This segment is useful in introducing students to the intramolecular forces (ionic, covalent and metallic) present in materials and the particular properties associated with each type of bonding, especially as it pertains to the functions of designed materials; relating the bonding type on the molecular level to the arrangement of valence electrons; and developing particle diagrams to represent bonding configurations from nonpolar covalent to ionic bonding.

Student Science Performance

Grade or course: 9-12 Chemistry	**Title**
Topic: Bonding	Bonding Basics

Performance Expectation for GSE:

SC2. Obtain, evaluate, and communicate information about the chemical and physical properties of matter resulting from the ability of atoms to form bonds.

a. Plan and carry out an investigation to gather evidence to compare the physical and chemical properties at the macroscopic scale to infer the strength of intermolecular and intramolecular forces.
b. Construct an argument by applying principles of inter- and intra-molecular forces to identify substances based on chemical and physical properties.
c. Construct an explanation about the importance of molecular-level structure in the functioning of designed materials. (*Clarification statement:* Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.)
d. Develop and use models to evaluate bonding configurations from nonpolar covalent to ionic bonding. (*Clarification statement:* VSEPR theory is not addressed in this element.)
e. Ask questions about chemical names to identify patterns in IUPAC nomenclature in order to predict chemical names for ionic (binary and ternary), acidic, and inorganic covalent compounds

Performance Expectations for Instruction:

1. Formulate questions to investigate when observing the differences in conductivity between materials such as a metal, salt, dissolved salt, etc.
2. Explain how the structure and bonding type within a material affects the function and use of that material.
3. Design and conduct an investigation to identify patterns in the physical and chemical properties associated with each type of bonding-metallic, ionic, polar covalent and nonpolar covalent. Apply this pattern in properties to identify six unknown substances and provide evidence to support the claim for their identity.
4. Analyze data to classify the bonding type in unknown substances.
5. Formulate questions to research and construct an explanation based on structure, to account for the differences in properties between molecular materials with polar and nonpolar covalent bonding.
6. Conduct a PHET simulation to research how differences in electronegativity can cause dipoles and affect the type of covalent (polar or nonpolar) bonding that occurs in molecular substances.
7. Predict bonding type using a table of electronegativity values.
8. Develop a particulate model or diagram, based on evidence and research, that demonstrates the differences, on a particle level, between the four types of bonding.
9. Develop a flowchart for naming compounds by examining patterns in compound names

Additional notes on student supports

Materials

Introductory Phenomenon - Conductivity

Conductivity testers; 50 mL beakers to hold samples;
Laptop and internet
Station 1 - Copper wire; Aluminum foil or wire;
Station 2 - Potassium iodide (KI) crystals; Aqueous potassium iodide solution; Magnesium sulfate ($MgSO_4$)

crystals; Aqueous magnesium sulfate solution; Control of distilled water;
Station 3 - Paraffin wax ($C_{30}H_{62}$); Sugar crystals ($C_{12}H_{22}O_{11}$); Aqueous sugar solution; control - distilled water

Lab - Investigating bonding & identifying Unknown Substances

Ionic substance (ex. Calcium carbonate ($CaCO_3$)); Metallic substance (ex. Zinc (Zn)); Polar covalent substance (ex. sucrose); Nonpolar covalent substance (Wax); 6 unknown samples *(choose a selection of substances from each bonding type and label A, B, C, D, E, & F)*; Bunsen burner; hot plate; Conductivity tester; Test tube rack & test tubes; Test tube holder; Distilled water; Beaker tongs; Watch glass; Stirring rod; Microwell plate; Beaker for water bath; Thermometer; [Bonding and Property Basics]

Safety equipment includes *ANSI Z87.1 chemical splash-proof goggles, aprons and gloves*

Molecule Polarity Demo and student activity:

2 burettes; 2 beakers; distilled water; hexane; balloon or glass rod; fabric to charge balloon or rod; laptop with internet access for PHET simulation student activity.

Students will continuously obtain, evaluate, and communicate information. This is not a linear process. Students will communicate through writing and discussions to allow for formative assessment. This benefits the teacher, student, and whole group to guide instruction to clarify misconceptions or extend content.

