The Chemistry of Water

Unit Plan

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Comprehensive Materials List

Lesson 1: Water's Role on Earth

- Heat lamp
- Ice
- Model of mountains, terrain, and ocean, encased in plastic
- (Additional materials vary depending on the experiments designed by students)

Lesson 2: Solubility

- Baking soda ($NaHCO_3$; Sodium Bicarbonate)
- Balances
- Corn Starch
- Cups
- Graduated Cylinder
- Ground Chalk ($CaCO_3$; Calcium Carbonate)
- Powerful magnet
- Salt (NaCl; Sodium Chloride)
- Sand (often SiO_2; Silicon Dioxide)
- Sugar ($C_6H_{12}O_6$; Glucose)
- Stirrer
- Water
- Water tap

Lesson 3: Attractive Forces

- Beakers
- Eye droppers
- Isopropyl alcohol ($(CH_3)_2CHOH$)
- Mercury
- Narrow transparent straws
- Oversaturated saltwater
- Pancake syrup
- Pennies
- Water
- Water

Lesson 4: Water Pollution

- Dish soap
- Generic Jumbo Chalk ($CaCO_3$; Calcium Carbonate; Limestone)
- Hydrochloric Acid 2M (HCl 2M); may be substituted with 6% Vinegar (CH_3COOH 6% by volume)
- Lighter
- Loops of string
- Pie pans (or similar large but shallow container)
- Small bits of straw
- Squeeze bottles filled with water
- Used motor oil
- Water

Activities & Process Skills

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Lesson 2: Solubility (Expansion)
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Background Information

Water is incredible. In many ways, water is the substance that allows for life – certainly life as we know it. Without it, the Earth would be a very different place.

Water is a molecule made up of only two elements, hydrogen and oxygen, with two hydrogen molecules for every oxygen molecule (H_2O).

The Water Cycle

For the most part, the water that we use today has existed for billions of years – almost as long as the Earth has been around. Due to a process called the water cycle, water is continuously cleaned and recycled naturally. There are three key stages to the water cycle (evaporation, condensation, precipitation), though because they are cyclic, there is no beginning or end. In addition to the key stages, there are other stages that are often taught, especially run-off, infiltration, and transpiration.

Evaporation is one key stage, where water undergoes a physical change from a liquid to a gas. It is this stage that occurs when a puddle of water disappears – while it looks like it has disappeared, the water in the puddle still exists – it has simply moved from the ground into the air. Evaporation occurs as a result of a rise in energy – as molecules gain energy, they shift from the liquid to gaseous state of matter.

Condensation is the key stage following evaporation, where the water shifts back from a gaseous state into a liquid, typically onto a dust particle in the sky. Water typically condenses high in the sky in order to form clouds, but the same thing can be observed around a cold bottle on a hot day. Condensation happens as a result of energy loss – as molecules lose energy, they can shift from the gaseous to liquid state.

Precipitation is what occurs when water falls from the sky in the form of rain, snow, or

hail. Precipitation occurs when there is too much water stored in the air (when the humidity reaches or exceeds one hundred percent), as can happen when the temperature drops. The form precipitation takes depends on the temperatures it encounters on its trip back to the earth.

Run-off is the last stage typically taught in the water cycle, and is the stage where water moves from one place to another (the broad idea being that water flows down from mountain peaks, through rivers, and collects in lakes or oceans). However, not all concepts of the water cycle include run-off because it is a step that can be skipped (water can precipitate onto pavement and be immediately evaporated again), and in a true cycle steps cannot be skipped. Similar to run-off, infiltration is the movement of water from the surface through the soil and into the groundwater system. Transpiration is evaporation from within plants.

Freshwater & Saltwater

As the name suggests, saltwater is different from freshwater only in that it has salts dissolved in it. A salt or electrolyte is anything that can dissolve (break into ions) in water. Table salt (NaCl) is the most common salt in water (at about fifty four of the salts in a typical three and a half percent salt solution), breaking up into Na^+ and Cl^-. While table salt is the most common, other salts do exist (for example, the Dead Sea has large concentrations of Mg^{2+} and Cl^- from $MgCl_2$). [Anthoni, J. F., 2007]

However, while freshwater and saltwater may seem very similar at the surface, they are very different as far as nature is concerned. Fish and other aquatic animals are designed to live in one or the other, typically with little tolerance for variation. Osmosis is the name given to diffusion of water from high to low concentrations, such as between a fish and the

ocean. If a freshwater fish were placed in the ocean, much of the water in the fish would move from the salt-poor fish into the relatively salt-rich ocean. [Gartrell, 1992]

Solubility & Polarity of Water

One of the properties of water that makes it so powerful is the fact that it there are many substances that can be dissolved in it. This propensity for dissolution is also called solubility.

The reason water is a good solvent is because it is a polar molecule – one side of the molecule has a partially negative charge, while the other side has a partially positive charge. As a result of these charges, other molecules that have positive or negative charges are easily attracted to the water molecules, which allows them to dissolve in solution in stead of floating or sinking.

More interesting than the solubility itself is how the solubility can result in water being a good conductor of electricity, as well as a good acid or base. While the water itself does not conduct electricity, any electrolytes dissolved in water may easily become excited, creating an electrical current.

Adhesion, Cohesion, and Capillary Action

Adhesion is the property of water or other substances that allows them to stick well to other substances. An excellent example of the adhesion of water is when it "sticks" to a window while it is raining. Cohesion is very similar to adhesion, except that it is the attraction between molecules of the same type. Water is very cohesive due to its polarity, and is evidenced in the same window example – droplets of water usually combine to form larger drops of water.

Because water will readily cling to other objects (adhesion) while still clinging to itself

(cohesion), a phenomenon known as capillary action occurs. The water will actually "climb up" the inside of a straw (the thinner the straw, the higher it will climb) or other solid object. Capillary action is the reason meniscuses are observed when measuring liquids in tall columns.

Water Pollution

About seventy percent of the planet is water (with about thirty percent being land), and of the water on the Earth, only two percent is freshwater (available for animals and humans to drink). Of that freshwater, four fifths is trapped in glaciers - that means less than a quarter of a percent of the water on Earth is available for consumption. [Montgomery, 2006]

Historically, water has been treated very poorly; while early humanoids may have been safe to wash human and animal waste down the river (following the false idea the dilution is the solution to pollution), there are now over six point seven billion people on the Earth, and because waste is not limited to organic waste, it is easy to contaminate our most valuable water sources [US Census Bureau, 2008]. When a water supply is contaminated, it endangers many animals. When the Exxon-Valdez lost eleven million gallons of oil on its way from Alaska to the continental United States, one thousand miles of shoreline was coated in oil and many animals died [Carr, 1991]. In addition to the problems ingestion of oil caused, many animals (especially birds and furry animals like otters) froze when the oil disrupted the creatures' natural insulation.

