Introduction to VSEPR Theory and Molecular Geometry

Subject Area(s): **Chemistry Honors**

Associated Unit: **Hillsborough County School District, Chemistry Honors Unit 5: Bonding**

Lesson Title: **VSEPR Theory and Molecular Geometry Virtual Lab**

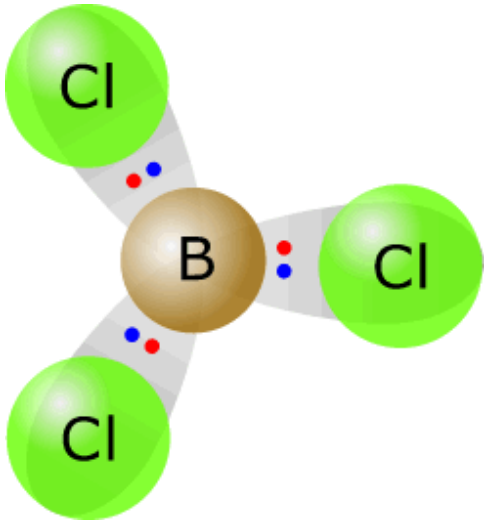


Figure 1

ADA Description: Boron Trichloride Molecule

Source: Image courtesy of *alevelchem.com*

Caption: Molecular Geometry of Boron Trichloride (BCl_3). Atom color: Chlorine = green and Boron = gold

Grade Level **10th to 12th grade**

Time Required: **100 minutes (Typically two class periods)**

Summary:

This lesson will require two class periods. On day one, students will watch an introduction video for VSEPR Theory as well as a tutorial video that will enable them to effectively use the computer software called *"Avogadro"*. During this part of the lesson, students will learn the basics of how to effectively use this molecule editor, such as building molecules, how to determine bond angle, optimization, etc. Students will observe several examples, as well complete different practice exercises. On day two, students will conduct the VSEPR Theory & Molecular Geometry Virtual Lab (see attachments), that will help them explore and understand the relationship between the central atom in a molecule and its bonded terminal atoms, as well as how these determine the molecular geometry of different substances.

Engineering Connection:

In this virtual lab students will be using molecular modeling software called Avogadro. It is user's friendly and students will be able to add new atoms, manipulate molecules, rotate, zoom in or out, and move the view, just by using the computer's mouse.

Engineering Category:

1) Relating science and/or math concept(s) to engineering.

2) Engineering design process.

Keywords:

Atoms, electrons, lone pairs, bond angles, terminal atoms, central atom, molecular geometry, VSEPR theory, computer simulation, computer software, valence electrons

Educational Standards

Florida Science Next Generation Sunshine State Standard(s):

SC.912.P.8.7: Interpret formula representation of molecules and compounds in terms of composition and structure.

SC.912.N.1.7: Recognize the role of creativity in constructing scientific questions, methods and explanations

ITEEA Educational Standard(s):

Standard 12 (Grades 9-12) Benchmark P: Use computers and calculators to access, retrieve, organized, process, maintain, interpret, and evaluate data and information in order to communicate.

Pre-Requisite Knowledge

Before this lesson students should be able to know:

1. *Chemical nomenclature* (naming & writing chemical names and/or formulas).
2. What are *valence electrons* and how to determine them for a given atom?
3. *Count individual atoms* in a given chemical formula.
4. Must be able to correctly draw *Lewis Structures* for a given molecule.
5. Determine the *electronegativity* of different atoms.
6. Difference between *covalent and ionic compounds*.

Learning Objectives:

After this lesson, students should be able to: ***1)*** use VSEPR theory to correctly describe the specific molecular geometry for a given chemical formula such as linear, tetrahedral, trigonal planar, trigonal pyramidal, and bent; ***2)*** determine the amount of lone and bond pairs of electrons in a molecule, in relationship to the central atom; ***3)*** correctly identify the bond angle for the different molecular shapes; and ***4)*** understand how electrons affects the shape of a molecule; by completing the VSEPR Theory Virtual Lab and accomplish 70% or higher in the VSEPR Theory Quiz (see attachments for quiz).

Introduction / Motivation (5E – Engage)

Computer simulations, as well as virtual labs, are becoming more popular among our new generation of students. When educators choose to use this approach, the likelihood of student's engagement and participation in the classroom increases positively. In this lesson we integrate technology to a very abstract chemistry topic. Students will watch the video "VSEPR Theory"

(https://www.youtube.com/watch?v=keHS-CASZfc). In this video they will start getting familiarized with the different types of molecular shapes, the bond angle for each of them as well as how the bonds between the central atoms and its terminal atoms determine the geometry of the molecule. After the video the teacher should briefly explain to the students that for the next couple of classes they will be learning: 1) how to use computer software to build molecules, 2) how to use the optimization option to have a more realistic shape, and 3) how to use their build molecule to determine bond angle and the geometry.

