SeaGlide_TEAM	Intermolecular Forces	Lesson #2 (60 minutes)

Description:
Students will learn about intermolecular forces by becoming lava lamp fanatics. The students will be writing a formal letter to the company where they purchase most of their lava lamps. However, their most recent purchase was a lava lamp that is completely homogenous. Through a lab activity, students will observe how intermolecular forces play a role in lava lamp functionality, then determine why their recently-purchased lava lamp is not working properly.

Students will be able to:
- Know the various intermolecular forces and their strengths
- Rank molecules in order of intermolecular strength
- Draw the interactions of multiple molecules of a compound

Students will understand:
In many areas within a lab, chemists work with solutions where they use intermolecular forces to determine the differences of hydrophilic (water-loving) and hydrophobic (water-hating) interactions. Understanding the bond strength of each intermolecular force aids in determining the physical properties of biological substances. All intermolecular forces are Van der Waals forces; that is, they are not true bonds in the sense of sharing or transferring electrons, but are weaker attractive forces. These forces include dipole-dipole forces, hydrogen bonding, and ionic interactions.

Key Definitions & Concepts: [1]
- **Intermolecular forces:** the forces which mediate interaction between molecules, including forces of attraction or repulsion, which act between molecules and other types of neighboring particles.
- **Electronegativity:** the property of an atom that increases with its tendency to attract the electrons of a bond.
- **van der Waals Forces:** attractive or repulsive force between molecules, including dipole-dipole, dipole-induced dipole, and London dispersion forces; does not include forces due to covalent or ionic bonding, or the attraction between ions and molecules
- **Dispersion Forces:** (also, London dispersion force) attraction between two rapidly fluctuating, temporary dipoles; significant only when particles are very close together
- **Induced Dipole**: temporary dipole formed when the electrons of an atom or molecule are distorted by the instantaneous dipole of a neighboring atom or molecule
- **Dipole-dipole forces:** exist between polar regions of different molecules. The presence of a dipole means that the molecule has a partially positive end and a partially negative end.
- **Hydrogen bonding:** the attractive force between the hydrogen attached to an electronegative atom of one molecule and an electronegative atom of a different molecule. Usually the electronegative atom is oxygen, nitrogen, or fluorine, which has a partial negative charge. The hydrogen, then, has the partial positive charge.
- **Ionic bond:** when a positively charged ion forms a bond with a negatively charged ions and one atom transfers electrons to another.

- **Covalent bond:** A chemical bond formed when electrons are shared between two atoms. Usually each atom contributes one electron to form a pair of electrons that are shared by both atoms.

Standards: [Copied from: 2]

3.2.10.A2: Compare and contrast different bond types that result in the formation of molecules and compounds.

- In relating to the different types of bonds associated with intermolecular forces it is important to distinguish what makes a specific bond stronger than the other as this will affect substances on a molecular scale.

3.2.C.A1: Differentiate between physical properties and chemical properties. Differentiate between pure substances and mixtures; differentiate between heterogeneous and homogeneous mixtures.

- Because of water's strong intermolecular bonds, its molecules exhibit polarity. This lends water its unique properties that makes it the universal solvent. Depending on the makeup of a chemical substance, it will determine if it is insoluble or soluble in water which can also imply a bond needs to be broken. Depending on which and how many bonds are broken, the structure of a chemical substance could be impacted.

Background Information

Prior Knowledge:

- Atoms are made of a nucleus, composed of protons and neutrons, that is surrounded by an electron cloud.
- Electrons in an atom's outermost shell are called valence electrons and they contribute to many of an element's characteristics.
- Objects of opposite charge attract each other whereas objects of the same charge repel each other.

Science Practices: [Copied from: 3]	Core Ideas: [Copied from: 4]	Cross Cutting Concepts: [Copied from: 5]
• Planning and Carrying Out Investigations • Obtaining, Evaluating, and Communicating Information	• Structure and Properties of Matter • Types of Interactions	• Patterns • Energy and Matter • Structure and Function

Possible Preconceptions/Misconceptions:

Prior to this lesson, students should know that valence electrons in an atom's outermost shell dictate its electrical properties. Initially, students will be confused as to why this idea is being discussed again. As the instructor leads them to the exploration introduction activity, the students will discover that electrons can be evenly or unevenly distributed throughout a molecule due to element electronegativity. This unequal distribution leads to molecules exhibiting positive and negative charges, leading them to see how intermolecular forces form dipole-dipole and Hydrogen bonds.