Water pollution is best prevented, but water (including sewage) can be purified through expensive multi-step processes. Better yet, some waste water generated by humans can be recycled; water used to clean dishes, for example, is often used to irrigate golf courses [Youngquist Brothers, Inc., 2007].

Acids and Acid Rain

Acids are substances rich in the hydronium ion (H^+ / H_3O^+), and work to neutralize the hydroxide ion (OH^-) in bases. The concentration of H^+ is used to measure pH, where seven is neutral and each decrease of one means the substance is ten times more acidic.

Acid rain is formed both naturally and artificially as a result of air pollution. The most common cause is the emission of sulfur through industrial processes and power generation (SO_2) which, when mixed with water, can be converted into sulfuric acid (H_2SO_4). When the sulfuric acid falls in the form of rainwater, it raises the acidity of lakes (affecting animals) or interacts with hydroxide-rich rock (especially limestone), which decays rock.

Because acid rain is caused by air pollution and pollution can travel many miles, it is often not the industrial areas that suffer most – the Atlantic Northeast and Canada receive the bulk of the acid rain produced in the United States, as does Scandinavia from the rest of Europe. Acid rain is best prevented instead of cured, and better regulations on emissions have reduced the amount of damage due to acid rain (though there is still a lot of room for improvement). [Baines, 1989]

References

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Carr, T. (1991). *Spill! The story of the Exxon Valdez*. New York: Franklin Watts.

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Montgomery, C. W. (2006). *Environmental geology.* New York: McGraw-Hill, 243.

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Instructional Statements

Grade Level: This unit plan is designed for 5th graders. Fifth grade is the year many districts begin teaching physical science, and a chemistry unit based on the familiar concept of water is an appropriate transition into new content. The unit contains a lot of hands-on activities designed to ensure understanding of these new concepts.

Accommodation: Because much of the unit is manipulative, students at many different levels should be able to learn through up-close observation. Many of the activities are designed to function either as a hands-on activity or as a demonstration, so even students with considerable physical handicaps should not be excluded from learning. In addition to observation, much of the unit give students an opportunity learn from one another and the instructor aurally.

Learning Environment: The unit is designed to promote a stimulating environment. Students are encouraged to contribute to their own learning in an authentic/practical way. The unit is designed with the students' interests in mind, allowing them to explore real-world problems in a positive way.

Learning Styles: The unit is designed to allow students an opportunity to contribute to or take new information from the lessons in a wide variety of ways. Students are frequently allowed to express observations, opinions, and explanations verbally, which satisfies the linguistic and interpersonal intelligence as well as oral and aural learners. Students are given many opportunities to examine problems, engaging the logical, spatial, and naturalistic intelligences, as well as the visual learner. Many activities are hands-on, ensuring the kinesthetic intelligence and kinesthetic learners are satisfied. Following learning, many of the lessons involve a reflective component, targeting those students with intrapersonal intelligence.

Inquiry: This exploration of water and its chemical properties is set specifically to be that – exploratory. The inquiry approach ensures students are always engaged, promoting constant growth as a result of performance.

Technology: While it is not specifically built into the unit (as the availability of technology is not always consistent throughout schools or districts), there are many points where lessons can be enhanced by technology. In recording data and analyzing results, many of the experiments would benefit from the incorporation of technologies like spreadsheets, which allow for clear data presentation and more-or-less automated calculations such as averages. Additionally, the author of the unit has written computer software designed to assess students electronically, including an easy-to-use JeoParty presentation game and a full-fledged testing suite capable of grading the most common exam questions (multiple choice, matching, true/false, short answer, short essay) – providing a level of comfort and engagement not always available through traditional testing methods as well as valuable statistical data for the instructor to see exactly where problems lie.

Parents & Community: "The Chemistry of Water" was designed to take place almost entirely within the classroom, but there is a lot of room for expansion outside of the classroom. The unit concludes with a lesson which targets the social issues of air and water pollution – a topic which can be easily extended into the community (both in contributions to and from parents and community members). While it is not critical, the interaction with the community would go a long way in encouraging students to learn.

Science Concepts and Standards

By Concept:

Students will learn:

1. The steps of the water cycle (Lesson 1: Water on Earth – *IL.12.C.2b, IL.12.E.2a*)
2. The differences between freshwater and saltwater (Lesson 1: Water on Earth – *IL.11.A.2a*)
3. The concept of solubility (Lesson 2: Solubility – *IL.11.A.2b, IL.12.C*)
4. The processes behind molecular attraction (Lesson 2: Solubility – *IL.12.C*)
5. How attractive forces work to create surface tension (Lesson 3: Attractive Forces – *IL.12.C.2b*)
6. How attractive forces work together to create capillary action (Lesson 3: Attractive Forces – *IL.12.C.2b*)
7. The dangers of water pollution and some methods to prevent, contain, or reverse it (Lesson 4: Water Pollution – *IL.12.E.2b*)
8. The dangers of air pollution and some methods to prevent, contain, or reverse it (Lesson 4: Water Pollution – *IL.12.E.2b*)

By Standard:

IL.11.A.2a Formulate questions on a specific science topic and choose the steps needed to answer the questions.

- The differences between freshwater and saltwater (Lesson 1: Water on Earth)

IL.11.A.2b Collect data for investigations using scientific process skills including observing, estimating and measuring.

- The concept of solubility (Lesson 2: Solubility)

IL.12.C Know and apply concepts that describe properties of matter and energy and the interactions between them.

- The concept of solubility (Lesson 2: Solubility)
- The processes behind molecular attraction (Lesson 2: Solubility)

IL.12.C.2b Describe and explain the properties of solids, liquids and gases.

- How attractive forces work to create surface tension (Lesson 3: Attractive Forces)
- How attractive forces work together to create capillary action (Lesson 3: Attractive Forces)
- The steps of the water cycle (Lesson 1: Water on Earth)

IL.12.E.2a Identify and explain natural cycles of the Earth's land, water and atmospheric systems (e.g., rock cycle, water cycle, weather patterns).

- The steps of the water cycle (Lesson 1: Water on Earth)

IL.12.E.2b Describe and explain short-term and long-term interactions of the Earth's components (e.g., earthquakes, types of erosion).

