Intermolecular Forces

High School Physical Science
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Idaho State Science Performance Standards:

- **PSC1-HS-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.
- **PSC1-HS-5**. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Science & Engineering Practices:

- Developing and Using Models
- Constructing Explanations and Designing Solutions

Crosscutting Concepts:

- Structure and Function

Idaho Math & ELA Standards:

ELA/Literacy

- **CCRA.R.7.** Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.
- **CCRA.W.1.** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
- **SL.9-10.4.** Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

Mathematics

- Make inferences and justify conclusions from sample surveys, experiments, and observational studies 6. Evaluate reports based on data

Essential Question:

Why do things stick or not stick?

Guiding Questions:

What questions will constantly focus the students on the Big ideas/Critical Question within the unit in student language?

- What is a solid? What is a liquid? What is a gas?
- What happens to atoms/molecules when something melts?
- What happens to atoms/molecules when something boils?
- What happens to atoms/molecules when something heats up or cools down?
- How can we express phase changes visually?
- How can I make something boil or freeze? What else can I do?
- How do both pressure and temperature affect phase change?
- Why is water special?
- Why does polarity matter?
- What is vapor pressure?
- Why do some things evaporate fast and other things evaporate slowly?
- What are intermolecular forces and why do we care about them?
- Why do some substances mix and other substances don't?
- Why do some things stick to each other and other things won't?
- How can I use intermolecular forces to explain how different substances behave?

Misconceptions/Evolving Conceptions:

What might students commonly misunderstand about the subject? How will I directly address these?

- **The temperature of a material changes during phase change.**
    - Students will watch the temperature of water as an ice cube melts and heats to boiling. They will see that temperature doesn't change during phase change and be asked to brainstorm how that can possibly be true because energy is being added and has to go somewhere. Students will be questioned into the idea that the energy is going into breaking some kind of bond.
- **When you get something hot enough it will always turn into a gas.**
    - Explore the idea of critical point and critical fluids. Show videos and talk about observations and what they mean in terms of temperature/kinetic energy and pressure/closeness/Coulombic attraction. Imagine that the kinetic energy is so

high that the molecules are moving ridiculously fast and because they are moving so fast their kinetic energy always overcomes their intermolecular interactions, however the pressure is also very high so the molecules are forced to be very close together and because they are so close the Coulombic attractions are greater and there are some intermolecular interactions. Critical fluids have very strange behaviors because they have characteristics of both gases and liquids.

- **Pressure doesn't matter for boiling temperature or state of matter.**
    - Use a bell jar and vacuum pump to show that the temperature of acetone or ethanol stays the same, but the liquid will start to boil at room temperature. Show videos of water boiling at low temperatures. Tell the story of trying to make spaghetti while camping just off of Hurricane Pass in the Tetons elevation 10,338 ft. Water boiled at 193 F rather than 212 F or 90 C instead of 100 C. This is enough to make it so that the spaghetti did not cook well and it was more like eating paste. It was awful. Why was it awful?
- **Intermolecular forces are attractions between molecules not within molecules.**
    - Interstate highways go between states. Intermolecular forces go between molecules or distant parts of the same very large molecule.
- **Hydrogen bonds are any covalent bond with hydrogen in it.**
    - The chemistry definition is very limited to interactions between hydrogen bound to oxygen, fluorine, or nitrogen and an oxygen, fluorine, or nitrogen. It's a definition.

Scaffold of Activities:

What is your lesson sequence you will use to get students to the culminating project?
For Full Unit/Lesson Plans Click Here

1. **Day 0:** Pretest
2. **Frontloading/Introduction (Day 1)**
    a. Begin with Solids Liquids and Gases OH MY! and tape activity to help students remember what they know.
        i. students write down what they already know about solids, liquids, and gases on a grid. Each student only has to have one idea to begin then they move around the room and get other ideas from other students. As a group, we build a long list of what we already know.
        ii. At the end of this they have always had a list of characteristics that include some details of intermolecular forces even if they don't know that. By asking them to look for similarities between the tape experience and the states of matter ideas and asking them to connect it back to Coulombic attraction which is a lens that they have used all year long, I want them to wonder why things stick.
    b. Show water balloons at OG NASA Water Balloons in Zero G (High Quality) how does this relate to everything else? Create a long list of hypotheses to test over the course of the unit.
3. **Day 2-3**: Phase Change Lab.