	Lesson Plan - 5E(+) Model	

Engage: [6]

The instructor will begin the lesson by handing out the *Lava Lamp* half sheet and by showing the students a video on lava lamps. Based on the video, students should write down observations construct a hypothesis about how a lava lamp functions. Through their constructed hypotheses, students should provide a prediction about what is the driving force behind the rise and fall pattern of the "lava" within the lamp. The instructor should give the students 3 minutes to fill out their responses on the half-sheet then lead the class in an open discussion to introduce students to intermolecular forces, the different characteristics associated with each force, and how the structures of molecules are impacted. Reference the *Lava Lamp* answer key for notes on this discussion. This section should take less than 10 minutes to complete.

Explore:

Part I: Introduction

The instructor will lead the students through open discussion to complete the *Distribution Investigation* worksheet and compare the two molecules regarding the distribution of electrons. In completing this worksheet, the instructor should prompt the students with the following questions: How does electron distribution affect these molecules? Would these molecules interact with one another? This activity will introduce the students to understanding how the electron cloud affects molecule polarity. The instructor should also guide students towards applying this activity to the lava lamp video. Students' responses should pertain to how the electron distribution affects the relative charges of the molecules in the lava lamp. Allow no more than 10 minutes to this introduction.

Part II: *Benchmark Lesson*: Lava Lamp Experiment

The students will follow the procedure listed in the "Lava Lamp Lab" activity. As the students are working through the lab, they will write down if the solutes dissolve or not, and students will be challenged to identify the intermolecular forces at play. After completing the lab, the students will discuss what factors determine if the solute will dissolve in the solvent. The students are expected to identify if the solvent feels oily or not. From there, the students will then need to identify if the molecule exhibits Hydrogen bonding from electrophilic atoms. This will extend student understanding to predict what the interaction would look like between these molecules. The instructor should allot no more than 30 minutes for the students to complete this lab activity.

Part III: *Investigation Lesson*: Density in Lava Lamps [7]

Following the lab activity, the students will dive deeper into how lava lamps function. The instructor will play the video How Does it Work? - Lava Lamps. This video summarizes the information about polar molecules that students discovered in the Lava Lamp Experiment and connects polarity to the concept of density. The video also discusses the Archimedes Principle and how it relates to a lava lamp's function by introducing the concepts of buoyant force, water displacement, and volume differentiation through temperature change. For this lesson, students need to know that density decreases as temperature increases in order to explain how a lava lamp functions properly. During the video, students should complete the *How Does it Work* worksheet. This worksheet contains questions about the materials commonly used in lava lamps and about how lava lamps function. All of the questions' answers are discussed in the video, so students should individually complete the worksheet while the video is running. Once the video is completed, the instructor should lead an open class discussion to review the students' responses and to correct any misconceptions as necessary. This section should take up to 10 minutes.

Explain:

Throughout the exploration of this lesson, students will engage in discussions and activities that seek to discover their understanding of the topic at-hand as it relates to intermolecular forces. Instructors should informally ask questions to promote thoughtful discussion that is designed to aid in addressing any questions or concerns that some students may have. Students are expected to formalize their answers throughout the entirety of the lesson.

Elaborate:

The majority of this lesson consists of terminology that relates to intermolecular forces and their relationship with water and other molecular substances involving bonds. Students should use what they know about water being a powerful solvent to carry out the experiment in determining which bonds are essential in terms of how different solute to solvent combinations would react with one another. This activity is found within their lab activity worksheet. When conducting the experiment, students will observe the changes and different interactions from the water with other solvents and solutes to study the reactions. This will lead them to identify which combination closely resembles the movement and activity within a lava lamp. Instructors will provide students with several scenarios, and they will determine (based on their observations) the factors that will allow a substance to dissolve in a liquid on a molecular level. The phenomenon of substances not mixing is seen in many facets of life, for example, an oil rig spill. Students are able to apply their understanding of intermolecular forces to natural disasters such as this, or even baking, where dissolving substances in liquids is common.

