cons of reattachment and outcomes.

Driving Question: Can you design a container and cold pack using thermochemical understandings to chill a finger or organ donation between 4℃- 8℃ for transport to a hospital? Show students a mock finger (vienna sausage).

Instructional Sequence 1	
Performance Expectation(s) and Concepts from: ➢ ***Evidence Statements***	**HS-PS3-3.** **Design, build, and refine a device that works within given constraints to convert one form of energy** PS3.A: Definitions of Energy • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. PS3.D: Energy in Chemical Processes • Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. ETS1.A: Defining and Delimiting Engineering Problems • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
Concepts from: ➢ ***Clarification Statements***	.* [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices.[*Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.*]
Investigative Phenomenon	Students watch the video clip of finger lost to a firework accident. Man loses 2 fingers in fireworks accident 3A: Students generate examples of related phenomena they have experienced. 4A: Students generate questions that could lead to uncovering important ideas. 4B: Students go public and build a record of questions. 4C: Students generate investigation ideas that could lead to uncovering important ideas in target DCIs. 4D: Students go public and build a record of their ideas for investigations..

5E Stage	Driving Question / Sub-Phenomena	What the Teacher Does	What the Student Does
Engage: Anchoring Phen.	How is it possible to reattach a lost appendage? What engineering and medical knowledge is necessary?	● Facilitate class creation of public records of observations, initial models and Driving Question Board ● Ask students if they have known anyone who has lost an appendage. ● Show Man loses 2 fingers in fireworks accident ● Have students read First Aid Basics for an accidental amputation.	● Record and discuss initial observations ● Record and discuss ideas for related phenomena ● Record and discuss initial models and/or hypotheses ● Record and discuss wonderings ● Start Summary Chart
Engage: Investigative Phen.	What makes a good insulator?	● Ask students "What is an insulator? ● And "Where do you see them in the world?" ● Add responses to Driving Question Board	● Students come up with responses such as: ○ Insulators keep heat in ○ Insulators regulate temperature change ○ Insulators prevent energy flow ● Students come up with responses such as ○ Coffee cups ○ Houses ○ Ice chests
Explore	What do engineers do?	● Give students prelab for homework or before starting lab	● Students read Background- Engineering in Medicine and look a the career spotlight ● Students read the Scenario and answer the review questions about engineering and organ transport.
	How can I build an insulated container with time and cost restraints?	● Provide students with insulating materials for lab	● Carry out the "Calorimeter Design Project" ○ Design a calorimeter with lab group ○ Test the calorimeter by measuring temperature change of hot water over 5 minutes ○ Calculate rate of change for temperature of water

			○ Share findings with class on large whiteboards (cost, temperature change, rate of change)
Explain	What are common features of effective insulators?	● Teacher facilitates class discussion looking at data on whiteboards and comparing with different calorimeters	● Students record findings in their notebooks for what makes an efficient insulator with evidence from the whiteboards ● Students are given a chance to revise or rebuilt parts of their calorimeter if they choose to, keeping in mind it will be used for the remainder of the unit.
Explore	How can I quantitatively measure the efficiency of my calorimeter?	● Teacher facilitates "Efficiency testing part 2" ● Provide students with hot plates, ice, two different beakers, thermometers, two different graduated cylinders ● This is the first introduction to the concept "quantity of heat" and the equation "$q=mc\Delta T$"	● Carry out "Efficiency testing part 2" ○ Model what will happen when two different water temperatures are mixed together ○ Use data to calculate the "q"- energy lost to the calorimeter ○ Share findings with class on large whiteboards (cost, rate of change, q efficiency value)
Explain		● Facilitates class post it feedback ● Facilitates class discussion on what "q" value means- asking questions like ○ "Would you want a large or small q?" ○ "In an ideal world, what should the equilibrium temperature have been of the mixed waters?" ○ "Why did some groups end up with temperatures below 35°C?" ○ "Why did some groups end up with temperatures above 35°C?"	● Students get a post it to give feedback to another group on their calorimeter device ● Students answer questions during class discussion
Elaborate		● Show students commercial of a real insulating device for organ transport ● The link to the company site for more information	● Students finish the activity "Post Lab" by carrying out the post lab- creating a marketing advertisement for their calorimeter device