- The dangers of air pollution and some methods to prevent, contain, or reverse it (Lesson 4: Water Pollution)
- The dangers of water pollution and some methods to prevent, contain, or reverse it (Lesson 4: Water Pollution)

Student Resources

Children's Literature

Carr, T. (1991). *Spill! The story of the Exxon Valdez*. New York: Franklin Watts.
Cobb, V. (2002). *I get wet.* New York: HarperCollins.
Geiger, B. (2008). *Clean water.* San Diego: Sally Ride Science.
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Locker, T. (2002). *Water dance*. New York: Voyager Books.
Smith, D. J. (2002). *If the world were a village: A book about the world's people*. Toronto: Kids Can Press.
Wick, W. (1997). *A drop of water: A book of science and wonder.* New York: Scholastic.
Woods, P. (1967). *Air and water.* New York: Grosset & Dunlap.

Other Resources

Aquatic Illinois [computer software]. (2003). Springfield, IL: Illinois Dept. of Natural Resources.
Downey, F. (2007). Water wonders. *National Geographic Explorer, Vol. 7*(3), 2-7.
Enote, J. (2008). The wonder of water. *National Geographic Explorer, Volume 8*(1), 24-27.
Ground water and land use in the water cycle [poster]. (1993). Springfield, IL: State of Illinois. (Available from EIU Booth Library, 600 Lincoln Ave., Charleston, IL 61920).
Hydrologic cycle [poster]. (1994). Champaign, IL: Illinois State water Survey. (Available from EIU Booth Library, 600 Lincoln Ave., Charleston, IL 61920).
Land & water [computer software]. (2004). Discovery Communications.

Web Resources

City of Oceanside Clean Water Program. *What's storm water pollution?* Retrieved March 10, 2009 from http://www.oceansidecleanwaterprogram.org/kids.asp.
Clark, Josh. *What is gray water and can it solve the global water crisis*. Retrieved March 10, 2009 from http://www.howstuffworks.com/gray-water.htm.
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US EPA. (2007). *The Tale of Lucy Lake*. Retrieved March 10, 2009 from http://www.epa.gov/acidrain/education/site_students/lucy1.html.
US EPA. (2008). *What's wrong with this picture?* Retrieved March 10, 2009 from http://www.epa.gov/owow/nps/kids/whatwrng.html.

Lesson 1: Water on Earth

Activity Objective: Students will gain an understanding of the water cycle through observation of a realistic model.

Learning Standards

- **IL.11.A.2a** Formulate questions on a specific science topic and choose the steps needed to answer the questions.
- **IL.12.C.2b** Describe and explain the properties of solids, liquids and gases.
- **IL.12.E.2a** Identify and explain natural cycles of the Earth's land, water and atmospheric systems (e.g., rock cycle, water cycle, weather patterns).
- **NSES.6.4** Structure of the earth system.

Safety Concerns and Precautions

- Position the heat lamp somewhere where students will be unable to reach it. Caution them against touching it.
- The teacher should have Material Safety Data Sheets available for each substance used in the expansion set.

Exploration:

Concept for Lesson: Students will learn the steps of the water cycle.

Materials:

- Model of mountains, terrain, and ocean, encased in plastic
- Ice
- Heat lamp

Process Skills Used: Observation, predicting, questioning

Procedure:

1. Before students arrive for the day, set up a model of the water cycle in the plastic case, with ice placed on the top of one side of the case and the heat lamp on the opposite side.
2. Allow students some time to observe the environment before science class.

Explanation:

Questions: After allowing students time to carefully observe the environment:

1. Share something you observed in our model. *water, land, mist, "sweat"*
2. Where have you seen mist before? *mountains*
3. What was it like outside? *cold*
4. Where have you seen "sweat" before? w*ater bottle*
5. What was different between the bottle and the air? *temperature*
6. What is another name for "sweat"? *condensation*
7. Where does the water on the outside come from? *air*
8. What is the name for water in the air? *water vapor*
9. What state of matter is water vapor in? *gas*
10. What state of matter is water in? *liquid*

11. If condensation is the name for water changing from a gas into a liquid, what is the name for water changing from a liquid into a gas? *evaporation*
12. What is water falling from the sky called? *precipitation*
13. What are some forms of precipitation? *rain, snow, hail,...*
14. From what we've just talked about, can anyone tell me the three main parts of the water cycle? *Condensation, evaporation, precipitation*
15. What caused the water to evaporate? *heat lamp / added energy*
16. What caused the water to condense? *ice / loss of energy*
17. Does rain always fall to the ground as soon as it condenses? *no, forms clouds*
18. Why does it form clouds? *condenses on particles in the air*
19. Where does water go when it has fallen from the sky? *ground, plants, sewers,...*
20. If rain falls in the mountains, where does it go? *downhill*
21. Run-off is sometimes considered another part of the water cycle. Define it. *movement of water*
22. Evaporation of water from inside a plant has a special name. What is it? *transpiration*

Vocabulary:

- **Evaporation:** Change from liquid to gaseous state of matter following absorption of energy
- **Condensation:** Change from gaseous to liquid state of matter following loss of energy
- **Precipitation:** Any form of water (including rain, hail, and snow) that falls to the ground
- **Run-off:** Movement of water from one place to another (typically high to low altitude)
- **Transpiration:** Evaporation of water from a plant's leaves (plant-based perspiration)

Expansion:

Concept for Lesson: Students will recognize the differences between fresh and saltwater.

Materials:

- (Materials vary depending on the experiments designed by students)

Process Skills Used: communicating, experimenting, observing, predicting

Procedure:

1. Divide students into groups.
2. Ask students to develop experiments (with clear controls and variables) in order to discover differences between freshwater and saltwater. *Some possibilities: floating, solubility, conductivity, boiling point*
3. Give the students an opportunity to perform the experiment they have designed (may need to be the next day depending on availability of materials).
4. Discuss the results of each experiment as a class.
5. Discuss the following vocabulary:

- **Saltwater:** Water with dissolved salts or electrolytes
- **Salt:** A compound that can break into ions when dissolved in water
- **Diffusion:** Movement of any substance from an area of high to low concentration
- **Osmosis:** Movement of water from an area of high to low concentration

Evaluation: Administer the water cycle quiz (Appendix). This is an formal assessment of all 3 learning standards.

Resources: N/A

Lesson 2: Solubility

Activity Objective: Students will investigate and understand the significance of solubility and the polarity of water.

Learning Standards

- **IL.11.A.2b** Collect data for investigations using scientific process skills including observing, estimating and measuring.
- **IL.12.C** Know and apply concepts that describe properties of matter and energy and the interactions between them.
- **NSES.6.2** Properties and changes of properties in matter.

Safety Concerns and Precautions

- In the exploration step, the students should not put any of the materials into their mouths.
- The teacher should have Material Safety Data Sheets available for each substance listed in the exploratory set.
- Goggles should be used whenever liquids or small particles are used.