Evaluate:

This lesson is designed with having both informal and formal evaluations throughout its entirety. The informal evaluations occur throughout the exploration because of the leading and open-ended questions and class discussions. This allows teachers to gauge surface-level student understanding. By surveying the students during completion of the worksheets, teachers will be able to hear and address any misconceptions or misunderstandings as necessary. The formal evaluation of this lesson is the exit ticket. This 5 minute, individual worksheet prompts the students to analyze the given solvent and state if it is polar or nonpolar. The students will then be prompted to determine if the given solutes would be soluble or insoluble in the solvent. The analysis questions align with the goals of understanding intermolecular forces, as well as their relative strengths and what they look like.

Enrich:

This lesson can be differentiated by having students conduct an experiment where they collect DNA evidence from a crime scene. From this experiment, they will be able to determine what intermolecular force aids in the creation of the DNA helical structure. The DNA double helix provides a unique example of how intermolecular forces combine to determine macromolecular structure. Students should have prior knowledge on the different strengths of intermolecular forces which will allow for the discovery of how hydrogen bonds, London-Dispersion forces, and dipole interactions make DNA the most stable as a double helix.

All associated documents are attached below

Reference *Annotated Bibliography* on the very last page of this packet

Name: ____ Date: _________________

Lava Lamp [6]

1. Observations:

2. Hypothesis: How does it work?

3. Notes from the discussion:

Name: ____ Date: _________________

Lava Lamp [6]

1. Observations:

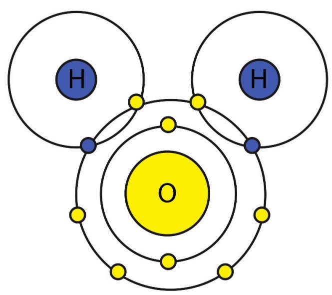
2. Hypothesis: How does it work?

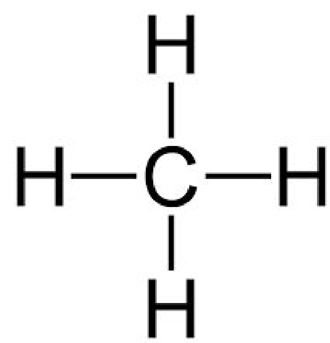
3. Notes from the discussion:

Name: ____ Date: ________________

Distribution Investigation

Observe the following molecules of water (left) and methane (right). Working in small groups, identify the distribution of electrons. Are they even or uneven? How does this affect the molecule? Write down all of your observations below the images.





1. How does electron distribution affect these molecules?

2. Would these molecules interact with one another?

3. How does this relate to the lava lamp video?

Name: ____ Date: _________________

Lava Lamp Lab

Introduction:

Ever since you were young, you have been obsessed with lava lamps. You're not entirely sure why, but you think it's because of how blobs of goop remain suspended in the water, rising and falling. Recently, you purchased the newest lava lamp from Larry's Lava Lamp Emporium, your favorite producer of collectable lava lamps. When you open the box, you discover that your lava lamp doesn't contain blobs like the other ones do. Instead, it's just a purplish liquid. You decide to use your chemistry skills to uncover why the lava lamp looks unfamiliar, then write a letter to the company as to why their new lava lamps are not working properly.

Materials:

- Clear Plastic Cups
- Water
- Vegetable Oil
- Mineral Oil
- Rubbing Alcohol & Water Solution
- Sugar
- Food Coloring

Procedure:

1. For the first solute-solvent combination, write down your hypothesis. What do you think will happen?
2. Mix the solute into the solvent. What happened? Was your hypothesis similar or different from what you observed?
3. Repeat Steps 1 & 2 until all solute-solvent combinations have been completed.
4. As a group, discuss your results. Why do you think these were the results?
5. After discussing with your group, predict if the given combinations will be soluble or not. Defend your answer.