Evaluate, and/or Revise Anchoring Phen. Models		• Revisit summary chart.	• Students volunteer answers to add to the summary chart

Instructional Sequence 2	
Performance Expectation(s)	HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
Concepts from: ➢ ***Evidence Statements*** ➢ ***Clarification Statements***	• Students identify and describe* the components to be computationally modeled, including:
3 Dimensions of Focus	**SEP**: **Create a computational model or simulation of a phenomenon, designed device, process, or system.** **CCC**: **Systems and System Models,** Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. **DCI**: **Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems,** Science assumes the universe is a vast single system in which basic laws are consistent.
Guiding Questions	What will happen when different chemicals are dissolved in water. Why do some produce or release heat? If you were to make a cold pack, then which chemical would you use and why?
Investigative Phenomenon Phenomena Resources Anchoring vs. Investigative	Students watch video of Cold injuries in heart transplants 3A: Students generate examples of related phenomena they have experienced. 4A: Students generate questions that could lead to uncovering important ideas. 4B: Students go public and build a record of questions. 4C: Students generate investigation ideas that could lead to uncovering important ideas in target DCIs. 4D: Students go public and build a record of their ideas for investigations..

	Driving Question / Sub-Phenomena	What the Teacher Does	What the Student Does
Engage: Investigative Phen. Phenomenon promotes curiosity, elicits students' prior knowledge, exposes prior conceptions, and organizes students' thinking.	Design a product that can chill and keep body parts at 4℃	1. Show video of Cold injuries in heart transplants	1) Have students discuss if ice is really the best option to keep organs cold in transport? 2) What are other options?
Explore Students work through activities using SEP's to make sense of the phenomenon, generating new ideas and exploring questions. Students design and conduct investigations rather than following set directions for labs.	When some chemicals are added to water they will release or absorb energy. The energy lost or absorbed will result in a hot or cold pack..	Students will weigh 5 g of each chemical, Urea, Potassium chloride, Ammonium nitrate and calcium chloride. 5 g of ice should be used as well but not mixed with water. 50 ml of water is added to their calorimeter they will take the temperature of it and record. Each chemical is dissolved separately in water, stirred, and the temperature is recorded at the highest or lowest reading.	Students will carry out investigation: Cold Pack Chemistry- Medical Research and Activity
	Which chemicals produce the greatest amount of heat in kJ given one mole of the chemcal?	Teacher allows students to explore content using online simulations	Hot/cold pack CK-12 simulation with handout
Explain Students demonstrate their understanding as they make sense of the phenomenon and build academic	Which chemicals are you using to make your hot	Teacher will provide students with the interpreting graphics assignment A discussion should follow regarding the three enthalpies	Students complete Enthalpy worksheet with help of CK-12 reading 11.3 • Label the three enthalpies in the diagram

