VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE

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Investigating Ionic, Covalent and Metallic Bonding

2018-2019 VINSE/VSVS Rural

Acknowledgement: We want to thank NASA and the Tennessee Space Consortium for funds to purchase the Elenco Snap Circuit™ kits.

Goal: To measure the conductivity of solids and solutions using an LED in a circuit.

TN Curriculum Alignment:

VSVSer Lesson Outline

________ **I. Introduction to Bonding in Ionic, Molecular and Metallic Compounds and Metals**

Students are introduced to ionic, molecular and metallic compounds
Explain Static and Current electricity. Write the vocabulary words on the board and explain conductors and nonconductors.

_______ **II. Explaining the Circuit – Demonstration**

Explain the circuit and LED and demonstrate how the students will use the red and black lead wires to test conductivity. Students discover that an electrical current will flow through a metal nail (which has metallic bonding) but not through a plastic cap.

_______ **III. Conductivity of Solutions of Ionic and Molecular Compounds**

Explain that some solutions conduct an electrical current. Students will test a number of solutions. Make sure they understand the importance of rinsing off the metal leads of the red and black wires in distilled water between each conductivity test.

_______ **IV. Using a Polymer to Distinguish Between Ionic and Molecular Compounds**

Students add ionic or molecular compounds to a gel of sodium polyacrylate and observe results.

a. Testing ionic and molecular compounds

_______ **V. Review** Review the results of the lesson and the vocabulary words.

Materials

1 ea	Models of NaCl and water compounds
1	plastic bag containing a n assembled grid and nail and plastic bottle cap
16	sets of grids with assembled circuit
16	sets of instruction sheets
32	observation sheets
64	jars containing: salt, sodium bicarbonate, sugar and glucose
80	2oz cups
16	bags containing 4 taster spoons,1 chemwipe tissue, 4 toothpicks
16	100 mL bottles distilled water
16	10 oz cups
16	12 oz cups (the opaque ones)
2	containers sodium Polyacrylate
4	teaspoons
1	1L container of distilled water
16	Plates
16	6-well plates

1. In the car ride, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.

Lesson Quiz

1. What is the difference between static electricity and current electricity?
2. How can you tell the difference between a good conductor and a poor conductor through a conductivity test?
3. Will an ionic compound or a molecular compound conduct electricity when dissolved in water? Why?
4. Is sugar solution a conductor? Why?
5. At the conclusion of the lesson should the leads be snapped together before they are placed back in the kit? (NO)

Do not hand out materials until you have discussed the following background information.

Unpacking the Kit – What you will need for each section:

For Part I. Introduction

While one person is giving the Introduction, another VSVS member writes the following vocabulary words on the board: ionic compounds, ionic bonds, molecular compounds, covalent bonds, conductors, insulators. Other VSVSers count the number of students in the class and put 1 tsp sodium polyacrylate into a 12 oz cup (the opaque one) and 200mL water into 10 oz cups

For Part II. Explaining the Circuit – Demonstration

1 grid with assembled circuit, plus a bag with a nail and a bottle cap for demonstrating conductivity.

For Part III. Conductivity of Solutions

Materials for each pair: 1 grids with assembled circuit, 1 instruction sheets , 2 observation sheets
4 jars containing: salt , sodium bicarbonate, sugar and glucose,5 2oz cups, 1 bag containing
4 tasterspoons,1 chemwipe tissue, 4 toothpicks, water bottle,

For Part IV. Using a Polymer to Distinguish Between Ionic and Molecular Compounds

1 10 oz cups containing 1tsp sodium Polyacrylate, 1 10 oz cups containing 200 ml water, 1 teaspoon
1 Plate, 1 6-well plates
4 jars containing: salt , sodium bicarbonate, sugar and glucose5 2oz cups, 1 bag containing
4 tasterspoons,1 chemwipe tissue, 4 toothpicks from Part III

For Part V. Experiment -

1. Introduction to Bonding in Ionic and Molecular Compounds and Metals

Materials: Models of ionic NaCl, and molecular water H_2O

Note: This section is meant to be a refresher of material they have already learned in class. It is more important that you get to the experimental parts.

Ask students: What are the different types of bonding that can form between atoms?