<u>Exploration:</u>
Concept for Lesson: Students will understand the concept of solubility.
Materials:

- Water
- Baking soda (NaHCO3; Sodium Bicarbonate)
- Corn Starch
- Goggles
- Ground Chalk ($CaCO_3$; Calcium Carbonate)
- Salt (NaCl; Sodium Chloride)
- Sand (often SiO_2; Silicon Dioxide)
- Sugar ($C_6H_{12}O_6$; Glucose)
- Cups
- Graduated Cylinder
- Balances
- Stirrer

Process Skills Used: analyzing, experimenting, observing, predicting
Procedure:

1. Divide the class into groups.
2. Distribute materials to groups.
3. Ask students to predict which substance will dissolve best in water.
4. For each substance / solute, instruct students to:
    1. Place 100mL of water into a cup and weigh it.
    2. Measure ~0.25g of the solute, record the mass, then stir it into the water.
    3. If all of the solute has dissolved, measure another 0.25g and stir it in.

4. Repeat step 3 until there is some solute at the bottom of the cup that will not dissolve.
5. After each group has completed all of their experiments, combine all of the data into one class data table so averages can be calculated.

Explanation:

Vocabulary: Ask students to define each of the vocabulary words:

- **Polar Molecules:** molecules with different charges (positive and negative) on opposite sides (poles)
- **Solubility:** The tendency of a solute to dissolve in a solvent.
- **Solute:** A substance (usually a solid) that may be dissolved into another substance.
- **Solvent:** A substance (usually a liquid) which will dissolve another substance.

Questions: Upon completion of the exploratory set, have students construct a bar graph using the class averages for each substance and write responses to the following prompts:

1. Which substance dissolved best in the water?
2. Do you think polar substances dissolve more easily than non-polar substances in water? Why? *polar; water is polar and opposites attract*
3. Do you think water is polar or non-polar? *polar*
4. What other substances do you think could be dissolved in water?
5. What other substances do you think might dissolve sugar?
6. Which was the solute: water or salt? *salt*
7. Which was the solvent: water or salt? *water*
8. Rank the solubility of the different substances used in our experiment from lowest solubility to highest.

Expansion:

Concept for Lesson: Students will build a basic understanding of molecular attraction through magnetism.

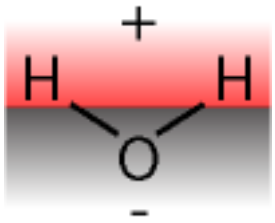
Materials:

- Water tap
- Powerful magnet

Process Skills Used: analyzing, communicating, observing, questioning

Procedure:

1. Tell the class the materials in the experiment: water and a magnet. Ask them what they think will happen.
2. Turn on the tap and hold the magnet close to the stream of water. Move it slowly closer and further from the stream.
3. Ask students what happened. Is water a polar molecule? *yes*
4. Illustrate the simple appearance of a water molecule. (Next page)



Evaluation: Ask students to write a story about attraction from the point of view of a molecule of water. This is a formal assessment of Illinois Standard 12C and NSES Standard 6.2.

Concepts / Use of Vocabulary	**15** 4+ words used correctly	**12** 3 words used correctly	**9** 2 words used correctly	**6** 1 word used correctly	**3** No words used correctly
Spelling	**5** No spelling errors.	**4** No more than 2 spelling errors	**3** No more than 4 spelling errors	**2** No more than 6 spelling errors	**1** 7 or more spelling errors
Grammar	**5** No grammar errors.	**4** Few grammar errors.	**3** Some grammar errors.	**2** Many grammar errors.	**1** I can't read this.

Resources: N/A

Lesson 3: Attractive Forces

Activity Objective: Students will gain an understanding of how attractive forces influence the behavior of matter.

Learning Standards

- **IL.12.C.2b** Describe and explain the properties of solids, liquids and gases.
- **NSES.6.2** Properties and changes of properties in matter.

Safety Concerns and Precautions

- No materials in the expansion set should be touched.
- Students should be careful not to handle the isopropyl alcohol (flammable), or pancake syrup (messy).
- The teacher should have Material Safety Data Sheets available for each material listed in the expansion set.
- Goggles should be used whenever liquids or small particles are used.

Exploration:

Concept for Lesson: Students will understand how attractive forces work to create surface tension.

Materials:

- Eye droppers
- Pennies
- Water

Process Skills Used: observing, questioning

Procedure:

1. Distribute materials (one eye dropper and penny per student; one container of water per table).
2. Ask students to record their hypothesis of how many drops of water will fit on the penny before it overflows.
3. Ask students to test the number of drops that can fit on a penny before it overflows.
4. Create a list of values on the board.
5. Looking at the list, ask students to record an estimate of the average drops held.
6. Find the calculated average, have students record it, and compare the estimate to the answer.

Explanation:

Vocabulary: Ask students to describe each of the following:

- **Adhesion:** attraction between two different types of molecules
- **Cohesion:** attraction between two of the same type of molecule
- **Surface Tension:** The strength of interaction between surface molecules which is a direct result of adhesive and cohesive strength.

- **Viscosity:** Resistance to flow. Adhesive/cohesive molecules have a higher viscosity (more resistance).

Questions: After allowing students time to examine the objects, ask the following questions verbally:

1. How did the average compare to your hypotheses?
2. Why were the number of drops different for different people? e*ye droppers are not exact, some pennies may have a different type of surface (ie corrosion), table uneven?*
3. Why is water adhesive (why does it attract other molecules)? w*ater is polar*
4. Why is water cohesive (why does it attract itself)? *water is polar*
5. Would the results be different if we used something other than water? *Yes – adhesion and cohesion is different for different substances*
6. Which is more adhesive, glue or water? *glue*
7. Which is more cohesive, glue or water? *glue*
8. Which has a stronger surface tension, glue or water? *glue*
9. Which has a higher viscosity, glue or water? *glue*
10. Which has a higher viscosity, glue or molasses? *molasses*

Expansion:

Concept for Lesson: Students will learn how attractive forces work together to create capillary action.

Materials:

- Narrow transparent straws
- Beakers
- Goggles
- Water
- Isopropyl alcohol ($(CH_3)_2CHOH$)
- Pancake syrup
- Oversaturated saltwater

Process Skills Used: analyzing, observing, predicting

Procedure:

1. Divide students into groups.
2. Distribute a beaker full of water and a straw to each group.
3. At the same time, have each group insert the straw into their beaker.
4. Ask students to describe what happened.
5. Ask students to record their hypotheses regarding what will happen when the straw is inserted into each of the other liquids.
6. Distribute materials to 3 stations where a beaker full of the liquid and allow students to rotate around the stations (should be quick).
7. While they are at the stations, ask students to place the straw into each remaining liquid and (keeping the exploratory set in mind) record their observations.
8. Ask students to individually analyze their findings and write an explanation for the behavior of each liquid.