Lesson Background & Concepts for Teachers (5E – Explain)

Before the lesson the teacher needs to make sure that the students are familiar and understands:

- ✓ How to write the name and the chemical formula of ionic as well as covalent compounds.
- ✓ Correctly identify the number of valence electrons for any given atom.
- ✓ How to determine the amount of individual atoms in a chemical formula (i.e. CH_4: C=1 & H=4).
- ✓ How to correctly draw the Lewis Structure for different molecules.

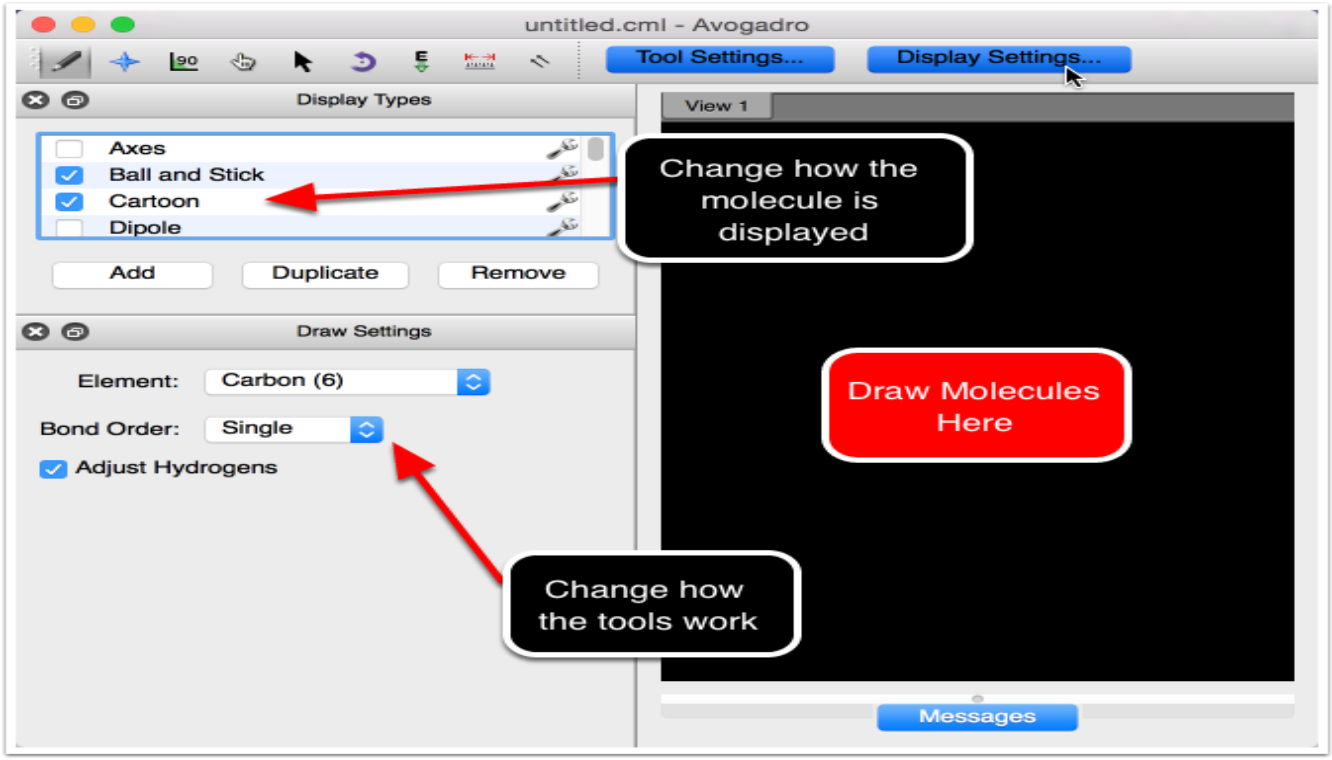


Figure 2

ADA Description: Screen shot of Avogadro's opening page.

Source: https://manual.avogadro.cc/content/getting-started/introduction.html

Caption: When you initially open Avogadro you will be presented with a screen such as the one shown in figure 2.

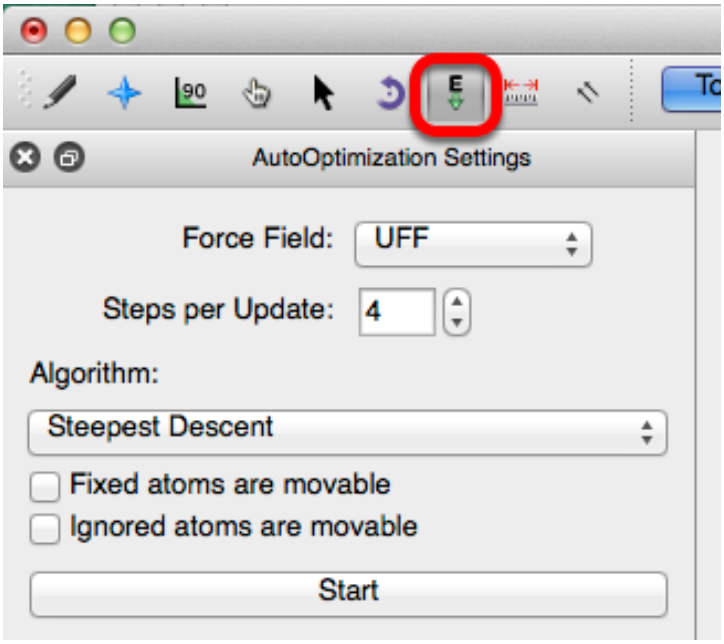


Figure 3

ADA Description: Screen shot of Avogadro's Auto Optimization Setting.