Engaging Learners

Phenomenon

Students rotate three stations and use a conductivity tester (*Alternatively use a multimeter or light bulb testing apparatus.*) to test a selection of materials for conductivity. The following phenomena result:

Station 1: Sections of copper wire and aluminum foil/wire result in both red and green lights lighting up indicating material is a good electrical conductor of an electrical current. *(Use any metals.)*

Station 2: KI crystals - do not conduct but KI crystals in water conduct.
$MgSO_4$ crystals - do not conduct but $MgSO_4$ crystals in water conduct.
Distilled water does not conduct. (*Use any selection of salts or materials with ionic bonding.)*

Station 3: Paraffin wax as well as plastic beads do not conduct. (*Use any material with covalent bonding.*)

Obtaining

1. Students perform the experiment in groups of 2-3.
2. Students individually record their observations and come up with questions that they would like to answer based on their data. *Some suggestions are*
    - *Why did KI not conduct but when it was dissolved in water, it did conduct? (also water on its own did not conduct?*
    - *Is conductivity a chemical or a physical change? How do we know?*
    - *What happens when an electrical current passes through a material?*
    - *What is occurring at the molecular level of ALL these materials that helps explain why some materials conduct and some are insulators and do not?*
    - *Is there any pattern that allows us to predict if something will conduct or not? Are particular elements associated with conductors and insulators?*
    - *What parts of the atom are involved in bonding?*
    - *Are other properties associated with this type of bonding?*

    In groups, the students obtain information relating to their question. (*Teacher may need to provide links to appropriate websites (include websites for each type of bonding with explanations and diagrams to facilitate research process) and guide to make sure that students are answering questions*

	related to bonding.)
	Evaluating In groups, the students write a paragraph that summarizes their research and discusses how the type of bonding present has an effect on conductivity. The paragraph should outline the forces present in each type of bonding and the behavior of electrons. Each group should also develop a particle diagram that models the molecular structure of one of the materials at each lab station. (*Metallic - electron sea diagram; Ionic should show how polar water molecules allow the K and I to separate into ions which can conduct electricity; Covalent - shows discrete molecules that do not carry a charge. Additionally, models could show the transfer or sharing of electrons.)* Here is a link to a student investigation worksheet that may facilitate a teacher in evaluation. [Bonding and Property Basics]
	Communicating **Group** - Students present their models on whiteboards or posters *(Each group could present one type of bonding to save time.)*. Each group receives student and teacher feedback and may revise their conclusions and explanations. **Individual** - Students individually have analysis questions that ask them to construct an explanation for why a particular function is suitable for a material.
Exploring ***Exploring Phenomena*** Students engage in Obtaining information and data to use as evidence to support explanations of the phenomenon of the engagement experience and/or novel, but related phenomenon. The exploration performances provide concrete experiences to extend students' current understanding and demonstrate their abilities to make sense of science phenomenon. Students should have experiences formulating explanations, investigating phenomena, observing patterns, and developing cognitive	*Obtaining* ● Students (in groups of 2-3) are asked to design an investigation in in which they will identify patterns in physical and chemical properties that will allow them to identify the type of bonding in substances. ● Students are provided with four substances that each represent a type of chemical bond - metallic, ionic, polar covalent and nonpolar covalent. They are also provided with testing materials and safe procedures for standard test. *(Examples of qualitative assessments include but are not limited to: color and appearance of solid; solubility in water; conductivity of solid and aqueous solution; melting point range determination (safe procedure for this is included in the student worksheet linked below); pH; etc. Safe handling includes the following:* ○ *Students need to wear ANSI Z87.1 chemical splash-proof goggles, aprons and gloves.* ○ *Bunsen burner safety precautions should be reviewed as this is required for the melting point range determination.* ○ *Some of the chemicals may be flammable and present a fire risk. Keep these away from flames and heat.* ○ *Hands should be washed thoroughly before leaving the lab.* ○ *Please note that any ionic compound, & metal can be used. However, be careful when substituting for covalent compounds, as many are flammable liquids and should NOT be used close to a bunsen or heated on a hot plate. Please exercise appropriate caution if using these substances.* ○ *Sulfur (S_4)- chosen as an example of nonpolar bonding.* ● Students, in groups of 2-3, will develop a data table to collect their data. ● The students will analyze the data and determine which properties and tests are important in identifying the unknown substances. Students then decide how they will identify bonding type in six unknown substances.

and physical abilities. The teacher's role is listening, observing, and guiding students in using core ideas and crosscutting concepts to make sense of phenomena.

- *Properties that student could choose to observe:*
  - *Color and appearance of solid*
  - *Solubility in water*
  - *Melting point range: a) Below 100 C; b) 100-400 C; c) >400 C*
  - *Conductivity of solid and conductivity of aqueous solution*
  - *pH of aqueous solution*
  - *Other testing approved by teacher.*

Click on the link below to access a student worksheet to guide students through the exploration, explanation and elaboration processes.

Investigation - How does Bonding affect Properties?

Communicating

- Students will communicate their data in student-developed data tables.
- Students will share their data tables and conclusions with other groups allowing them to revise and modify their investigation as they see fit. Their final conclusion should summarize the physical and chemical properties associated with each type of bonding.
- Students will design an investigation in order to identify six unknown substances.