9. After students have turned in their written work from the labs, ask them to define the following:

- **Capillary Action:** A phenomenon caused by attractive forces between an liquid and solid as well as liquid surface tension that causes an unusual rise in level.
- **Meniscus:** The curved upper surface of a liquid in a narrow tube, caused by the difference in strength of adhesion between liquid and tube versus the strength of the liquid's internal cohesion. Scientists always measure from the bottom of a meniscus.

Evaluation: Assess the written work of each student in the experiments. Award points for the presence of each hypothesis, the estimate, and the average. Award points (partial points possible) for reasonable responses to the remaining prompts as exhibited in the check list below. This is an assessment of Illinois state standard 12.C.2b.

Attractive Forces Experiment Evaluation	
Completion	
Penny Hypothesis	/ 2
Penny Estimate	/ 2
Isopropyl Alcohol Hypothesis	/ 2
Pancake Syrup Hypothesis	/ 2
Saltwater Hypothesis	/ 2
Reasonable / Correct	
Penny Average	/ 2
Water Observations	/ 2
Isopropyl Alcohol Observations	/ 2
Pancake Syrup Observations	/ 2
Saltwater Observations	/ 2
Isopropyl Alcohol Explanation	/ 3
Pancake Syrup Explanation	/ 3
Saltwater Explanation	/ 3
	/ 29

Resources: *Penny experiment* [personal communication], B. Poelker, February 2009.

Lesson 4: Water Pollution

Activity Objective: Students will learn about the dangers of water and air pollution and some methods to prevent, contain, or reverse both.

Learning Standards

- **IL.12.E.2b** Describe and explain short-term and long-term interactions of the Earth's components (e.g., earthquakes, types of erosion).
- **NSES.6.6** Risks and benefits in relation to the environment.

Safety Concerns and Precautions

- The students should not ingest any of the materials used in the experiment.
- The students should not touch any of the "Acid rainwater".
- The teacher should have Material Safety Data Sheets available for each substance listed (if applicable).
- Goggles should be used whenever liquids or small particles are used.
- All of the liquid materials contaminated with oil should be disposed of properly (not sent through the school's plumbing).

Exploration:

Concept for Lesson: Students will learn about the dangers of water pollution and some methods to prevent, contain, or reverse it.

Materials:

- Goggles
- Water
- Pie pans (or similar large but shallow container)
- Used motor oil
- Loops of string
- Squeeze bottles filled with water
- Dish soap
- Small bits of straw
- Lighter

Process Skills Used: observing, experimenting, analyzing

Procedure:

1. Divide students into groups.
2. Distribute materials – one pie pan full of water, a film canister of oil, a loop of string (containment boom), a squeeze bottle (beach washing), container of soap, and small pile of straw for each group.
3. Students should carefully add a very small amount of oil to an undisturbed section of their pan before using each of the "oil problem solutions". (It should be possible to complete all of the experiments in the same pie pan environment without starting anew.)
    1. Containment boom: surround the oil with the string to prevent it from spreading

   2. Beach washing: move the oil from one place to another using the force of the water jet
   3. Soap: repel the oil using the soap.
   4. Straw: place the straw on top of the oil
4. After the students have performed experiments individually, have them gather around another pie pan with a larger amount of oil. Make a show of cautioning students to stand away as you adorn safety goggles and reach out (lighter in hand) to set the oil ablaze. (The oil will not catch on fire.)
5. Tell the story of the Exxon-Valdez (refer to background information) and compare the real-world experiences to the students' experience in the lab.

Explanation:

Questions: After performing all of the experiments, ask the students the following questions:

1. Is oil flammable? y*es*
2. Why didn't the oil we used catch on fire? *because it is motor oil, the oil has been specially refined not to burn (do you want your car's engine to become engulfed in flames?). Crude oil (oil straight from the ground) such as what the Exxon-Valdez carried IS flammable, even surrounded by water.*
3. Which are the advantages of the containment boom? *contains the problem*
4. Which are the disadvantages of the containment boom? *only contains the problem – does not solve it*
5. Which are the advantages of the beach washing? *can be used to manipulate the oil*
6. Which are the disadvantages of the beach washing? *only moves the problem – does not solve it*
7. Which are the advantages of the soap? *can be used to manipulate the oil*
8. Which are the disadvantages of the soap? *may be toxic to animals, only moves the problem – does not solve it*
9. Which are the advantages of the straw? *picks up some of the oil*
10. Which are the disadvantages of the straw? *straw and oil must be placed in landfills*
11. Which are the advantages of the fire? o*il is no longer a threat*
12. Which are the disadvantages of the fire? *creates air pollution, may burn sea creatures*
13. What other options do you think there are for dealing with oil spills? *soaking up in other ways – sponges, cloth, etc.*
14. Are there any disadvantages to those methods? *must be placed in landfills – moves problems somewhere else*

Expansion:

Concept for Lesson: Students will learn about the dangers of air pollution and some methods to prevent, contain, or reverse it.

Materials:

- Goggles
- Hydrochloric Acid 2M (HCl 2M); may be substituted with 6% Vinegar (CH_3COOH 6% by volume)
- Generic Jumbo Chalk ($CaCO_3$; Calcium Carbonate; Limestone)

Process Skills Used: observing, experimenting, communicating
Procedure:

1. (This experiment may be performed as a demonstration or in groups).
2. Explain that chalk is made of the same material that a lot of rock is – chalk is essentially the same thing as limestone.
3. Place the chalk in a clear container of acid.
4. Ask students to describe what is happening. *Chalk is disappearing as bubbles are created.*
5. Ask students the following questions:
    1. What do you think the bubbles are? *carbon dioxide, the same gas that comes out of us as we breathe ($HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$)*
    2. What else do you see being created? *small amount of calcium chloride precipitate*
    3. Do you think anything else is being created? *water – all acids and bases interact to create water*
    4. How can we tie this experiment to air pollution? *Air pollution creates acids in the atmosphere, acid interacts with rock on earth*
    5. How strong of an acid do you think acid rain can be? *Up to a pH of 2, which is an 10,000 times stronger than pure water. This is the same acidity of lemon juice – a tenth of the strongest acids available (battery acid).*
6. Discuss the following vocabulary:

- **Acid:** A substance with a high concentration of H^+ ions whose pH registers below 7.
- **Base:** A substance with a high concentration of OH^- ions whose pH registers above 7.
- **pH:** A measure of acidity, where seven is neutral and each increase in one means the substance is ten times more acidic
- **Water:** The resulting compound when acids and bases are combined.