language. Students explain to other students. The teacher or other resources may guide learners toward a deeper understanding.	pack for the finger?	Enthalpy #1= energy released (-) when the dissolved cation and anions are attracted to the polar water molecules (hydration enthalpy) Enthalpy #2 = energy required to dissolve an ionic solid (lattice dissociation enthalpy) Enthalpy #3= Lattice Energy enthalpy + Hydration enthalpy total	• Explain the energy differences between a hot and a cold pack. • Use the vocabulary; Endothermic, Exothermic and Solution Enthalpy.
Elaborate Students apply what they have learned in a new way.	Student lab groups create a computational model of their chemical cold pack using the chemical of choice.	Students will read and do problems around calorimetry and endo and exothermic processes.	Student calorimetry reading with review questions assignment Student exo/endo reading with review questions assignment
Evaluate Students demonstrate their mastery of the performance expectations through the use of science and engineering practices.	Did the cold pack you made generate enough heat to lower the water from room temperature to 4℃?	**Lab Follow Up:** The student cold packs most likely did not chill the water to 4℃ , therefore challenge student teams to use math, and the formula $q=mc\Delta t$ and determine how many moles or grams of their chosen chemical are required to chill the water. Once students solve for q in joules, the joules must be converted to kJ. (divide by 1000 or move the decimal three places to the left) The chemical enthalpy of solution value chosen by the student needs to be compared to calculated kJ value. For example: using $CaCl_2$ Calculated j value of	Students need to solve for q(joules) with a Δt of 16℃, (4℃ minus 20℃) with the amount of water of 50g and the specific heat of water 4.186J/g℃ Error exists with the mass of water not including the mass of chemical, corrections can be made at the lab bench. Once students solve for q in joules, the joules must be converted to kJ. The chemical enthalpy

		7,116.2 J = (100g of water) (4.186 J/g℃) (17℃) $\frac{7.12kJ}{X\ moles} = \frac{80\ kJ\ for\ CaCl_2\ x}{1\ mole}$ I like using proportions to solve for these problems because it demonstrates the crosscutting concept of scale and proportion; fundamental to balanced equations and stoichiometry. Dimensional analysis example given is student section. Solve for x moles and then convert moles to grams * Remember converting from moles is always "moltiply" by Avogadros number for particles, molar mass for mass or 22.4 L for gases at STP. Reversing the conversion is division.	chosen by the student needs to be compared to kJ value so for example: using $CaCl_2$ 7,116.2 J = (100g) (4.186 J/g℃) (17℃) 7,116.2J/1000= 7.12 kJ $\frac{7.12kJ}{X\ moles} = \frac{80\ kJ}{1\ mole} =$ .89 mole of $CaCl_2$ Solve for x moles and then convert moles to grams .89 mole of $CaCl_2$ x 110g/mol = 9.79 g $CaCl_2$ Or the traditional dimensional analysis method: $\frac{7{,}116.2\ J}{} \times \frac{1\ mole}{80\ kJ} \times \frac{110g CaCl2}{1\ mole} \times \frac{1\ kJ}{1000J} =$ 9.79g $CaCl_2$

Note: Add additional rows as needed.

Instructional Sequence 3	
Performance Expectation(s)	
Concepts from: ➢ ***Evidence Statements*** ➢ ***Clarification Statements***	**1)Using scientific knowledge to generate the design solution** **a Students design a device that converts one form of energy into another form of energy.** **b Students develop a plan for the device in which they:** **i. Identify what scientific principles provide the basis for the energy conversion design;** **ii. Identify the forms of energy that will be converted from one form to another in the designed system;** **iii. Identify losses of energy by the design system to the surrounding environment;** **iv. Describe* the scientific rationale for choices of materials and structure of the device, including how student-generated evidence influenced the design; and** **v. Describe* that this device is an example of how the application of scientific knowledge and engineering design can increase benefits for modern civilization while decreasing costs and risk.** **2 Describing criteria and constraints, including quantification when appropriate** **Students describe* and quantify (when appropriate) prioritized criteria and constraints for the design of the device, along with the tradeoffs implicit in these design solutions. Examples of constraints to be considered are cost and efficiency of energy conversion.** **3 Evaluating potential solutions** **a Students build and test the device according to the plan.** **b Students systematically and quantitatively evaluate the performance of the device against the criteria and constraints.** **4 Refining and/or optimizing the design solution** **a Students use the results of the tests to improve the device performance by increasing the efficiency of energy conversion, keeping in mind the criteria and constraints, and noting any modifications in tradeoffs.**
3 Dimensions of Focus	**SEP**: Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence

	consistent with scientific ideas, principles, and theories. Design, evaluate, and/or refine a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade of considerations. **CCC**: PS3.D: Energy in Chemical Processes Although energy cannot be destroyed, it can be converted to less useful forms — for example, to thermal energy in the surrounding environment. ETS1.A: Defining and Delimiting an Engineering Problem Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. **DCI**: Energy and Matter Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering and Technology on Society and the Natural World Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
Guiding Question(s)	**How much energy in joules is required to lower the temperature of a vienna sausage (finger) at 4.4℃ ?**
Investigative Phenomenon	Video about finger reattachment