Evaluating

Teachers should encourage student groups to evaluate each other's data tables and paragraph summarizing the physical and chemical properties associated with each type of bonding. A sample data table illustrating properties characteristic of each type of bonding is included below but students could choose other properties to assess in addition to these:

Physical Property	Ionic Compounds	Polar Covalent	Nonpolar Covalent	Metallic
Appearance	Crystalline	Crystalline/powder	Liquid or softer solid	Hard, shiny & malleable
Solubility in Water	Soluble	Soluble	Insoluble	Insoluble
Conductivity - Solid	No	No	NA	Conducts
Conductivity-solid in water	Conducts	No	NA	NA
Melting < 100 C	No	No	Yes	No
Melting Point 100-400 C	No	Yes	NA	No
Melting Point > 400 C	Yes	No	No	Yes

Formative Assessment of Student Learning

Explaining

Finalizing Model

Explaining Phenomena

The scientific explanation for causes of phenomena are prominent in this phase. Students engage in three-dimensional performances. The focus is on accurate use of Core Ideas and Crosscutting Concepts in the performance of

Obtaining - student investigation worksheet for this already linked above.

1. Students are now given six unknown substances and are asked to apply the results of their prior investigation in order to identify the substances based on their characteristic properties. Supply a list of names of potential chemicals to help students narrow down their research and a knowledge of the properties associated with each bonding type will play a role in making the final identification.
2. Students will test each of the substances, analyze their properties and determine the bonding type. Then they will attempt to match their unknown chemical to one from the list of potential chemicals with the same type of bonding. Further research on physical properties such as color, texture, etc will allow a final match.
3. Students identify each unknown substance and support their claim with evidence.
4. Students will then conduct research, so they can explain the reasons behind the properties characteristic of each type of bonding. (*For example, all ionic*

making sense of the phenomena featured in the engage and explore phase. The teacher directs students' attention to key aspects of the prior phases and first asks students for their explanations. Both the teacher and student formatively assess the learning progress.	*compounds have extremely high melting and boiling points)* 5. Students produce a particle diagram that models the arrangement of particles during each type of bonding.
	Evaluating ● Students will communicate their data in student-developed data tables. *To help evaluation, a sample data table is included below and as a handout- [Sample Data Table]()* ● Students will share their data tables and conclusions with other groups allowing them to revise and modify their investigation as they see fit. Their final conclusion should identify each unknown substance and support their claim with evidence from their data and research.
	Communicating ● Within a group, students share their data, research, and initial conclusions with each other. Each group member should take a different type of bonding and develop an explanation and model to explain why the arrangement of the particles in bonding affects the characteristic properties of the substance. ● Each group presents their findings to other groups or can present to the class. After receiving feedback, groups can revise their claims, models and explanations. ● Individually students write a paragraph identifying each substance and develop an argument using evidence to support their claim. They also explain how the forces and arrangement of particles characteristic of each bond type results in characteristic properties. *Some examples of how structure affects properties:* ○ *Ionic compounds only conduct electricity when dissolved in water because intermolecular forces between the water and ionic compounds forms a hydration shell around each ion, dissociating the ions and freeing them to move.* ○ *Ionic points have high melting points because the electrostatic attraction between the cation and anion within the lattice arrangement is very strong and requires a lot of energy to break.*
Elaborating Applying Model to Solve a Problems	**Phenomenon** Teacher performs the following demo illustrating the difference in properties between polar and nonpolar substances: ● Clamp two 25 mL burettes to a support stand. Place a large beaker below each burette. ● Fill one burette with a polar substance such as water. Fill the other burette with a nonpolar substance such as hexane. ● Charge a balloon by rubbing against fabric or har. Alternatively, charge a glass rod with silk. ● Open the stopcock on the burette and allow a thin stream of water to low into the beaker. Place the charged object next to the stream of water and observe. *(Water will bend dramatically towards the charged object)* ● Repeat step 4 for the burette with hexane and observe. *(The charged object has no effect on hexane).* ● Discuss observations with students and get them to come up with questions

they would like to answer. Some examples could include:

- *If both have covalent bonding, why did they behave differently?*
- *Why is a molecular substance behaving as if if has a charge?*
- *How can we explain a charge in a covalent bond?*

Obtaining

Students:

- Teachers will provide students with an online link to a simulation that will allow them to explore polarity of molecules:

[Polarity of Molecules]

(Attribution: PhET Interactive Simulations University of Colorado Boulder [https://phet.colorado.edu] *PHET is a free and interactive simulation provided by the University of Colorado. It can be used online or downloaded. Teachers may register in order to access additional resources related to the simulation. There are many versions of student worksheets that teacher can download to accompany the simulation; this simulation will work on computers and Chromebooks)*

- Conduct additional online research if necessary and come up with an explanation for the differences between the two substances in the demo and how this can be explained by aspects of their covalent bond.
- Develop a particle diagram that shows a model of polar covalent bonding and non-covalent bonding.
- Should be able to classify substances as polar or nonpolar covalent based on their electronegativity values.
- Will ask questions about patterns in naming compounds using the [Naming Ionic Compounds Guided Inquiry] activity.