a. Students will each get a thermometer frozen in a small block of ice, they will draw particulate level diagrams of what water looks like as a solid, a liquid and a gas. They will describe what makes a solid a solid, a liquid a liquid, and a gas a gas. They will create a hypothesis of what they think a temperature time graph will look like if a constant amount of energy is added to the ice. Then they will slowly heat the ice until it boils and create an actual graph of the temperature vs time. They will also be asked to relate temperature to kinetic vs potential energy and be asked to answer the question, where did the energy go? For each section of the graph that they create they will be asked to define if there is a change in kinetic or potential energy and justify their answer. They already have an understanding of energy and the idea that potential energy is stored in bonds and kinetic energy is a measure of temperature. They will also be asked if bonds within molecules or bonds between molecules break. In the end, they be asked to hypothesize, What takes a solid apart? and How do solids stick together?

4. **Day 3-4 Direct Instruction**
   a. Phase Change and Phase Change Diagrams with practice interpreting diagrams for different substances. Introduce sublimation and deposition as gas to solid or solid to gas direct transitions. Interpretive dance of Kinetic Molecular Theory (students in desks are solid, I am a liquid, they can melt and be a liquid too, when the bell rings they all become a liquid and flow into the hall, at the end of the day they evaporate and fly out of the building as a gas)
   b. Phase Change PowerPoint (pdf link here)
   c. Fill in the blank notes link
5. **Day 5: Dry ice bombs and Phase Change Diagram practice.**
   a. Students will work through Phase Change Diagram Assignment and vocab sheet while waiting for a turn at the dry ice bombs. Students should never be allowed to do the dry ice bombs without direct adult supervision, this means that 2-4 students at a time will observe the following. **Students should never directly handle dry ice or dry ice in a sealed container of any type.** Put a small amount of dry ice into a clear pipet bulb, krimp the opening and put the pipet bulb in water. Observe the changes that CO2 undergoes. Discuss these observations in terms of pressure and temperature. Tell story about trying to make spaghetti in hurricane pass (easily the worst dinner of my entire life). How are these two sets of observations related? What does pressure have to do with it? Brainstorm possible relations between phase change and pressure.
      i. Example of dry ice set up at
         1. dry ice pipette explosion
         2. Simple, Small-Scale Dry Ice Explosions
         3. Wet Dry Ice Lab
      ii. Wet Dry Ice Lab link
      iii. Phase Change Diagram Practice
   b. Vocab sheet
6. **Day 6**
   a. Phase Change Diagram Quiz:

b. Direct Instruction on Phase Diagrams using pressure vs. temperature. Use videos for critical point and triple point observation. Practice interpreting phase diagrams. Answer the question why does ice skating work?
    i. Triple Point video
        1. Did you see this yesterday?
    ii. Critical Point and supercritical helium videos
    iii. Powerpoint (pdf link here)
        1. Fill in the blank notes
    iv. How does ice skating really work video
    v. Phase Change Diagram Practice