5E Stage	Driving Question(s)	What the Teacher Does	What the Student Does
Engage Investigative Phen. Phenomenon promotes curiosity, elicits students'	When is it worth it to reattach a severed finger?	Video about finger reattachment Have students read article: Finger Reattachment	Students read article. Students write responses to article using this graphic organizer Pair share or whole group discussion of article.

prior knowledge, exposes prior conceptions, and organizes students' thinking.			
Explore Students work through activities using SEP's to make sense of the phenomenon, generating new ideas and exploring questions. Students design and conduct investigations rather than following set directions for labs.	How much of an endothermic chemical will we need to chill a severed finger (sausage)? What types of experiments can be done to measure energy transfer?	**This section is essential for students to understand what heat capacity is Here are several explore options:** 1) Simulation lab for students to practice solving for specific heat using calorimetry.	Flash lab simulation: Determination of Specific Heat
		2) Another option is for the teacher demo the lab simulation on the overhead projector 3) Another option is to have students practice getting specific heat doing the classic metal calorimetry lab, so they can see they will use the same technique for the finger. The one provided recommends using thermometer probeware.	Have the students do the calculations together. PASCO - Specific Heat Lab
Explain Students demonstrate their understanding as they make sense of the phenomenon and build academic language. Students explain to other students. The teacher or other resources may guide learners toward a deeper understanding.	How can energy flow from the specific heat experiments be illustrated?	Make sure students are completely aware of the need to understand the flow of energy out of the calorimeter, out of the finger and out of the water. The energy flowing out must equal the energy flowing into the chemical in order for the chemical to dissolve in the water. Give students guidelines to draw a model of energy flow in an organ transport device. The model must show:	Draw an energy model diagram on a whiteboard as a group. Students get a post it to give feedback to another group on their energy flow model device

		- Calorimeter, sausage, cold pack, water - Arrows for heat flow - Labels	
Elaborate **Students apply what they have learned in a new way.**	How much energy in Joules is required to raise the temperature of a chilled 4.4 ℃ finger (vienna sausage) to body temperature?	Teacher holds up a chilled vienna sausage and challenges students to use the equation: $q=mc\Delta t$ and solve for q. Have equation on board and help students identify what do we have, what can we measure, what do we need to solve for… etc. Hopefully students will realize that they can mass the finger, calculate the Δt, but they do not know the c (specific heat of vienna sausage) So this will have to be solved for at the lab bench!	Try to answer the question: How much energy in Joules is required to raise the temperature of a chilled 4.4 ℃ finger (vienna sausage) to body temperature? Perform finger calorimetry lab activities: [Emergency Transport of the Dismembered Finger] Activity 1: Specific Heat of the Sausage Activity 2: Modeling and Calculations for energy flow and cold pack chemical quantity Students will design their cold pack to remove enough heat in joules to lower the temperature of the water in the cold pack and chill the finger to 4-8 ℃ . The amount of chemical added to the ziplock bag should produce the exact amount of joules for this energy flow. Activity 3: Write a procedure and test the cold pack transporter
Evaluate **Students demonstrate their mastery of the performance expectations through the use of science and engineering practices.**	Is it effective to use chemicals to keep a severed appendage cold for a period of longer than two hours in	Direct students to make a graph using available software. Possible options are Microsoft Excel, Google Sheets, and Desmos. Here is an example from students who used Desmos	Make digital graph, calculate temp. after 120 min (organs only stay viable for 2 hrs.), Publish results in a document the form of a research abstract based on one from this small start up company

	order to reattach?		

Note: Add additional rows as needed.