Evaluating

- Student worksheet that accompanies the PHET simulation.
- Student paragraph explaining the differences should reference:
  - electronegativity differences using Pauling Scale *(for example: Ionic >1.7; Polar covalent 0.4 - 1.7; Non-polar < 0.4)*
  - the effect on the shared electrons and
  - how a dipole is created.
- Student model should depict the polar substances having a partial negative charge on one atom and a partial positive charge on the other. The nonpolar covalent molecule will show equal sharing of the electrons and no dipole. *A simple interpretation of this is illustrated below where the * represent two shared electrons between atoms A and B.*

```
Non-Polar                                   Polar
    *                               +         *   -
A ---------- B                        A ---------- B
    *                                          *
```

- Teachers should also provide a worksheet with an electronegativity value table, so students can classify substances as polar covalent or nonpolar covalent.

Communicating

Groups will share their paragraph, research and models with one another, revise as necessary and individually answer the worksheet questions.

Evaluation	***Assessment of Student Learning***
	Formative Assessment:

	• Paragraph summarizing how bonding affects properties and the designed function of materials - individual work • Particle diagrams that model the behavior of the particles in each type of bonding • Student presentations of models and descriptions of each bonding type • Data table organizing the properties exhibited by the four substances representative of each bond type - group work • Paragraph describing the investigation and the process for identifying the six unknown substances • Data table for the investigation of the six unknown substances • PHET simulation research of polarity and electronegativity - group work **Summative Assessments - Individual work** • Evaluation and identification of the six unknowns - this includes evidence and argument to support the identity of each substance • Analysis - Peer-edited particle diagram for each type of bonding along with an explanation of how the particle arrangement affects at least two of the properties • Presentation of models • Elaboration: Particle diagram or representations of a polar bond and a nonpolar bond along with descriptions that illustrate the differences between them • Analysis questions - individual work • Flow chart of compound naming patterns *Examples of answers are included in each section.*
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	• Pose questions that seek evidence relevant to the question. • Pose models to describe mechanisms at unobservable scales and explain phenomena. • Plan and design investigations that collect data and generate evidence to answer scientific questions. • Analyze and interpret data. • Share explanations and arguments based on evidence from multiple sources and peer review. • Generate and communicate ideas using scientific language and reasoning.
Crosscutting Concepts	• Use models to investigate patterns in phenomena. • Identify the causes of observed patterns in natural systems. • Use patterns that can be observed at one scale to explain phenomena at another scale. • Use diagrams and representations to model systems. • Explain how energy is involved when matter changes. • Describe how the materials that objects are constructed from affect the function of the object.
Disciplinary Core Ideas	• Chemical and Physical Properties • Intermolecular forces • Intramolecular forces • Material science and material engineering • Covalent (polar and nonpolar) and ionic bonding • Metallic bonding

	• Electronegativity • Bonding configurations • Nomenclature

<table>
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<u>Additional Supports for struggling learners:</u>

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.
</td></tr>
<tr><td colspan="3">General supports for the following categories:</td></tr>
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<u>Reading:</u>

1. Provide reading support by reading aloud or doing partner reads
2. Have the teacher model what they are thinking when reading the text
3. Annotate the text with students so that they may refer to it as they work through the lab
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<u>Writing:</u>

1. The teacher can provide a sentence starter for the students.
2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic).
3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.
</td><td>

<u>Math:</u>

1. Provide calculators as needed.
2. Provide graph paper as needed.
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<tr><td colspan="3">Supports for this specific lesson if needed:</td></tr>
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Performance expectations for instruction:

1. The teacher should provide information to students in various formats to reach as many students as possible.
2. The students should be given adequate time to complete each part of the lesson.
3. The students should be allowed to express their knowledge in various formats.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.
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Engage:

1. The teacher will need to explicitly teach students to use the conductivity tester.
2. The teacher should remind students of directions as needed.
3. The teacher should use intentional and flexible grouping. Best practice is to use data to drive instruction.
4. The teacher should consider giving students an organizer to record observations, data and generated questions.
5. The teacher should consider having students share the questions they generated and then help the students to determine which questions are important and should be researched. The teacher can use guiding questions to help students narrow it down to the questions that most relate to the standard and lesson.
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6. The teacher should consider giving students sources to find information relating to the questions.
7. The teacher should consider giving students multiple formats to communicate their knowledge. This could be drawing, writing or designing a presentation.
8. The teacher should consider doing an example of a particle diagram with students.
9. The teacher should have clear and consistent guidelines for student presentations.
10. Students may need additional time to revise their explanations.