Data Table:

Solute-Solvent Combination	Hypothesis	Observations	Comparre (Hypothesis & Observations)
Water & Sugar			
Water-Rubbing Alcohol Solution & Food Coloring			
Vegetable Oil & Sugar			
Mineral Oil & Food Coloring			

Predict if the given combinations will be soluble or not. Defend your answer.

1. Water & Baking Soda

2. Vegetable Oil & Salt

3. Hexane (an organic liquid) & Baking Soda

Name: ____ Date: _________________

How Does it Work? [7]

1. What is the significance of density to a lava lamp?

2. How is the density of the “lava” varied within a lava lamp?

3. What are the basic, foundational materials used to make the “lava” and the liquid of a lava lamp?
   a. Lava:

   b. Liquid:

4. What is the significance of ensuring that the “lava” is slightly more dense than the liquid?

5. What is the significance of utilizing the heat from the light bulb?

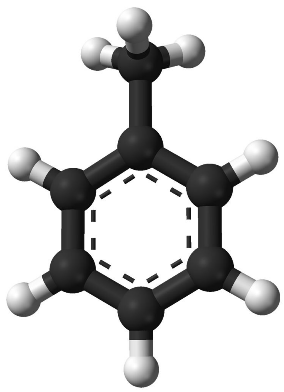
6. Describe the Archimedes Principle. (Hint: discuss density, buoyant force and water displacement).

7. Bonus! Was your hypothesis at the beginning of class correct? Why or why not?

Name: ____ Date: __________________

Exit Ticket [8]

1. Below is an image of a molecule of the organic liquid Toluene. Identify if the liquid is polar or nonpolar, then what type of intermolecular forces it experiences. Explain your answer (Hint: Would valence, bonding electrons be evenly or unevenly distributed throughout the molecule?)



2. Using your answer from the previous question, identify if the following solutes would be soluble or insoluble in Toluene. Defend your answer.
    a. Sugar

    b. Salt

    c. Mineral Oil

Name: ___________________Answer Key____________________ Date: __________________

Lava Lamp [6]

1. Observations:
   Students' answers will vary. Expect them to discuss the cycling of the "lava" within the lamp, and expect them to discuss the light at the bottom of the lamp. Students may not yet understand how the heat is significant, but they should already know that light produces heat.

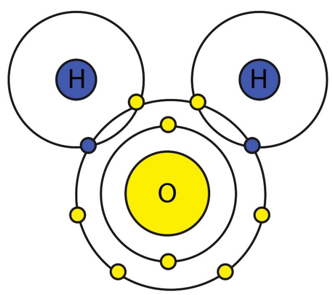
2. Hypothesis: How does it work?
   Students' responses will vary. Expect some students to make the connection that the heat radiating from the light is the driving factor in making the "lava" follow the rise and fall pattern.

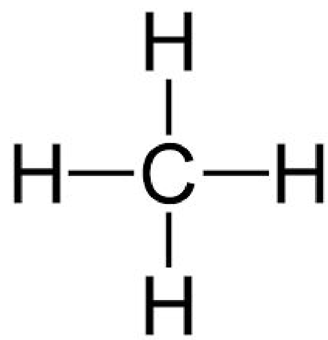
3. Notes from discussion:
   This activity is meant to introduce students to the concept of intermolecular forces and how they are used in everyday life. Lava lamps are a good depiction of intermolecular forces because substances consisting of different intermolecular forces do not interact with one another. Students can visually see that the substances do not mix, and they will understand that the water and wax will always separate due to the water's hydrogen bonding and the wax's london dispersion forces.

Name: ___________________Answer Key____________________ Date: __________________

Distribution Investigation

Observe the following molecules of water (left) and methane (right). Working in small groups, identify the distribution of electrons. Are they even or uneven? How does this affect the molecule? Write down all of your observations below the images.





1. How does electron distribution affect these molecules?
   In methane, the electrons are distributed evenly because there is no electronegative element present. In water, the electrons are not distributed evenly. This is because the oxygen is electronegative, pulling the electrons towards it.

2. Would these molecules interact with one another?
   These molecules would not interact with one another. Methane does not exhibit polarity, so the water cannot dissolve it.

