Topic: Physical and Chemical Properties of different substances
Grade Level: High School Chemistry
Time: 2 weeks (6 40 minute periods and 4 80 minute periods)

NGSS Standards:
HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

SEP	DCI	CCC
Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3)	**PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3), (secondary to HS-PS2-6)	**Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-1),(HS-PS1-2), (HS-PS1-3),(HSPS1-5)

CCSS Standards:
Quantities★ N-Q
Reason quantitatively and use units to solve problems
3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Engaging Contexts:
The engaging “hooks” for this lesson are: a video showing various substances melting at different temperatures, students making their own partial vacuum to show water boiling without changing the temperature, and an article on how surfaces of electronics are water repellent to boil water to keep them cool. The electronics connects to technology and engineering where designs need to be included that keep devices from overheating and functioning properly, the video shows how the composition of substances affects their physical properties such as melting point- where structure and function are a component of almost all science classes, and the partial vacuum shows how manipulating the physical conditions of a substance, like the pressure can change their physical properties.

Justification:
Technology- Throughout the course of this lesson the students will need to incorporate technology to research and develop laboratory experiments to test the physical and chemical properties of substances.

Mathematics- Students will need to incorporate mathematical analysis to determine the effectiveness, accuracy, and limitations of the data they collect throughout their experiments.
Science- Students will need to use their research and results to determine the type of bonding that exists within the substances and make general statements and connections to the type of bonding, elements involved, and the physical/chemical properties of the bonded compounds.
Engineering- Lastly, they will need to use engineering skills to design a solution utilizing their results to solve a problem proposed to them. From their designed solution the class will peer review each of the proposed designs to determine the best one.

Measurable Objectives:

- Students will be able to conduct research and then develop appropriate laboratory techniques to determine the physical and chemical properties of different substances.
- Accurate lab designs will be generated and conducted by each group of students to obtain measurable data using lab techniques available to them keeping in mind the cost of materials, trials, time needed to conduct the experiments, and any risks their experiments might have
- Mathematical calculations and analysis will be conducted to determine the accuracy of the measured data as well as what limitations the lab equipment they used has
- Students will analyze their data to explain the patterns they observed across each of the samples tested and categorize the samples in a meaningful way based on the type of bonding that is present within each of the samples.
- Students will design a system that solves a proposed problem keeping in mind the limitations of the materials they tested. Students' design will need to be selected and supported with evidence they collected, then presented and justified to the class for peer review.

Lesson Procedure:

Engage:

1. Show the class the following gif on a loop: https://media.giphy.com/media/KHJkhwI48cC3AihWlu/giphy.gif Do not say anything about it and have the students write down any questions/observations they have about the video.
2. Have the students share their questions with the person sitting next to them and then generate new combined questions together on a new list. Conduct a whip around and have the students share out with the class one of their combined questions until every question has been shared. The conversation will flow based on student answers but the goal is to get to the idea that different substances have different physical and chemical properties. Create a list of the questions on the board.

3. In small groups, have the students use small plastic bell jars, clear film canisters filled with water, and syringes to create a miniature vacuum and show the water boiling without changing the temperature, but the physical properties. Ask the students think about what they think happened inside the bell jar, but don't answer any questions on it. Have each group share a question as you move around the groups, creating a list on the board.

Explore:

1. Students will research methods/lab techniques to test the physical and chemical properties of the different substances provided. As a class we will discuss the different sources they can use for their research as well as what things they should be testing for as and what tests will be off limits based on the constraints of the classroom and student safety. These two things will both be generated as a list in the front of the room for the students to reference throughout the research and design process. There is a graphic organizer provided below to help guide the students research.
2. From their research they will have to be able to analyze and determine what tests can be run in the classroom based on cost, safety, availability of materials, time needed, reliability, how many trials is appropriate.
3. As they are researching what tests they want to conduct to determine the different physical and chemical properties of the substances and then categorize them based on those properties, the students will need to determine what tools/techniques would be best to use to minimize error and increase precision and accuracy when collecting their data.
4. Lastly, the students will then need to run the tests with trials (as needed and predetermined) and collect their data in a meaningful way. While they class is researching and conducting their experiments, do not tell them what substances they are going to be testing. You do not want them to research the substances before they run their tests.
   ****TEACHER NOTE:** Throughout this process students will be asking questions, choosing how to design their experiments, what type of data to collect, etc. As the teacher only answer questions based on the available materials and anything to do with safety. Have the students determine how to record data, what to record, how the trials should be designed, etc. The purpose of the lesson and the standards is to have them think through the process of designing and conducting experiments.