Exploring:

1. The teacher should use intentional and flexible grouping. Best practice is to use data to drive instruction.
2. The teacher may need to review physical and chemical properties.
3. The teacher may need to go over the procedures of the lab multiple times with students.
4. The teacher should remind students of safety procedures in the lab.
5. The teacher should consider giving a pre-made data table to struggling students. There are various levels of completion that they table may be in when given to students. Some students may require a completed data table, but others may be successful with a partially completed data table that their group can complete.
6. The teacher should check for understanding as moving through the lesson and re-teach, review or enrich as needed.
7. The teacher should give students in the investigation sheet for use as students move through the lesson.
8. The teacher may need to assist students in cleaning up and recording their data correctly.
9. The teacher may want to consider having students do a gallery walk rather than sharing with the entire class.
10. The teacher should provide students with an organizer to help plan their investigation.
11. The teacher should consider giving students multiple formats to communicate their knowledge. This could be drawing, writing or designing a presentation.

Explaining:

1. The teacher should consider giving the students the data table for students to record their results and an organizer to record their research.
2. The teacher should consider giving students a list of the chemicals that the unknowns could be and have students do a little research about each chemical.
3. The teacher should consider giving sources to students for use in their research.
4. The teacher should have students check one another's identification of the chemicals.
5. The teacher should remind students of what qualifies as evidence for their identification.
6. The teacher should consider giving students multiple formats to communicate their knowledge. This could be drawing, writing or designing a presentation.
7. The teacher should have clear and consistent guidelines for groups sharing information with one another.
8. The teacher should provide the CER template to students.
9. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student grouping.
10. The teacher should consider assigning types of bonding to members within each group. This way each

group member has something to focus their research on and then share within the group.

11. Students may need additional time to revise their argument.
12. The teacher should check for understanding and re-teach, review or enrich as needed.

Elaborating:

1. The teacher may need to do the demo more than once to ensure that students have been able to observe the difference in polar and non-polar.
2. The teacher should consider giving students question stems to get the students started generating questions.
3. The teacher should have clear and consistent guidelines for class discussions. This should reduce student anxiety and increase student participation.
4. The teacher should have students share questions that have been generated. Then the teacher can help students narrow down questions to ones that relate to the standard and lesson.
5. The teacher should consider giving students sources to use when researching answers to questions that they have generated.
6. The teacher should provide the PHET activity sheet to students.
7. The teacher should have students explain polarity to one another and listen for misconceptions that need correcting.
8. The teacher should help students understand the electronegativity values and how to apply them to determine if something is polar or non-polar covalent. The teacher should consider showing students how to apply the values, have the students practice using the values within a group and then use the values individually.
9. The teacher should consider having students evaluate each other’s diagrams of polar covalent and polar non-covalent bonding. Have the students revise as needed.
10. Students may need additional time to complete their assignments.
11. The teacher should consider giving students multiple formats to communicate their knowledge. This could be drawing, writing or designing a presentation.

Evaluating:

1. The teacher should consider giving students multiple formats to communicate their knowledge. This could be drawing, writing or designing a presentation.
2. Students may need additional time to complete their assignments.

Bonding and Property Basics

Phenomenon – *Test and explore the conductivity of the materials provided at three stations.*

Engaging and Gathering:

Testing Procedure:

- Test the conductivity of the samples provided at each station using a conductivity meter. Electrical conductivity is determined by observing a light bulb on the meter. The brighter the light, the greater the electrical conductivity of the sample. If no light is observed, the solution does not conduct. Be sure to rinse the electrode with distilled water and dry it before testing another sample to avoid cross-contamination.
    - Station 1 – Copper (Cu) wire; Aluminum (Al) foil
    - Station 2 – Potassium iodide (KI) crystals; Potassium iodide crystals dissolved in water
      - Magnesium sulfate ($MgSO_4$) crystals; Magnesium sulfate crystals dissolved in water
    - Station 3 – Paraffin or candle wax ($C_{30}H_{62}$); Sugar ($C_{12}H_{22}O_{11}$) crystals & sugar dissolved in water

Observations: Make a table in the space below to keep a careful record of your observations.

Questions:

Evaluation & Communication: Conduct internet research to help answer your questions in relation to ONE/ALL of the materials observed in the investigation. Using your research and conductivity data, develop (a) model(s) to explain the importance of molecular structure in explaining macroscopic properties like conductivity, etc.

- As a group, write a paragraph describing your model on the atomic level.
- Develop a diagram to represent your model.
- Each group will make a presentation to the class. (*Take notes on ALL models in student presentations for analysis questions*)
- Model may be revised and finalized before next investigation.

Group Work: Model – Drawing and Description

Model of ________________	**Description of ___________________**

Individual Analysis:

1. Using your research or information gleaned from class presentations and investigation data to construct an explanation as to why ***copper is used in electrical connections on circuit boards***.

2. Use your research & investigation data or evidence gained from class presentations to construct an explanation as to why **potassium hydroxide is used as an electrolyte in batteries**.

3. Use your research & investigation data or evidence presented in class to construct an explanation as to why ***isoprene is used in electrical cords.***

4. What type of compounds would be preferable for use in ***dyes for clothing***? Justify your answer.

Return to Instructional Segment

Investigation - How does Bonding Effect Properties?