7. **Day 7-8:**
    a. Phase Diagram Quiz: Where are all of these interactions coming from? What do we know about water?
    b. Veritasium phases of matter video
    c. Look at water molecular structure, use water molecule magnet models
    d. Video simulation of ice melting
    e. Molecular animation of ice melting
    f. What Is So Special About Water? POGIL type activity based on Intermolecular Forces and Phase Changes Target Inquiry at Miami University, 2014 Kyle Jones, Fairfield High School
        i. Look at water molecular structure, use ethane molecule magnet models
        ii. Compare these two molecules in terms of coulombic attractions and periodic trends.
        iii. Name the concept of polarity and polar bonds and define them. Lewis Structure/Molecular structure review and polarity practice.
            1. Is it Polar flow chart
            2. Polarity and structure chart
            3. Fill in the blank notes on polarity for direct instruction
                a. Powerpoint (pdf link here) for polarity direct instruction.
            4. Polarity practice with key
            5. Electronegativity chart
8. **Day 9: Why does polarity matter? Vapor Pressure POGIL and activity.** Students will use Vapor Pressure to model the differences in Intermolecular Forces based on polarity. They will wipe acetone, ethanol and water on their desks with cotton balls and make observations about what the liquids look like, how they interact with the desk, and how fast they evaporate. Students will be given the structures of these molecules and asked to reconcile their observations with these structures.
    a.
9. **Day 10-11: Intermolecular Forces POGIL.** Students will use guided inquiry to interpret diagrams and models to come to an understanding of Intermolecular Forces.
    a.
10. **Day 12:**
    a. Polarity Quiz
    b. Lab. Investigate differences in physical and chemical properties (such as melting point, boiling point, vapor pressure, surface tension, solubility in polar or

nonpolar solvents, etc.) explain observations as they relate to a chemical's respective intermolecular forces of attraction (London dispersion forces, dipole-dipole forces, and hydrogen bonding). Use examples of multiple types of substances given structures to predict or rank properties.

11. **Day 13-15: Culminating Project**
    a. Read Stuck on You from February/March 2016 ChemMatters
    b. Discuss how structure and function are related in muscle glue. Ask students to identify materials that stick to some things but not other things.
    c. Watch Stuff Stronger NOVA to see more examples of engineered materials.
    d. Provide a handout with the assignment and rubric.
    e. Students should be given 2 days with computers to research and write-up their results.

Ongoing Formative Assessments:

- Record results of Solids Liquids gases OH MY! for a baseline of understanding
- Phase Change Lab: assess understanding of the relationship between types of energy and physical characteristics of a substance
- Phase Diagram Practice: assess understanding of phase change diagrams in terms of energy, specific heat, and intermolecular forces between particles.
- Phase Change Diagram Quiz to address Boise Schools Learning Objective 10.4 Interpret a phase change graph (heating curve/cooling curve) to identify areas of kinetic and potential energy changes.
- Pay attention to questions and answers during direct instruction and videos.
- Dry Ice Lab: assess discovery of the effect of pressure on phase change.
- Phase Diagram Quiz to address Boise Schools Learning Objective 10.5 Interpret a phase diagram with pressure and temperature (including critical and triple point)
- Polarity Quiz to address Boise Schools Learning Objective 10.1 Determine and predict polarity of simple molecules. and Boise Schools Learning Objective 10.2 Differentiate polar and nonpolar covalent bonds.
- Vapor Pressure POGIL (Process Oriented Guided Inquiry Learning) and activity, do they make the connection between structure and behavior?
- Do they make the connection between structure and behavior given multiple examples.
- Force vs Property Quiz address Boise Schools Learning Objective 10.6 Investigate differences in physical and chemical properties (such as melting point, boiling point, vapor pressure, surface tension, solubility in polar or nonpolar solvents, etc.) explain observations as they relate to a chemical's respective intermolecular forces of attraction (London dispersion forces, dipole-dipole forces, and hydrogen bonding).

Summative Assessment/Culminating Project:

Students pick one designed substance such as teflon, specific plastics, vulcanized rubber, aluminum alloys, steel, epoxy, silicone rubber, car paint, surface coatings, pharmaceuticals, or anything that they can research and find a molecular structure of and using that structure explain why that substance sticks or does not stick to at least three other materials one polar, one nonpolar, and one metallic (water, oil, and metal)

Additional Helpful Resources:

- What Makes Sticky Things Stick? NPR
    - [What Makes Sticky Things Stick?]()
- Interventions will include additional videos and concrete examples for students that struggle as well as questioning for understanding and reflection.
- Extensions will include more difficult structures and bond environments leading to more complicated but interesting interactions. Gecko feet, teflon