7. Ask students the following questions:
    1. What can we do to neutralize an acid (what mixed with an acid will make neutral water)? *a base such as lime (harvested limestone transported so critical limestone is not eroded)*
    2. How can acid rain be prevented? *stricter rules on industry emissions, less/more efficient vehicular traffic, burn cleaner coal (coal is a large source of sulfur for sulfuric acid), use less energy anywhere*
    3. Does acid rain travel from its source? *yes, like water, pollutants can move with clouds*
    4. What does this mean for preventing acid rain? p*ollutants may come from some place outside of your control – Canada may be affected by US pollution, Texas may be affected by Mexican pollution*

Evaluation: Present the student with a writing prompt (Appendix) where they are tasked to write a plan to help the Illinois Department of Natural Resources. This is an authentic assessment addressing both the state and national standard for this lesson.

Rubric on following page.

Grading Rubric

Reason	**10** Reason well-explained	**8** Reasonable explanation	**6** Questionable explanation	**4** Poorly explained	**2** Not explained
Ideas	**30** Provides at least 5 ideas with adequate support	**25** Provides at least 4 ideas with adequate support	**20** Provides at least 3 ideas with adequate support	**15** Provides at least 2 ideas with adequate support	**10** Provides at least 1 idea with adequate support
Spelling	**10** No spelling errors.	**8** No more than 2 spelling errors	**6** No more than 4 spelling errors	**4** No more than 6 spelling errors	**2** 7 or more spelling errors
Grammar	**5** No grammar errors.	**4** Few grammar errors.	**3** Some grammar errors.	**2** Many grammar errors.	**1** I can't read this.
Format	**5** Includes all information in the model (sender address, recipient, introduction, salutation, signature block)	**4** Missing one component in the model.	**3** Missing two components in the model.	**2** Missing three components in the model.	**1** Missing four or more components in the model.

Resources: Oil experiment [personal communication], T. Buscher, 2004.

Unit Exam

Name: _____

0. (Extra Credit) What percent of the human body is made up of water?
    A. 75%
    B. 89%
    C. 50%
    D. 42%

1. What is the name of the stage of the water cycle where water changes from a liquid to a gas?
    A. Evaporation
    B. Condensation
    C. Run-off
    D. Infiltration
    Concept 1 – Standard IL.12.E.2a

2. What is the name of the stage of the water cycle where water changes from a gas into a liquid?
    A. Condensation
    B. Evaporation
    C. Run-off
    D. Precipitation
    Concept 1 – Standard IL.12.E.2a

3. What is the name of the stage of the water cycle where water falls from the sky to the ground?
    A. Precipitation
    B. Condensation
    C. Run-off
    D. Transpiration
    Concept 1 – Standard IL.12.E.2a

4. What is the name of the stage of the water cycle where water moves from one place to another (usually from high to low)?
    A. Run-off
    B. Condensation
    C. Diffusion
    D. Transpiration
    Concept 1 – Standard IL.12.E.2a

5. When does water evaporate?
    A. A water molecule absorbs energy
    B. A water packet rises into the sky
    C. Evaporation is a random occurrence
    D. Water loses energy
    Concept 1 – Standard IL.12.C.2b

6. Describe a salt.
    A. A substance that can be dissolved.
    B. A contaminant of water
    C. Something to put on french fries
    D. A product of infiltration
    Concept 2 – Standard IL.12.C

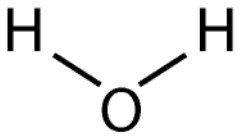
7. Which of the following is a difference between freshwater and saltwater?
    A. Things float better in saltwater
    B. Things float better in freshwater
    C. Freshwater is newer
    D. Saltwater is contaminated
    Concept 2 – Standard IL.11.A.2a

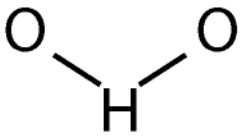
8. This process is tied directly to the weather.
    A. The water cycle
    B. Run-off
    C. Removing salt from saltwater
    D. The use of a well
    Concept 1 – Standard IL.12.E.2a

9. Which stage of the water cycle will a water molecule go through next if it has just formed into a cloud?
    A. Precipitation
    B. Condensation
    C. Run-off
    D. Infiltration
    Concept 1 – Standard IL.12.E.2a

10. Which stage of the water cycle will a water molecule go through next if it has just risen from the lake into the air?
    A. Condensation
    B. Evaporation
    C. Run-off
    D. Transpiration
    Concept 1 – Standard IL.12.E.2a

11. Which of the following accurately represents a water molecule?

A. 

B. 

C. 

D. 

Concept 4 – Standard IL.12.C.2b

12. Which of the following is LEAST SOLUBLE in water?
    A. sand
    B. chalk
    C. salt
    D. sugar

    Concept 3 – Standard IL.12.C

13. In an experiment with solubility, which of the following is most important to record?
    A. Mass of solid
    B. Time of experiment
    C. Weight of liquid
    D. Strength of light in the room

    Concept 3 – Standard IL.11.A.2b

14. An experiment has been conducted which yielded the results of 28g, 39g, 14g, and 19g. What is the average of all of the results?
    A. 25g
    B. 20g
    C. 24g
    D. 28g

    Concept 3 – Standard IL.11.A.2b

15. What is the substance (usually a solid) that may be dissolved in another substance?
    A. solute
    B. solution
    C. solvent
    D. solid
    Concept 3 – Standard IL.12.C

16. What is the substance (usually a liquid) that may dissolve another substance?
    A. solvent
    B. solute
    C. liquid
    D. solution
    Concept 3 – Standard IL.12.C

17. Which of the following is the closest synonym to SOLUTION?
    A. A mixture
    B. A gas
    C. A part of the water cycle
    D. A solid
    Concept 3 – Standard IL.12.C

18. Which of the following describes a polar molecule?
    A. A molecule with positive and negative sides
    B. A molecule with two positive sides
    C. A molecule with two negative sides
    D. A molecule with neither a positive or negative side
    Concept 4 – Standard IL.12.C

19. Is water a polar molecule?
    A. Yes
    B. No
    C. Maybe so
    D. My aunt would know
    Concept 4 – Standard IL.12.C

20. Find the best estimation of the answer to the following multiplication problem:
    24 * 9 * 41 * 8
    A. 96000
    B. 80000
    C. 6000
    D. 2000
    Concept 4 – Standard IL.11.A.2b

21. What is the name given to the attractive force between two DIFFERENT molecules?
    A. adhesion
    B. cohesion
    C. capillary action
    D. meniscus
    Concept 5 – Standard IL.12.C.2b

22. What is the name given to the attractive force between two molecules of the SAME type?
    A. cohesion
    B. adhesion
    C. meniscus
    D. capillary action
    Concept 5 – Standard IL.12.C.2b