Answer: ionic, covalent or metallic

1. **Ionic Compounds**:

Show students the model of sodium chloride and explain that the sodium chloride crystal has a repeating pattern of equal numbers of Na^+ and Cl^- ions in 3 dimensions. This is called a crystal lattice.

An **ionic compound** forms between positive and negative ions that are created when atoms either

lose or gain electrons.

Some ions are formed from single atoms, such as the sodium and chloride ions in salt (sodium chloride). Some ions are made of more than one atom, such as the bicarbonate ion (HCO_3^-) in sodium bicarbonate ($NaHCO_3$).

2. Molecular Compounds:

Show students the plastic bag containing the water molecules. The hydrogen and oxygen molecules are covalently bonded.

A **molecular compound** is made up of atoms that are **covalently** bonded. Covalent bonds are formed when atoms **share electrons**.

3. **Metals** easily lose valence electrons and become metal ions.
   a. Metallic bonds, like covalent bonds, also involve sharing electrons.
   b. But in metals, the electrons are shared over millions of atoms, while in molecular compounds, the electrons are shared between just 2 or 3 atoms.
   c. For example, in a covalently bonded compound like oxygen (O_2), electrons are shared between the 2 oxygen atoms; however, in a metallically bonded compound like a gold bar, electrons are shared over all gold atoms in that bar.

You might hear metallic bonding referred to as a 'sea of electrons' for this reason.

One of the differences in properties between ionic and covalent compounds is the ability to conduct an electrical current when they are added to water.

Tell students that they are going to conduct an experiment to determine if a compound is ionic or covalent.

Why is the science in this lesson important?

- In the food service/production industry, cooking equipment may be sanitized with harsh chemicals that have high concentrations of ions. A conductivity test can be used to determine if the cleaning agent has been sufficiently rinsed away. If there is still significant conductivity when pure water is in contact with the equipment, then the equipment should be further rinsed to remove the cleaning agent.
- Public water facilities often monitor the conductivity of their output water to determine how much material is dissolved in the water (total dissolved solids). It is important to note that this test only accounts for the dissolved solids that are conductive. However, this method would be useful to determine if water has been demineralized, that is, if hard water has been effectively treated to remove some of the contaminating ions. As another example, conductivity tests can be used to determine if desalination processes have removed all of the salt from ocean water so that it becomes fit for human consumption.

II. Explaining the Circuit

Learning Goals: Students define static and current electricity and observe that metallic compounds conduct electricity and molecular compounds do not.

Materials

1 grid with assembled circuit, plus a bag with a nail and a plastic bottle cap for demonstrating conductivity.

Ask students if they know what the 2 types of electricity are.

1. Static electricity is the build-up of electrical charge. It does not flow. Lightning is an example of static electricity being "discharged" after having been built up.
2. Current electricity is moving electrical charge, usually electrons. Some materials have more "free" electrons than others. Current electricity flows through a completed circuit.

Demonstration

Materials per pair

1 set of grids with assembled circuit
1 set of <u>instruction sheets</u>
2 <u>observation sheets</u>

Learning Goals: Students learn what an LED is, and understand how it is used to show that a circuit is complete.

VSVS team members should hold up the demonstration circuit to show the students.
Tell the students to look at **Diagram 1and their circuit board**.
Point out the different parts – batteries, circuit connectors, black and red leads, resistor and LED light.
Point out that a "lead" is a wire wrapped in an insulator.

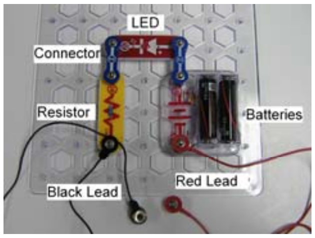


Diagram 1

Explain LED's to the students: LED's (Light Emitting Diodes) are more sensitive than light bulbs and glow brightly with small currents.

VSVS information only: LED's are made from semiconductors. They can be damaged by high currents and so are used with resistors to limit the current. Do NOT allow the students to remove the resistor.

Ask the students what you should do to make the LED glow. *Touch the black and red lead together to complete the circuit.*
Show the students that this is correct and that the LED emits light. **Tell the students that the circuit is closed when the red and black leads are touching.**
Electrical current can flow through LEDs in one direction only. Show the students the direction of flow.

Current flows from the positive end ("knob") of the battery to the negative ("flat") end.

Tell the students that electricity flows through some materials better than others.