3. How does this relate to the lava lamp video?
   Students' responses should pertain to how the electron distribution affects the relative charges of the molecules in the lava lamp. Students should make the connection that wax is similar to methane in that it will not mix with water. This will lead students to discover that wax is nonpolar.

Name: ___________________Answer Key___________________ Date: _________________

Lava Lamp Lab

Introduction:

Ever since you were young, you have been obsessed with lava lamps You're not entirely sure why, but you think it's because of how blobs of goop remain suspended in the water, rising and falling. Recently, you purchased the newest lava lamp from Larry's Lava Lamp Emporium, your favorite producer of collector lava lamps. When you open the box, you discover that your lava lamp doesn't contain blobs like the other ones do. Instead, it's just a purplish liquid. You decide to use your chemistry skills to uncover why the lava lamp looks familiar, then write a letter to the company as to why their new lava lamps are not working properly.

Materials:

- Clear Plastic Cups
- Water
- Vegetable Oil
- Mineral Oil
- Rubbing Alcohol & Water Solution
- Sugar
- Food Coloring

Procedure:

1. For the first solute-solvent combination, write down your hypothesis. What do you think will happen?
2. Mix the solute into the solvent. What happened? Was your hypothesis similar or different from what you observed?
3. Repeat Step 2 until all solute-solvent combinations have been completed.
4. As a group, discuss your results. Why do you think these were the results?
5. After discussing with your group, predict if the given combinations will be soluble or not. Defend your answer.

Data Table:

Solute-Solvent Combination	Hypothesis	Observations	Comparre (Hypothesis & Observations)
Water & Sugar	(varies by student)	Dissolves	(varies by student)
Water-Rubbing Alcohol Solution & Food Coloring	(varies by student)	Dissolves	(varies by student)
Vegetable Oil & Sugar	(varies by student)	Does not dissolve	(varies by student)
Mineral Oil & Food Coloring	(varies by student)	Does not dissolve	(varies by student)

Predict if the given combinations will be soluble or not. Defend your answer.

1. Water & Baking Soda

   <u>The baking soda will dissolve in the water because baking soda is a polar solute and water is a polar solvent.</u>

2. Vegetable Oil & Salt

   <u>The salt will not dissolve in the vegetable oil because salt is a polar solute, but vegetable oil is a nonpolar solvent.</u>

3. Hexane (an organic liquid) & Baking Soda

   <u>The baking soda will not dissolve in the hexane because baking soda is a polar solute, but hexane is a nonpolar solvent.</u>

Name: ___________________Answer Key___________________ Date: __________________

How Does it Work? [7]

1. What is the significance of density to a lava lamp?
   When the lava is less dense than the liquid, it floats to the surface. When the lava is more dense than the liquid, it sinks to the bottom.

2. How is the density of the "lava" varied within a lava lamp?
   The lamp uses heat to change the volume of the lava.

3. What are the basic, foundational materials used to make the "lava" and the liquid of a lava lamp?
   a. Lava: Coloring and Wax
   b. Liquid: Water

4. What is the significance of ensuring that the "lava" is slightly more dense than the liquid?
   For the same volumes of wax and water, the wax is slightly heavier than the liquid because of its higher density. This means that the wax should always be at the bottom of the lamp.

5. What is the significance of utilizing the heat from the light bulb?
   Heat is key to varying the density of the wax.

   A heated coil transfers the heat from the bulb to the wax at the bottom of the lamp. The heat makes the wax molecules expand. Thus, the volume of the wax increases even though its weight stays exactly the same. Hence, the wax is now less dense than the water surrounding it, and the wax floats towards the top of the lamp. Cool wax is heavier than the water it displaces, so it begins to fall back to the bottom of the lamp.

6. Describe the Archimedes Principle. (Hint: discuss density, buoyant force and water displacement).
   If an object is heavier than the water it displaces, then the object sinks. If the object is lighter than the water it displaces, then the object rises.