23. Which of the following best defines capillary action?
    A. A phenomenon caused by attractive forces between an liquid and solid as well as liquid surface tension that causes an unusual rise in level
    B. A condition where water seems to be suspended in the air without any connection to the ground
    C. A condition of the human heart which may require hospitalization
    D. That thing we saw in class
    Concept 6 – Standard IL.12.C.2b

24. Which of the following would have the strongest surface tension?
    A. Molasses in a tall, thin container
    B. Water in a tall, thin container
    C. Molasses in a short, wide container
    D. Water in a short, wide container
    Concept 5 – Standard IL.12.C.2b

25. What is the name given to a material's resistance to flow?
    A. viscosity
    B. vilification
    C. tension
    D. tertiary
    Concept 5 – Standard IL.12.C.2b

26. A meniscus is the "dip" or "hump" at the top of a column of water (or other liquid). What causes the meniscus to appear?
    A. Adhesion and cohesion
    B. Capillary action
    C. The addition of salt to water
    D. The shaking of the water
    Concept 6 – Standard IL.12.C.2b

27. Where do scientists measure the meniscus?
    A. At the bottom (where the water fills the column all of the way across)
    B. At the top (where the water just barely rises on the sides)
    C. At the top (where the water just barely rises in the middle)
    D. At the bottom (the lowest point where you can see water)
    Concept 6 – Standard IL.11.A.2b

28. How do salts affect cohesion?
    A. Weaken cohesion – salts weaken bond
    B. Weaken cohesion – salts remove energy
    C. Strengthen cohesion – salts add energy
    D. Strengthen cohesion – salts strengthen bonds
    Concept 5 – Standard IL.12.C.2b

29. In which of the following materials would capillary action be most apparent?
    A. Mercury
    B. Saltwater
    C. Sugarwater
    D. Water
    Concept 6 – Standard IL.12.C.2b

30. Which of the following parts of the water cycle is affected by adhesion and cohesion?
    A. All of the below
    B. Evaporation
    C. Condensation
    D. Precipitation
    Concept 1 – Standard IL.12.C.2b

31. What did the Exxon-Valdez spill in 1989?
    A. oil
    B. soap
    C. straw
    D. otters
    Concept 7 – Standard IL.12.E.2b

32. What is the name of the loop used to contain the spill?
    A. containment boom
    B. containment loop
    C. U.S.S. Mercury
    D. Exxon-Valdez
    Concept 7 – Standard IL.12.E.2b

33. What is the name of the method represented by the squeeze bottle in our experiment?
    A. Beach washing
    B. Power washing
    C. Beach cleaning
    D. Water displacement
    Concept 7 – Standard IL.12.E.2b

34. Which method below simply moved the problem?
    A. soap
    B. containment
    C. straw
    D. Exxon-Valdez
    Concept 7 – Standard IL.12.E.2b

35. How might burning help eliminate the spill?
    A. Animals protected from sticky spill
    B. Animals protected from ashes
    C. Moves spill directly from water to land
    D. Moves spill directly from land to water
    Concept 7 – Standard IL.12.E.2b

36. Which of the following best describes an acid?
    A. a substance whose pH registers below 7
    B. a substance whose pH registers at 7
    C. a substance whose pH registers above 7
    D. a substance whose pOH registers above 7
    Concept 8 – Standard IL.12.E.2b

37. What charge does a base have?
    A. negative
    B. positive
    C. neutral
    D. no charge
    Concept 8 – Standard IL.12.E.2b

38. What does pH measure?
    A. H^+ ions
    B. OH^- ions
    C. Cl^- ions
    D. O^{2-} ions
    Concept 8 – Standard IL.12.E.2b

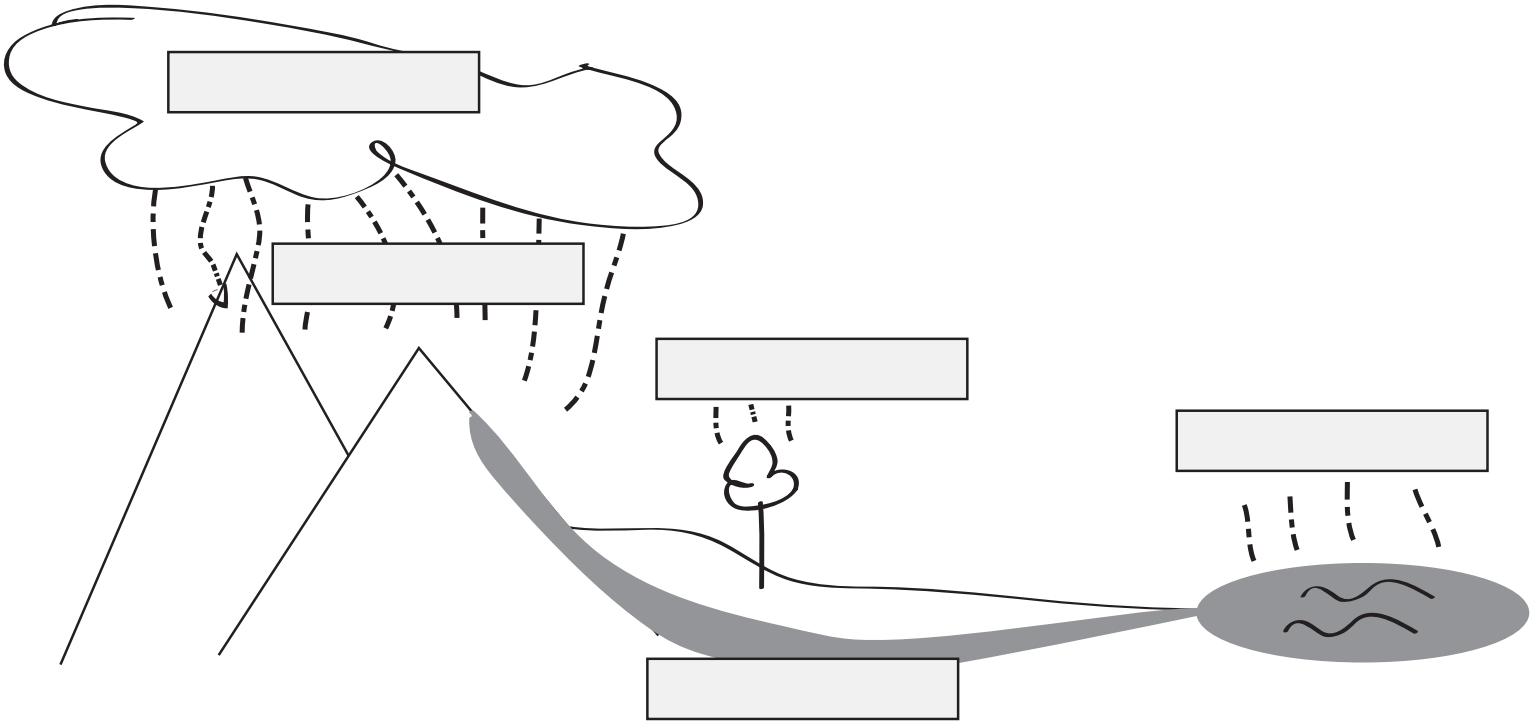
39. Which of the following will combine to make water?
    A. An acid and a base
    B. Two different acids
    C. Two different bases
    D. Either an acid or a base
    Concept 8 – Standard IL.12.E.2b