- **Conductors** are materials that allow the movement of electrons through them. Metals have many "free" electrons that can easily move, and therefore are *good* <u>conductors</u>. "Free" electrons are those not strongly held by the atom's nucleus. Since they are not strongly held, they are able to "jump" from one atom to another.

Now touch the end of one lead wire to the head of the nail and the end of the other lead to the point of the nail. The LED again lights up indicating that the circuit is closed. The metal nail is a *good* <u>conductor</u> of electricity and completes the circuit. **Remember that metallic bonding involves a "sea of electrons" that allows electrical currents to flow.**
Repeat with the bottle cap, putting the ends of the leads on opposite sides of the bottle cap. The LED will not light up, indicating the plastic bottle cap is not a conductor. Plastic bottle tops are made from molecular compounds, which have covalent bonds.

III. Conductivity of Solutions of Ionic and Molecular compounds

Learning Goals: Students understand that solutions of ionic solutions conduct electricity and solutions of molecular compounds do not.

Materials per pair

16	sets of grids with assembled circuit
16	sets of instruction sheets
32	observation sheets
16	sets of jars containing: salt , sodium bicarbonate, sugar and glucose solids
80	2oz cups
16	bags containing 4 taster spoons,1 chemwipe tissue, 4 toothpicks
16	500 mL water bottles (containing distilled water)

Background information for VSVS members only (electrolytes and non-electrolytes are not in the 7th grade vocabulary):
Conducting liquids are called **electrolytes.** An **electrolyte** contains electrically charged ions that can conduct electricity. Some examples of electrolytic solutions are acids and bases and salt solutions such as sodium chloride (table salt) in water.
A **non-electrolyte** does not allow the flow of electric current because it does not have electrically charged ions that can conduct electricity. Some examples of non-electrolytic solutions are distilled water, sugar water.
Electrolytes are important to humans because they are necessary for proper cellular function, muscle function, and neurological function. A greater level of electrolytes is needed during strenuous muscular activity because more electrolytes are lost due to increased sweating. This is the reason why Gatorade and other sports drinks advertise that they replenish electrolytes.

Hand out the jars of solids to each group.
Tell the students to follow the instruction sheet and to record their results.

Tell students to:
- Rinse the metal ends of the black and red lead wires by dipping them into the cup of distilled water. Tell the students they will need to do this in between each test, to avoid contaminating the next test sample with the one just tested (make sure that the students know what contamination means).
- Place the 5 2oz cups containing distilled water on top of the diagram on the instruction sheet.
- Place the corresponding jar of solid next to the cup. Make sure that the students have the order correct. **Students must remove only ONE lid at a time, and replace it after pairs have tested the liquid.**
- Students **MUST** test the solutions in the order given, 1-5
  - The non-conducting solutions are tested first, followed by conducting solutions. This will help avoid contamination of the solutions.

1. Testing distilled water:
Put the metal ends of both lead wires in the cup containing distilled water, as far apart as possible, and note if the LED is glowing. (It should not). Remove the leads.

2. Testing water plus sucrose (sugar):

Remove the lid of the 1st jar (sugar) and add 1 mini spoon to the water. Stir with a toothpick, and then snap the toothpick in half so it cannot be used again. Repeat the conductivity test. Record your results. Replace the lid on the jar. The LED should not glow.

Rinse the metal ends of the wires in the distilled water jar..

3. Testing water plus glucose:

Remove the lid of the 2nd jar (glucose). Repeat the conductivity test. Record your results. Replace the lid. The LED should not glow.

Rinse the metal ends of the wires in the rinse cup.

4. Testing water plus sodium chloride (salt):

Remove the lid of jar 3 (salt).

Repeat the conductivity test Replace the lid. Record your results. The LED should glow.

Rinse the metal ends of the wires in the rinse cup.

5. Testing water plus sodium bicarbonate (baking soda):

Remove the lid of the 4th jar and repeat the conductivity test. Replace the lid. The LED should glow.

Record your results. Rinse the metal ends of the wires in the rinse cup

Ask students if they can explain the results.