Guiding Question: *How can macroscopic, observable evidence, like chemical and physical properties, allow us to interpret arrangements at the microscopic level between atoms and molecules, specifically in relation to bonding?*

Exploratory Investigation:

In your introductory activity, you investigated how conductivity and the ability to dissolve (or not to dissolve) in water was related to the bonding type in a substance. Now you will explore how other properties, like melting point and physical appearance, relate to bonding type. You will produce a table of bonding types and the properties associated with each in order to classify six unknown substances (A-F).

Purpose:

Construct an argument with supporting evidence by analyzing physical and chemical properties in order to determine the identity of mystery solids.

Challenge:

You have been given four substances that have properties characteristic of a bonding type:

- *Sodium Chloride – Ionic Bonding*
- *Citric acid – Polar Covalent*
- *Paraffin wax – Non-Polar Covalent*
- *Iron pieces - Metallic*

1. Select properties that you would like to observe or test for each substance. (Safe procedure for melting point determination is given below)
2. Use your data to create a classification table based on properties.
3. Then utilize your data in order to identify six unknown substances (A-F). You will categorize their bonding types in order to assist in the identification of the compounds.

Materials:

Iron pieces	Paraffin Wax	pH Paper
Sodium Chloride	Citric acid	Thermometer
6 Unknown samples, A-F	Stirring rod	Test-tube holder
Bunsen burner and hot plate	Watch glass	Test-tubes/Rack
Conductivity tester	24 microwell plate	Tongs
Distilled water, 20 mL	Beaker for hot water bath	

Safety Precautions:

Some chemicals may be flammable and kept away from the Bunsen and hot plate. Avoid contact of chemicals with eyes and skin. Wear goggles, gloves and aprons. Wash hands after the lab.

Melting Point Test:

1. Use the tip of a splint amount of solid and 2-3 mL of water for testing (only add a tiny portion of solid)
2. **Melting point testing**: ***ONLY TEST SOLIDS. Keep any liquids away from Bunsen flame and hot plate.***
   a. Place a tiny amount of each solid using a splint in separate locations on a watch glass. Using tongs, suspend the dish above a boiling water bath (<100 C). Observe if the solids melt at < 100°C.
   b. If the substance did NOT melt above boiling water, place a half a pea-size amount in a test tube and heat just above a cool Bunsen flame (yellow NOT blue which is too hot; should be approximately 300 C) for 1-2 minutes. Record observations.
   c. If the substance did not melt in the test tube, then assume its melting point is above 400 C.
3. Record your data in a data table.

Data:

- Make a data table that categorizes observed properties for each of the four types of bonding.

Communication:

- Students will share their data and observations with other groups.
- Students may revise or retest as necessary.

Conclusion:

Write a short paragraph discussing how you will test six unknown substances in order to classify their bonding and ultimately match the compound to a list of potential chemicals. In your answer, consider whether some tests are more important in your evaluation than other.

Error Analysis

- Discuss any errors associated with your testing of the solids. How could you make changes to improve your experiment and make your data more reliable?

Explaining – Finalizing your Model

- Based on your exploratory activity, use any relevant testing procedures to identify the bonding associated with unknown samples A-E.
- Produce a data table to record your observations.
- The names of A- F are included in the list of potential chemicals, which is provided below. Once you have identified the bonding associated with each unknown, narrow down the potential name of the chemical from the list and perform further research if necessary.
- Communicate your results with other groups and revise your data or perform more experimentation if necessary.
- In a data table, identify each solid. Be sure to provide evidence from your data to support each claim.

Data Table:

Potential Chemicals for A-F

Zinc	**Calcium carbonate**	**Sucrose**
Ibuprofen	**Magnesium**	**Hexane**
Iron Chloride	**Copper**	**Copper sulfate**

Communication:

- Students will share their data and observations with other groups.
- Students may revise or retest as necessary.

Evaluation:

UNKNOWN	CHEMICAL	EVIDENCE & ARGUMENT *(include bonding type in discussion)*
A		
B		
C		
D		
E		
F		

Analysis:

Each group member should choose ionic, covalent or metallic bonding and draw a particle diagram showing the arrangement of the particles in that type of bonding. Write a paragraph explaining how the arrangement of particles affected at least two properties associated with that type of bonding. Students will then present their model and explanation.

Particle Diagram	Explanation of Properties

Elaboration:

Teacher demo - Observations when the charged object approached the stream of liquid:

Burette 1 containing water:

Burette 2 containing hexane:

What questions would you like to answer based on your observations?