Student Research Graphic Organizer

Topic/Problem:	Name of Partners: Start Date: End Date:

Goals of my research/what do I want to achieve? Restrictions/limitations to experiments I can conduct:

Research Results Space:

Explain:

1. After collecting and analyzing their data students will identify the patterns obtained from their results, categorize the substances tested in a meaningful way based on their results and NOT research, and then make conclusions about the types of bonding and intermolecular forces the substances have based on their research and results. The class would have already learned about the different types of bonds and IMFs.
2. After conducting their experiments the groups will need to present and explain their results so that the class can observe their results. This can be done in a variety of different ways, try to avoid suggesting how they can show what they tested and learned but lead them to the rubric attached to make sure they have included all of the important aspects.
3. In addition to sharing their results, they will need to mathematically analyze their results for the amount of error in their tests and the reliability of their tests. They will also need to suggest where some of the error occurred throughout the process and address some of the limitations of their research. They can use any mathematical methods to present their analysis, most commonly they would use percent error but they can use any mathematical ways they choose. At this point you will need to provide the students with the different substances they tested so they can obtain their known values.
4. The analysis, conclusion, and reporting of their results will refer back to the research they conducted about the different physical and chemical properties of substances and the types of bonding that exists within the substances.

Rubric 1: Results of Materials and their Physical/Chemical Properties based on Bonding and Intermolecular Forces (IMFs)				
Category	**4**	**3**	**2**	**1**
Identification of Patterns of results	Clearly identifies the patterns of results based on testing substances, not their research	Identifies the patterns of results based on testing their substances but some are not correctly categorized	Patterns are identified based on their research, not their testing of the substances	Patterns are not clearly identified and/or missing
Categorization of substances based on results	Each substance is categorized correctly based on the types of bonds/properties	Some substances (1-3) are improperly categorized	Most substances are improperly categorized	Substances are not categorized at all
Conclusions about types of bonding and IMFs in each compound based on results	Correct conclusions are made based on their results and research for each substance	Correct conclusions are made based on their results and research for most substances	Correct conclusions are made based on their results and research for a few substances.	Very few correct conclusions about the substances are made based on their research
Mathematical Analysis of results	Accurately analyses all aspects of the	Accurately analyses most aspects of the	Accurately analyses few aspects of the	Does not analyze the results mathematically

	results mathematically for error and understanding	results mathematically for error and understanding	results mathematically for error and understanding	for error and understanding
Suggestions and explanations of error throughout experiment	Suggests many areas of error that could have occurred and explains them accurately and thoroughly	Suggests some areas of error that could have occurred and explains them	Suggests few areas of error that could have occurred and does not fully explain them	Does not suggest areas of error or explanations are missing/not fully understood as accurate error sources
Addressing the limitations of their research	Clearly identifies and explains the limitations of conducting this research in a classroom with limited resources, materials, and equipment	Identifies and explains the limitations of conducting this research in a classroom with limited resources, materials, and equipment	Unclear about the identification or explanation of the limitations of conducting this research in a classroom with limited resources, materials, and equipment	Does not identify or explain the limitations of conducting this research in a classroom with limited resources, materials, and equipment

Elaborate/Extend:

1. Students will be presented with the following problem below and asked to use their research and results to come up with a viable and cost effective solution to solving the problem. They will be doing this with the same groups that they completed the first part of the lesson with.
2. They will then need to justify why they think their solution is the best to solve the problem and the class will vote on which solution they think is the most effective at solving the problem.
3. The proposed problem is: The shorelines of the LI sound get very windy and you want to design a casing (material, shape, size, etc.) for new wind turbine generators that is sturdy, able to withstand the elements while being outside in your region, not oxidize/rust, not conduct electricity, be cost effective, and easy to build in bulk. Select a substance from the ones you tested and design a casing to suite the needs described above. Refer to the rubric to ensure you are addressing all aspects of the design solution in your final proposal to the class. Below there is a graphic organizer for the students to use while conducting their research to help guide them.
4. Present students with the article below and have them read it for homework. Then in class the next day students will share their thoughts about the reading and how water behaves due to its bonding properties.