1. **Distilled water** does not contain ions and thus does not conduct electrical currents. Distilled water is a molecular compound with covalent bonds. (Note that TAP water can conduct an electrical current because it can contain metal salts that are ionic.)
2. **Sugar molecules** and **glucose molecules** are molecular compounds that do not split up into ions in water, and so do not conduct electrical currents
3. **<u>Solid</u> salt** and **<u>solid</u> sodium bicarbonate** will not conduct electricity because the sodium, chloride and bicarbonate ions are not free to move around in the solid form. However, when they are dissolved in water, the units dissociate completely into ions, and so are <u>conductors</u> of an electric current.

IV. Experiment: Using a Polymer to Determine if a Compound is Ionic or Molecular.

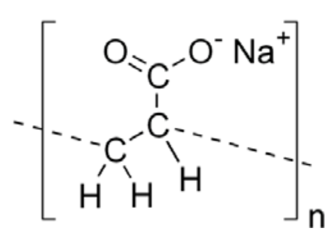
Materials:

16 12 oz cups containing 1tsp sodium Polyacrylate
16 10 oz cups containing 200 ml water
2 containers sodium Polyacrylate
16 teaspoons
16 Plates
16 6-well plates
16 1oz jar of sugar, 1oz jar of glucose, 1oz jar of sodium chloride (salt), 1oz jar of sodium bicarbonate (baking soda),
16 bags containing 4 taster spoons, 1 chemwipe tissue, 4 toothpicks

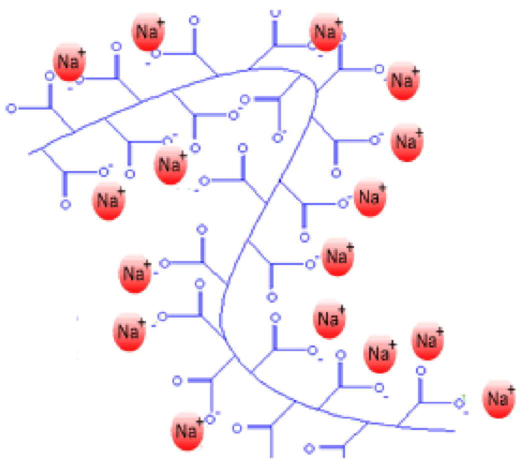
Sodium Polyacrylate is a **superabsorbent polymer** found in disposable diapers and moisture absorbent for automobile and jet fuels. A superabsorbent polymer can absorb and retain extremely large amounts of liquid relative to its own mass]

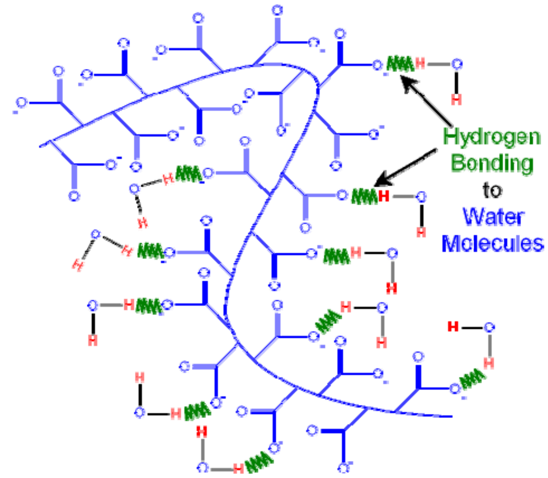
This polymer absorbs about 300 times its weight of tap water (800 times its weight of distilled water because the ions in tap water reduce the absorbing properties of the polymer).

Note for VSVS members only: It is a polymer that consists of repeating units of the monomer. The picture is a single unit.



It is able to absorb large amounts of water because the sodium ions (Na^+) that are attached to it are replaced by water.
Point to the diagrams of sodium polyacrylate on their handout. Point out the Na^+ ions that are replaced by water molecules





Making a gel with sodium polyacrylate.

- Give each pair a (10 oz) cup containing the sodium polyacrylate and a 10 oz cup containing 200 mL tap water.

Tell them to:

1. Pour the water into the cup with the sodium polyacrylate and stir with a spoon.
   Observe that all the water is absorbed (forms a gel) immediately.

VSVS Information only: Sodium polyacrylate will continue to absorb water until there is an equal concentration of water inside and outside the polymer. Each sodium polyacrylate molecule is able to attract and hold thousands of water molecules. Sodium polyacrylate, uses osmosis to soak up water. Because there is a higher concentration of water outside the sodium polyacrylate, it draws in the water through osmosis. Each sodium polyacrylate molecule is able to attract and hold thousands of water molecules.