40. What might be added to a pond in order to neutralize acid rain's effect on wildlife?
    A. lime
    B. citrus
    C. acid
    D. arid
    Concept 8 – Standard IL.12.E.2b

(Insert the 10 most troublesome questions from the last exam here)

Water Cycle Quiz Name: _____

Write the appropriate name of the water cycle stage in each box.



What is another name for the movement of water from one place to another (typically high to low altitude)?

What is water containing dissolved electrolytes called?

What is it called when water changes from a liquid to a gaseous state of matter following absorbtion of energy?

What is it called when water changes from a gaseous state to a liquid state of matter following loss of energy?

What is a general name for any form of water falling to the ground?

What is the movement of any substance from an area of high to low concentration?

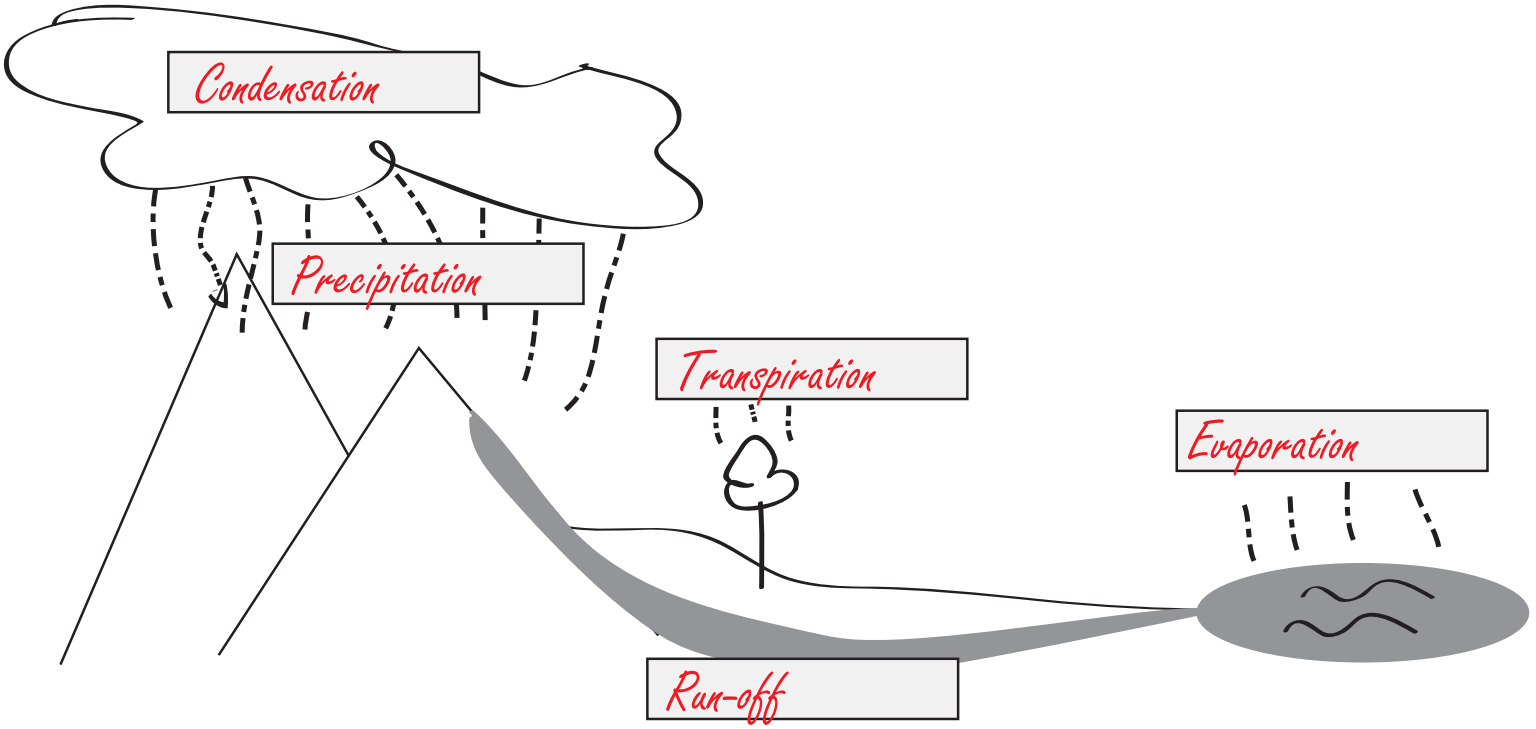
What is the movement of water from an area of high to low concentration?

What is the special name given to evaporation of water from a plant's leaves?

Water Cycle Quiz

Name: Key

Write the appropriate name of the water cycle stage in each box.



What is another name for the movement of water from one place to another (typically high to low altitude)?

Run-off

What is water containing dissolved electrolytes called?

Salt Water

What is it called when water changes from a liquid to a gaseous state of matter following absorbtion of energy?

Evaporation

What is it called when water changes from a gaseous state to a liquid state of matter following loss of energy?

Condensation

What is a general name for any form of water falling to the ground?

Precipitation

What is the movement of any substance from an area of high to low concentration?

Diffusion

What is the movement of water from an area of high to low concentration?

Osmosis

What is the special name given to evaporation of water from a plant's leaves?

Transpiration

Matthew Hagaman
1800 Spillway
River Lake, IL

Dear Governor Quinn:

I understand that you are having some problems with erosion as a result of acid rain in the state of Illinois. I would be happy to offer my expertise on the matter in an effort to alleviate your current concerns as well as prevent similar problems in the future.

Let me start by describing what is happening...

Respectfully Submitted,

Matthew Hagaman

Writing Prompt: Illinois has recently encountered some new problems as a result of pollution. Rock (identified as limestone) has begun to erode roadsides, underneath buildings (causing structural damage), and even key parts of tourist attractions (often the buildings themselves). Governor Quinn has come to you for help – what advice do you give him? First describe the problem as you see it, then offer your suggestions to fix the problems already occurring as well as prevent any problems in the future.