THINKING AND ACTING LIKE A SCIENTIST

TEACHER'S GUIDE

Predicting Chemical Products & Bond Types

What Periodic Table trends predict the products and bond types in simple chemical reactions?

GRADES 9–12

Physical Science

VAN ANDEL EDUCATION INSTITUTE
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INQUIRY-BASED SCIENCE

Physical

Predicting Chemical Products & Bond Types

Grade Level/ Content	9–12/Physical Science
Lesson Summary	In this lesson, students draw Lewis Structures for atoms with atomic numbers 1–18 to predict the products that result from simple chemical reactions. Students then write balanced chemical reactions for these simple reactions based on their observations. Once balanced, students calculate electronegativity values for bonds, and determine the bond types present in each reactant.
Estimated Time	2, 45-minute class periods
Materials	3x3 Post-it® Notes or similar sized notecards, Internet, Investigation Plan, journal
Secondary Resources	Khan Academy: Dot Structures I – Single Bonds Khan Academy: Dot Structures II – Multiple Bonds Chemical Bonding Electronegativity Values
NGSS Connection	**HS-PS1-2** Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the Periodic Table and knowledge of the patterns of chemical properties.
Learning Objectives	• Students will utilize Lewis Structures to model the valence electrons of elements with atomic numbers 1–18. • Students will combine Lewis Structures to identify the ratios of atoms that combine to form simple molecules. • Students will develop an explanation to describe how the number of valence electrons for reactants helps determine the composition of products in a balanced chemical reaction. • Students will revise their explanation to include bond types found in their chemical products based on electronegativity values.

What Periodic Table trends predict the products and bond types in simple chemical reactions?

The Periodic Table is critically important to the work of science. One of the joys of understanding the Periodic Table's capacity to help us understand the chemical properties of elements comes from unlocking the trends communicated by the placement of elements in its rows and columns.

In this lesson, students use Lewis Structures for atoms with atomic numbers 1–18 to predict the products that could result from simple chemical reactions. After balancing these simple reactions, students calculate electronegativity values to determine the bond types present in each of their reactants.

Investigation is based on the Van Andel Education Institute (VAEI) Instructional Model for Inquiry-Based Science. In all investigations:

Students don't know the "answer" they are supposed to get.

Students play a driving role in determining the process for learning.

Teachers and students construct meaning together by journaling.

Students are working as hard as the teacher.

Part 1

INVESTIGATION SETUP

Collect the materials necessary for each student group to perform the investigation.

- 3x3 Post-it® Notes or similar sized notecards
- Internet
- Investigation Plan
- Journal

Part 2

INVESTIGATION FACILITATION

Question

Introduce the investigation question.

What Periodic Table trends predict the products and bond types in simple chemical reactions?

Personal Knowledge

Students capture what they already know about chemical reactions, reactants, products, and chemical bonds.

- Have students identify key components of the investigation question.
- Ask them to write 3-5 ideas in their journal before sharing them with their table partners. Once they have shared with their table partners, ask students to also record new ideas in their journal.
- Encourage students to review their list and circle ideas and concepts that they are not sure about.

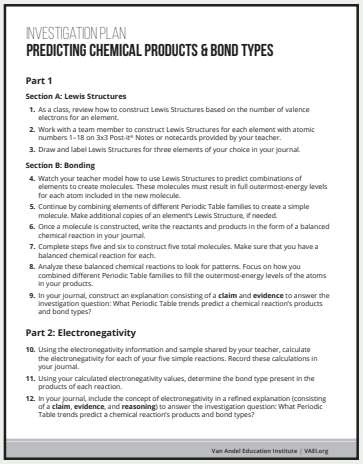
DISCOURSE

Consider having students participate in a *Take 10 Steps* activity to promote discourse and collaboration. Give students two minutes to consider the investigation question. Then have them walk 10 steps in any direction. They will share their list with the person closest to them. Once each person shares, they will continue this process until time is up. Have students include new ideas shared by peers to their list in the journal.