V. Experiment – Investigating the Effect of Adding Ionic and Molecular Compounds to Sodium Polyacrylate

Fill each well with about 1 tsp of the gel.

a. Add 1 mini spoon sugar to well 1
b. Add 1 mini spoon glucose to well 2
c. Add 1 mini spoon sodium chloride (salt) to well 4
d. Add 1 mini spoon sodium bicarbonate (baking soda) to well 5

Observe what happens to the gel.
Either the gel collapses into a watery mess (for the ionic compounds) or it is not affected (for the molecular compounds).

Ask students: based on the previous experiment, which compounds are ionic or molecular?
Answers: Sugar and glucose are molecular.

Sodium Chloride and sodium bicarbonate are ionic.

Which compounds caused the gel to breakdown?

Answers: The ionic compounds

The solids that have no effect are the molecular compounds that are covalently bonded.

Explanation: The compounds that cause the breakdown contain a combination of metals and non-metals and are **ionic** compounds. Charged particles or ions from ionic compounds interfere with the stability of the polymer/water interactions in the gel. When sodium chloride and sodium bicarbonate are added to the hydrated polymer, the sodium ions from them attract the water. As a result, water molecules diffuse back out of the polymer. The addition of the salt breaks the "gel" polymer apart as water leaves the polymer to try to balance the water concentration inside and outside the polymer network

VI. Review

How can we distinguish between ionic and molecular compounds using an electrical circuit?
How can we distinguish between ionic and molecular compounds usingthe polymer sodium polyacrylate?
Go over the observation sheet with the students.

Lesson modifications by:
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Conductivity Observation Sheet

Name ____

A. Testing the Circuit.
What happens when you touch the ends of the red and black lead wires together?
____

Explain____

B. Conductivity Tests with Solids
Which of the following materials cause the LED to light up?
Circle your answer.

1. iron nail	bright light
2 plastic bottle cap	no light

On this basis, what material has metallic bonding?
Which material is a molecular compound?

C. Conductivity Tests with Solutions
Which of the following solutions makes the LED glow brightly, dimly, or not at all?
Circle your answer.

1. distilled water	no light,	dim light,	bright light
2. sugar plus water	no light,	dim light,	bright light
3. glucose plus water	no light,	dim light,	bright light
4. sodium chloride plus water	no light,	dim light,	bright light
5. sodium bicarbonate plus water	no light,	dim light,	bright light

On the basis of the above results, which materials are ionic compounds?

____

Which materials are molecular compounds?

____

D. Testing the reaction of a polymer gel with ionic and covalent compounds
What happened to the polymer gel when the following were added?

1. Sucrose (sugar) ________________________________
2. Glucose ________________________________
3. Sodium chloride (table salt) ________________________________
4. Sodium bicarbonate (baking soda) ________________________________

On the basis of the above results, which materials "extract" water from the gel (the ionic or covalent compounds)?

Conductivity Answer Sheet

A. Testing the Circuit.

1. What happens when you touch the ends of the jumper cables together?

The LED lights up.

Explain: **Touching the ends of the leads together completes the circuit.**

B. Conductivity Tests with Solids

Which of the following materials cause the LED to light up?
Circle your answer.

1. iron nail	bright light
3. bottle cap	no light

On this basis, what material has metallic bonding? – iron nail
Which material is a molecular compound? Plastic cap

C. Conductivity Tests with Solutions

Which of the following solutions makes the LED glow brightly, dimly, or not at all?
Circle your answer.

1. distilled water	no light
2. sugar water	no light
3. glucose plus water	no light
4.. salt water	bright light
5. sodium bicarbonate plus water	dim light

On the basis of the above results, which materials are ionic compounds?

Sodium chloride and sodium bicarbonate

Which materials are molecular compounds

distilled water, sugar and cornstarch

D. Testing the reaction of a polymer gel with ionic and covalent compounds

What happened to the polymer gel when the following were added?

1. Sucrose (sugar)	nothing
2. Glucose	nothing
3. Sodium chloride (salt)	gel becomes watery
4. Sodium bicarbonate	gel becomes watery

On the basis of the above results, which materials "extract" water from the gel?

The ionic compounds, sodium chloride and sodium bicarbonate