Purdue University. (2018, April 30). Water-repellent surfaces can efficiently boil water, keep electronics cool. *ScienceDaily*. Retrieved June 18, 2019 from www.sciencedaily.com/releases/2018/04/180430131807.htm

Designing a Solution Graphic Organizer

Substance Selection from what you tested: Reasons why you selected it over other substances (this will help determine if you selected a valid substance):

Drawing/Design of your wind turbine casing:
Justification of design and material selection:
Reasons why your design is best (include things like cost, material availability, etc. and refer to the rubric):

Rubric 2: Designing a Solution				
Category	**4**	**3**	**2**	**1**
Justification of why their solution is best	Clearly justifies why their solution is best based on the research, results, and tests they conducted	Justifies why their solution is best based on the research, results, and tests they conducted, but it is unclear	Minimal justification of why their proposed solution is the best/design isn't supported with their results	Does not justify why their proposed solution is the best/design isn't supported with their results

Included aspects set in the proposed problem	Includes all aspects and limitations set in the proposed problem	Missing 1-2 aspects and limitations set in the proposed problem	Missing 3-5 aspects and limitations set in the proposed problem	Does not include any of the aspects and limitations set in the proposed problem
Created a viable design solution to the problem	Solution is all 3: 1) viable, 2) cost effective, and 3) accurately solves the proposed problem	Solution is proposed but is missing one of the following: 1) viable, 2) cost effective, or 3) accurately solves the proposed problem	Solution is proposed but is missing two of the following: 1) viable, 2) cost effective, or 3) accurately solves the proposed problem	The proposed solution does not make sense with the problem presented to them/doesn't help to solve the problem.
Accurately selected a substance from the ones tested	Accurately selected one of the substances from the ones tested to solve the proposed problem			Did not accurately selected one of the substances from the ones tested to solve the proposed problem

Evaluate:

1. The students will peer review their classmate's proposals for the wind turbine casing and the limitations/abilities to mass-produce them, costs required, and durability (etc.) to solve the problem.
2. Students will need to rank each design using a critical lens following the guidelines set out by the project analysis page. ***Students will not rank their own projects to avoid bias.***
3. The rubric for how they will evaluate each project will help them peer review the designs and determine if their research led them to develop a structure able to withstand the criteria

Rubric 3/Evaluation Sheet: Student Analysis of Designed solutions				
Group Number:				
Category	**4**	**3**	**2**	**1**
Limitations/abilities to mass produce	Proposed solution clearly addresses both the limitations and abilities of mass production	Proposed solution addresses both the limitations and abilities of mass production	Proposed solution does not clearly addresses both the limitations and abilities of mass production or one is missing	Proposed solution is not clearly addressed for both the limitations and abilities of mass production
Costs and durability	The costs and durability of the proposed	The costs and durability of the proposed	The costs and durability of the proposed	The costs and durability of the proposed solution

	solution are clearly identified and easy to understand	solution are identified and explained	solution are identified	are not identified/included in the design
Appearance	The proposed solution looks good and would be something you would want to see every day			The proposed solution does not look good and you wouldn't want to see it daily.
Personal Ranking: Please place a check in the correct box below to rank how you think the proposed design solution would fit within the community. Remember, you are not ranking your own projects.				
Individual Ranking:	Yes, this is a great solution and my community would embrace it.	It has a lot of potential but a few things need to be changed before our community would embrace it.	There are aspects that fir with our community but some that do not. Some changes would fix it for the community to embrace.	This does not fit with our community look and the community would not embrace it.

Additional Lesson Materials: The detailed description of the lesson plan is outlined above. This section includes the required materials for the lesson

1) **Engage-**
   - Access to the internet to show gif https://media.giphy.com/media/KHJkhwI48cC3AihWlu/giphy.gif
   - Mini vacuum bell jar kits with clear film canisters and syringes *This is only to show how changes to substances can change their properties and can be left out if materials are not owned or readily available*
2) **Explore-**
   - Various solids depending on availability. I am going to use sand, sugar, aluminum foil, various metals (zinc, magnesium, nickel, iron, copper), hydrates ($CuSO_4$, $NaNO_3$, and KNO_3), graphite and sulfur.
   - Internet access with devices
   - List/visual of all lab equipment they have access to for testing *I personally have Vernier melt stations in addition to Bunsen burners. This list can be as inclusive or exclusive as you want from the beginning
3) **Explain-**
   - Media presentation materials based on availability and what you want them to do. For example, computers for presentations, webcams with microphones for screencastify, videos, papers for charts, googledraw, materials for models, etc.

- Rubric for what they need to include in their explanation and how well they communicated it (labeled rubric 1 above)

4) **Elaborate/Extend-**
   - Description of the problem to solve, which you can change depending on your region
   - Rubric/guidelines for solving the problem (labeled rubric 2 above)
   - Computer access or library access to research for how to design their solutions.
5) **Evaluate-**
   - Media presentation materials based on availability and what you want them to do. For example, computers for presentations, screencastify for videos, papers for charts, googledraw, materials for models, etc.
   - Rubric/Evaluation sheet of how they should evaluate their classmates proposed design solutions (labeled rubric 3 above)