Investigation Plan

Students conduct an investigation using periodic trends to predict the products and bond types of chemical reactions.

- Have students work in teams of two.
- Have students follow the Investigation Plan.
- Review the big idea for Part 1, sections A and B. Set times for groups to complete each section so students know when you intend to provide additional **Secondary Knowledge** called for in the **Investigation Plan**.



INVESTIGATION PLAN

PREDICTING CHEMICAL PRODUCTS & BOND TYPES

Part 1

Section A: Lewis Structures

1. As a class, review how to construct Lewis Structures based on the number of valence electrons for an element.
2. Work with a team member to construct Lewis Structures for each element with atomic numbers 1–18 on 3x3 Post-it® Notes or notecards provided by your teacher.
3. Draw and label Lewis Structures for three elements of your choice in your journal.

Section B: Bonding

4. Watch your teacher model how to use Lewis Structures to predict combinations of elements to create molecules. These molecules must result in full outermost-energy levels for each atom included in the new molecule.
5. Continue by combining elements of different Periodic Table families to create a simple molecule. Make additional copies of an element's Lewis Structure, if needed.
6. Once a molecule is constructed, write the reactants and products in the form of a balanced chemical reaction in your journal.
7. Complete steps five and six to construct five total molecules. Make sure that you have a balanced chemical reaction for each.
8. Analyze these balanced chemical reactions to look for patterns. Focus on how you combined different Periodic Table families to fill the outermost-energy levels of the atoms in your products.
9. In your journal, construct an explanation consisting of a **claim** and **evidence** to answer the investigation question: What Periodic Table trends predict a chemical reaction's products and bond types?

Part 2: Electronegativity

10. Using the electronegativity information and sample shared by your teacher, calculate the electronegativity for each of your five simple reactions. Record these calculations in your journal.
11. Using your calculated electronegativity values, determine the bond type present in the products of each reaction.
12. In your journal, include the concept of electronegativity in a refined explanation (consisting of a **claim**, **evidence**, and **reasoning**) to answer the investigation question: What Periodic Table trends predict a chemical reaction's products and bond types?

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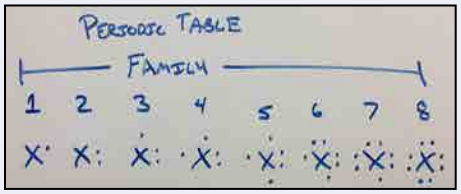
Investigation Plan

Secondary Knowledge

Provide students with background information for Parts A and B of the Investigation Plan.

Investigation Plan, Part 1 – Section A: Lewis Structures

- Provide an overview of how to construct Lewis Structures for atoms based on the number of valence electrons. Highlight the connection between the Periodic Table family and the number of valence electrons as a pattern within the Periodic Table.
- Students will complete Lewis Structures for elements with atomic numbers 1-18 on their Post-It® Notes or notecards.
- Students should understand that all elements follow this convention for Lewis Structures across the eight families.



Lewis Structures Convention

Investigation Plan, Part 1 – Section B: Bonding

- Complete Lewis Structures for Hydrogen and Oxygen. Combine the two to highlight the opportunity to add one more Hydrogen to form a water molecule.
- Continue with this example by representing the chemical reaction between Hydrogen and Oxygen combining to form water (H_2O). Ask students to count the number of H and O atoms to add as coefficients on the reactant (left-hand) side of the equation.
- From here, make the connection between the number of H and O atoms included in one molecule of water on the reactant (right-hand) side of the equation.
- Encourage students to make other simple molecules that result in full outermost-energy levels for each atom. *Resist the urge to identify molecules as not likely or not even possible. Instead ask them to focus on simple combinations that result in complete outermost-energy levels. You can play out this concept later when discussing the amount of energy it requires for reactions to take place. Simple in this case equates to lower levels of requisite energy to complete the reaction.*
- Share these resources (or ones you prefer) to provide additional guidance on how Lewis Structures are used to model chemical bonding.