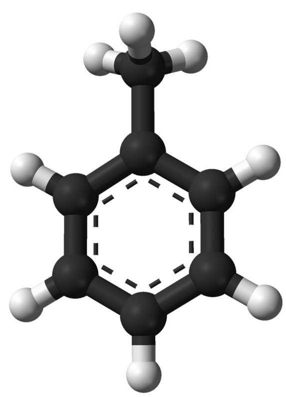
   When an object is submerged in water, it is pushed upwards with a buoyant force equal to the weight of the water being displaced. Even though the water is pushing on the object from all sides, its strongest push is upwards because water pressure increases as an object is submerged deeper. The larger the volume of an object, the more water it displaces. The more water it displaces, the stronger the buoyant force upward.

7. Bonus! Was your hypothesis at the beginning of class correct? Why or why not?
   Students' answers will vary depending on their answer during the engage activity.

Name: ________________Answer Key_____________________ Date: _________________

Exit Ticket [8]

1. Below is an image of a molecule of the organic liquid Toluene. Identify if the liquid is polar or nonpolar, then what type of intermolecular forces it experiences. Explain your answer (Hint: Would valence, bonding electrons be evenly or unevenly distributed throughout the molecule?)



Toluene is a nonpolar solvent. Because electrons are evenly distributed and shared throughout the molecule, a dipole moment does not occur. Therefore, the only intermolecular force this molecule experiences is London-Dispersion.

2. Using your answer from the previous question, identify if the following solutes would be soluble or insoluble in Toluene. Defend your answer.
   a. Sugar

      Because toluene is a nonpolar solvent and sugar is a polar solute, sugar will be insoluble in toluene.

   b. Salt

      Because toluene is a nonpolar solvent and salt is a polar solute, salt will be insoluble in toluene.

   c. Mineral Oil

      Because toluene is a nonpolar solvent and mineral oil is a nonpolar liquid, mineral oil will be soluble in toluene.

Annotated Bibliography

[1] OpenStax. (n.d.). 1.3 Physical and Chemical Properties. Retrieved January, 2019, from https://opentextbc.ca/chemistry/chapter/physical-and-chemical-properties/

This reference was used for excerption purposes. The definitions and information in this reference was directly excerpted for definitions used in this unit plan.

[2] Nsta. (n.d.). Access the Next Generation Science Standards by Topic. Retrieved January 18, 2019, from https://ngss.nsta.org/AccessStandardsByTopic.aspx

This website was used in each lesson in the Water Chemistry & Biology module to select proper national set standards for science subjects that each lesson is centered around.

[3] Nsta. (n.d.). Science and Engineering Practices. Retrieved January 18, 2019, from https://ngss.nsta.org/PracticesFull.aspx

This website used in every lesson in the Water Chemistry & Biology module to find Standards for Science and Engineering Practices that are applicable in each lesson.

[4] Nsta. (n.d.). Disciplinary Core Ideas. Retrieved from https://ngss.nsta.org/DisciplinaryCoreIdeasTop.aspx

This website was used in each lesson in the Water Chemistry & Biology module to select appropriate disciplinary core ideas set forth by the NSTA that are at the center of each lesson.

[5] Nsta. (n.d.). Crosscutting Concepts. Retrieved from https://ngss.nsta.org/CrosscuttingConceptsFull.aspx

This website was used in each lesson in the Water Chemistry & Biology module to selecting appropriate crosscutting concepts set forth by the NSTA that apply to each science lesson.

[6] Seufert, C. (2007, October 29). The Video Lava Lamp Sample (iScapes Vol. 3). Retrieved January, 2019, from https://www.youtube.com/watch?v=xB5FUYNXt9c

This reference was used as an educational tool within the Intermolecular Forces lesson plan. This reference was used to illustrate lava lamps to students for observation purposes.

[7] Triwood1973. (2010, April 28). How Does It Work? - Lava Lamps. Retrieved January, 2019, from https://www.youtube.com/watch?v=DL3Ez9bxMTo

This reference as used as an educational tool within the Intermolecular Forces lesson plan. This reference was used to demonstrate to students how lava lamps work and see how their observations and understandings from the lesson hold up.

[8] Clegg, B. (2015, November 4). Toluene. Retrieved January 2019, from https://www.chemistryworld.com/podcasts/toluene/9127.article

This reference was used for copying purposes. The image provided for the organic molecule Toluene was used in the exit ticket for this lesson. The copied image was used to illustrate the chemical composition and 3-D characteristics of Toluene.