PHET Simulation: Go to the following website. Your teacher will provide you with an activity sheet to explore the simulation. Use this research to answer your questions and develop particle diagrams that model: a) non-polar covalent bonding and b) polar covalent bonding.

https://phet.colorado.edu/en/simulation/molecule-polarity

Bond Type	Particle Diagram	Description
Non-Polar Covalent		
Polar Covalent		

Analysis Questions:

1. What is your understanding of electronegativity? How can it be used to classify bonding?

2. Why are C **-** H bonds considered nonpolar?

3. Which is more polar, an O – H or an N – H bond? **Explain your reasoning.**

4. What electronegativity difference and bonding type is essential for a substance to conduct electricity? Would you expect solid KCl to conduct electricity? Why or why not?

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Sample Data Table

Property	A	B	C	D	E	F
Appearance						
Solubility in water						
Conductivity as a solid						
Conductivity in water						
Melting point range (<100; 100-400 or >400)						
pH or other property						
Bonding type						

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Naming Ionic Compounds: A Guided Inquiry Exercise

Purpose: to name ionic compounds composed of various types of elements.

Introduction: Nomenclature of chemical compounds is one of the more important skills you will learn in General Chemistry. It allows you to work efficiently and safely in the laboratory while reinforcing ideas associated with writing chemical formulas. As such it is a basic form of communication in the chemical sciences, and it is a necessary skill for anyone working in a chemically oriented environment. This exercise will introduce the ideas behind chemical nomenclature by having you examine some chemical names and formulas to identify the nomenclature rules. In effect, you will reverse engineer the rules in a systematic fashion, allowing you to more fully understand why the rules take the form that they do.

Part I: Naming Binary Ionic Compounds Composed of Main Group Elements

This activity focuses on the nomenclature rules for ionic compounds composed of two different elements from groups 1, 2, 13, 14, 15, 16, and 17 on the periodic table of the elements. Collectively these elements comprise the Main Group elements.

Observing the Patterns:

Consider the following group of formulas and their corresponding names. Examine the formulas and names carefully to identify patterns associated with naming these compounds. Use only a periodic table as a reference.

Chemical Formula	Compound Name
KCl	potassium chloride
CaO	calcium oxide
$AlCl_3$	aluminum chloride
Li_3N	lithium nitride
Sr_3P_2	strontium phosphide

The Rules:

Use the patterns you observed to construct a set of rules for the nomenclature of binary ionic compounds composed of main group elements. Be certain that the rules you establish can be used to work from the chemical formula to the written form and vice versa.

Use the rules you have determined above to write the formulas of the binary ionic compounds listed below. Do these exercises without using any outside resources.

1. sodium bromide
2. calcium selenide
3. aluminum oxide
4. cesium arsenide
5. beryllium chloride
6. magnesium sulfide
7. lithium phosphide
8. gallium selenide

Use your rules to write the names of the following binary ionic compounds.

9. Na_2O
10. LiBr
11. Cs_3P
12. Ga_2O_3
13. RbI
14. CaF_2
15. MgO
16. AlN

Part II: Binary Ionic Compounds Containing Variably-Charged Ions

The portion of the nomenclature system introduced in Part I is used to name binary ionic compounds composed of main group elements. However, there are numerous binary ionic compounds that contain transition metals or metals from the lower portion of groups 13-15 of the periodic table. These elements are capable of bearing a variety of different cationic charge states. This activity builds upon the previous experiences of converting observed patterns in both chemical formulas and names into a set of rules that can be used to name all types of binary ionic compounds.

Observing the Patterns

Consider the following group of formulas and their corresponding names. Examine the formulas and names carefully to identify patterns associated with naming compounds.

Use only a periodic table as a reference. Do not use any other outside sources.

Chemical Formula	**Compound Name**
Fe_2O_3	iron (III) oxide
$FeCl_2$	iron (II) chloride
PbO_2	lead (IV) oxide
CuSe	copper (II) selenide
KCl	potassium chloride
SnF_4	tin (IV) fluoride
$NbCl_5$	niobium (V) chloride

The Rules:

Use the patterns you observed to construct a set of rules for the nomenclature of ***all*** binary ionic compounds. Be certain that rules you establish can be used to work from the chemical formula to the written form and vice versa.

Use the rules you have determined above to write the formulas of the binary ionic compounds listed below. Do these exercises without using any outside resources.

1. cobalt (III) chloride
2. platinum (IV) fluoride
3. chromium (III) oxide
4. titanium (II) chloride
5. lithium arsenide
6. Nickel (II) sulfide
7. beryllium nitride
8. Iron (III) iodide

Use the rules you have determined to write the names of the following binary ionic

9. MnF_2
10. PbS_2
11. $ScCl_3$
12. PbS
13. Ni_3P_2
14. Cs_2S
15. MgI_2
16. CuSe

Part III- Ionic Compounds Containing Polyatomic Ions

The chemical nomenclature system was introduced in Part I and further developed in Part II. Both of these activities limited themselves to ionic compounds composed only of two elements, or binary ionic compounds. Part III introduces polyatomic ions, or ions containing two or more atoms covalently bonded and bearing a charge. This activity builds upon the previous experiences of converting observed patterns in chemical formulas and names into a set of rules that can be used to name all types of ionic compounds.