  Khan Academy: Dot Structures I – Single Bonds

  Khan Academy: Dot Structures II – Multiple Bonds

  Chemical Bonding
- Have students create five simple molecules using their Lewis Structure combinations.

Observation

Students record balanced reactions for their simple reactions.

- Have students write balanced chemical reactions for their five simple reactions. Including a balanced number of reactants and products based on their use of Lewis Structures and resulting bonds is the key concept to focus on at this point.

Part 3

INVESTIGATION ANALYSIS AND DEVELOPMENT OF CLAIMS

Data Analysis

Students make sense of their data by organizing it and representing it visually.

- Have students analyze their data from Part 1, sections A & B, to find patterns and trends by focusing on the combinations of family groups to form simple molecules. They may **organize** their data and/or **represent** it visually to construct meaning.
- Have students **interpret** what their identified patterns or trends mean as they view the Periodic Table.
- Ensure they have enough data that it can be used as evidence to support a claim.

CRITICAL THINKING

Have students dig deeper into their sample molecules by trading out other molecules within the same Periodic Table family. Lewis Structures can help students quickly determine if this would play out correctly. Remind students that these ideas should be included in their reasoning when developing their explanation.

Explanation

Students write an explanation in the form of a claim and evidence to answer the investigation question.

- Have students use what they've learned to write a claim and evidence that answers their investigation question. Have them record their claim and evidence in their journal.
- Have students develop a **Claim** to answer the question: What Periodic Table trends predict the products and bond types in simple chemical reactions?
- Then, have them add **Evidence** (the analyzed data) to support their claim.

Claim

The Periodic Table family number represents the number of electrons in the outermost-energy level that are available to share with other atoms to form molecules.

Evidence

Atoms in Family 1 have one electron to share with other atoms. These atoms form simple molecules with Family 7 in a 1:1 ratio that results in a full outermost-energy level for each atom. Atoms in Family 1 combine in a 2:1 ratio with atoms in Family 6 because Family 6 atoms have room for two more electrons (with room for one electron from each of the two Family 1 atoms) in their outermost-energy level.

Secondary Knowledge

Provide students with background information related to Part 2 of the Investigation Plan.

Investigation Plan, Part 2

- Ask students to return to Part 2 of their **Investigation Plan** so you can introduce **electronegativity** as a physical characteristic of each element.

Continued

- Electronegativity is defined as the tendency of an atom to attract the electrons of another atom to form a chemical bond. Atoms with high electronegativity strongly attract the valence electrons of other atoms. Atoms with low electronegativity have a weaker attraction, so they are more likely to have their valence electrons pulled away.
- Share electronegativity values with your students and demonstrate how to calculate electronegativity values for bonds found in simple molecules. Refer to or display reference tables or charts for students, such as the one available online from the Science Notes website (Electronegativity Values). *Refrain from highlighting the trend in electronegativity shown by the colors in this chart in the hope that students pick up on this during the course of analyzing this information to include in their revised explanation.* If necessary, ask questions to facilitate a student discussion about Periodic Table trends in electronegativity.
- Continue with the use of water as an example as shown here:

  $\Delta EN = |EN_H - EN_O|$
  $\Delta EN = |2.1 - 3.5|$
  $\Delta EN = |-1.4|$
  Electronegativity = 1.4

- Once calculated, share ranges of electronegativity values for each of the three bond types to identify the two O-H bonds in water as polar covalent.

Electronegativity Difference*	Bond Type
0.0–0.5	nonpolar covalent
0.5–1.6	polar covalent
1.6–3.3	Ionic

*Textbook values differ in the ranges associated with each bond type. Adjust based on your preferred student resource.

Observation

Students calculate electronegativity values for the bonds in the products of their balanced reactions.

- Have students continue with Part 2 of the **Investigation Plan** to calculate the electronegativity of each bond. Once calculated, students should classify the bond types found in each of their five products in their journal.