Here is a list of some common polyatomic ions:

NH_4^+	ammonium	SO_4^{2-}	sulfate
OH^-	hydroxide	NO_3^-	nitrate
PO_4^{3-}	phosphate	$C_2H_3O_2^-$	acetate
CN^-	cyanide	CO_3^{2-}	carbonate
HCO_3^-	hydrogen carbonate	ClO_3^-	chlorate

Observing the Patterns:

Consider the following group of formulas and their corresponding names. Examine the formulas and names carefully to identify patterns associated with naming compounds.

Chemical Formula	Compound Name
$(NH_4)_2S$	ammonium sulfide
$CoSO_4$	cobalt (II) sulfate
$Fe(OH)_3$	iron(III) hydroxide
$Ca_3(PO_4)_2$	calcium phosphate
NH_4NO_3	ammonium nitrate

The Rules

Use the patterns you observed in parts I, II, and III to construct a set of rules for the nomenclature of all ionic compounds. Be certain that the rules you establish can be used to work from the chemical formula to the written form and vice versa.

Use your rules to write the formulas of the following binary ionic compounds.

1. iron (III) acetate
2. strontium sulfate
3. copper(I) sulfide
4. potassium cyanide
5. aluminum hydroxide
6. Lead (II) sulfate
7. ammonium nitride
8. magnesium carbonate

Use your rules to write the names of the following binary ionic compounds.

9. $Cu(OH)_2$
10. $Zn_3(PO_4)_2$
11. $NaHCO_3$
12. NH_4F
13. $Sn(C_2H_3O_2)_2$
14. $Pb(NO_3)_2$
15. $FeCO_3$
16. $MgSO_4$

Analysis: Answer in Complete Sentences!

1. Compare the rules you developed with the real rules. What were the differences? Did you include all rules? Did you omit any rules or details? Answer all of these questions for each of the 3 types of ionic compounds.

a. Binary Main Group Elements

b. Binary Variably Charged Ions

c. Polyatomic Ions

2. Review the real rules; go back and check if your names and formulas are correct. Circle 4 names and 4 formulas that you are confident are correct from EACH part.

Part IV: Binary Compounds of the Nonmetals

The previous activities have introduced the nomenclature system and its use in naming ionic compounds. The rules for naming binary compounds composed of nonmetals are explored in this activity, building upon the previous experiences of converting observed patterns in chemical formulas and written forms into a set of rules that can be used to name binary compounds of the nonmetals.

Observing the Patterns:

Consider the following group of formulas and their corresponding names. Examine the formulas and names carefully to identify patterns associated with naming molecules. Use only a periodic table as a reference. Do not use any other outside sources.

Chemical Formula	Compound Name
NF_3	nitrogen trifluoride
NO	nitrogen monoxide
NO_2	nitrogen dioxide
N_2O	dinitrogen monoxide
N_2O_4	dinitrogen tetroxide

Write down the patterns you observe in the both the chemical formula and written form for the compounds above. These patterns will later be used to establish the rules by which these compounds were named.

The Rules

Use the patterns you observed to construct a set of rules for the nomenclature of all binary covalent compounds. Be certain that the rules you establish can be used to work from the chemical formula to the written form and vice versa. Write these rules below.

Use the rules you have determined above to write the formulas of the following molecules.

1. carbon tetrachloride
2. phosphorus triiodide
3. boron trifluoride
4. tetraphosphorus decaoxide
5. dihydrogen monosulfide
6. sulfur dibromide
7. dioxygen difluoride
8. sulfur hexafluoride

Use the rules you have determined to write the names of the following molecules.

9. N_2H_4
10. SBr2
11. XeF_4
12. P_4O_3
13. OF_2
14. BCl_3
15. ClF_3
16. CS_2

Part V- Naming Acids

Consider the following group of formulas and their corresponding names. Examine the formulas and names carefully to identify patterns associated with naming molecules. Use only a periodic table as a reference. Do not use any other outside sources.

Chemical Formula	Compound Name
HNO_3	nitric acid
HNO_2	nitrous acid
HCl	hydrochloric acid
HCN	hydrocyanic acid
HI	hydroiodic acid

Part VI- Checking the Veracity of Your Rules

Compare the rules you developed with the real rules.

1. How well did you predict the correct rules? Describe how your rules were similar and different from the real ones.

2. If you missed any major rules, what did you miss in your observations of the names and/or formulas in this exercise?

3. Are you confident that you can name ionic and molecular compounds given the formula, or of predicting the formula of a compound if given the name? Why do you feel this way?

Assessment

Develop a flowchart for naming ALL TYPES of compound based on the naming rules you discovered.

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