Explanation

Students revise their previous explanation and include reasoning from Parts 1 and 2 of the Investigation Plan to answer the investigation question.

- Have students use what they've researched to write an explanation that answers their investigation question.
- Students may wish to use the Explanation prompt as a guide. Have them write their explanation in their journal.
- Have students revise their **Claim** to answer the question: What Periodic Table trends predict the products and bond types in simple chemical reactions?
- Then, have them add additional **Evidence** (the analyzed data) to support their revised claim.
- Finally, have them provide additional **Reasoning** for their claim. Reasoning should include the information obtained from both parts of this investigation, as well as science principles they have learned.

Continued

Claim

The Periodic Table family number represents the number of electrons in the outermost-energy level that are available to share with other atoms in order to form molecules. The position of the element on the Periodic Table also provides a sense of how tightly these valance electrons are held by the atom. This allows us to predict the type of bond found between atoms.

Evidence

Atoms in Family 1 have one electron to share with other atoms. These atoms form simple molecules with Family 7 in a 1:1 ratio that results in a full outermost-energy level for each atom. Atoms in Family 1 combine in a 2:1 ratio with atoms in Family 6 because these atoms have room for two more electrons (with room for one electron from each of the two Family 1 atoms) in their outermost-energy level. Electronegativity values for elements are lower for elements found on the lower left of the Periodic Table as compared to the higher electronegativity values found in the upper right of the Periodic Table.

Reasoning

Investigation: We followed the investigation plan carefully and confirmed our results with peers that chose the same reactions. Each of our reactions were balanced with an equal number of atoms for each element type in the reactants and products. We also calculated electronegativity values for each bond and assigned an ionic, polar covalent, or non-polar covalent bond type for each.

Science: From our class discussions and readings, we learned that electrons are shared by atoms to allow each atom to complete its outermost-energy level. The number of electrons available for sharing to form chemical bonds is indicated by the valence electrons which correspond to the family number in the Periodic Table. The degree to which these electrons are shared is calculated using electronegativity values for each atom in a bond. The calculated electronegativity value helps identify the bond type found in molecules.

- Once the explanation is written, have students discuss their results using a Present and Defend.

DISCOURSE

Select two groups to conduct a Present and Defend. This helps develop presentation and audience participation skills. Research teams present a summary of their investigation to the class. The class analyzes the information presented and asks clarifying questions, challenges and/or supports the arguments made, and even presents alternative explanations as appropriate. Research teams defend their explanation with evidence and reasoning.

Evaluation

Students reflect on the investigation.

Have students discuss:

- What surprised them?
- What question would they like to investigate next?

Part 4

INVESTIGATION ASSESSMENT AND EXTENSION

Application

Students continue their exploration of Periodic Table trends by exploring related concepts and applying their understanding to different reactions.

- Discuss the following questions:
  - Based on the sharing of valence electrons, how would you define ionic, polar covalent, and nonpolar covalent chemical bonds?
  - What additional Periodic Table trends help predict the products of chemical reactions?
- Pick three single replacement reactions for students to predict the products. Possible reactions include:

  $Ca + H_2O \rightarrow Ca(OH)_2 + H_2$

  $Zn + HCl \rightarrow ZnCl_2 + H_2$

  $Cl_2 + NaBr \rightarrow NaCl + Br_2$

  $Br_2 + KI \rightarrow KBr + I_2$

  Use this as a starting point to describe more complex single and double replacement reactions as well as activity series for cations and anions.

Assessment

Determine how well students:

- utilize Lewis Structures to model the valence electrons of elements with atomic numbers 1–18.
- combine Lewis Structures to identify the ratios of atoms that combine to form simple molecules.
- develop an explanation (**claim** and **evidence**) to describe how the number of valence electrons for reactants helps determine the composition of products in a balanced chemical reaction.
- revise an explanation (**claim**, **evidence**, and **reasoning**) to include the bond type found in chemical products based on electronegativity values.

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