Source: https://manual.avogadro.cc/content/getting-started/introduction.html

Caption: The Auto Optimization tool provides an interactive interface, allowing you to manipulate a molecule while its molecular geometry is being optimized.

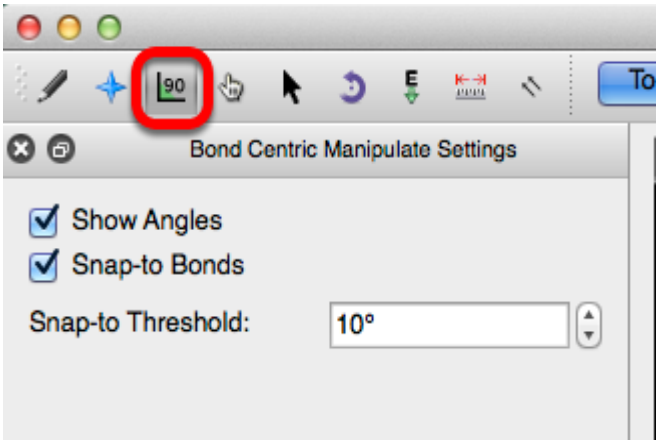
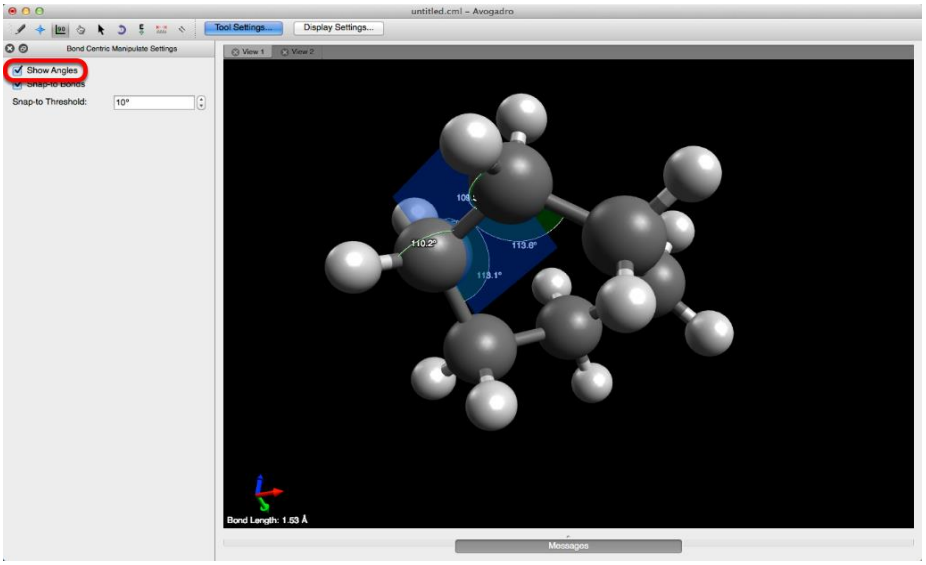


Figure 4 & 5

ADA Description: Screen shot of Avogadro's Bond Centric Manipulate Settings.

Source: https://manual.avogadro.cc/content/getting-started/introduction.html

Caption: The Bond-Centric Manipulate tool alters angles, bonds, and torsions of a molecule.



Vocabulary / Definitions

Word	Definition
VSEPR Theory (**V**alence **S**hell **E**lectron **P**air **R**epulsion Theory)	Theory that proposes that the geometric arrangement of terminal atoms, or groups of atoms about a central atom in a covalent compound, or charged ion, is determined solely by the repulsions between electron pairs present in the valence shell of the central atom. (intro.chem.okstate.edu/1314F97/Chapter9/VSEPR.html)
Molecular Geometry	The arrangement of atoms (not lone pair of electrons) around a central atom of a molecule or polyatomic ion. (Chemistry-Dictionary.com)
Avogadro Molecule Editor	An advanced molecule editor and visualizer designed for cross-platform use in computational chemistry, molecular modeling, bioinformatics, materials science, and related areas. It offers flexible high quality rendering and powerful plugin architecture. (http://avogadro.cc/)

Associated Activities (5E – Explore)

Day 1: The teacher will show the video "VSEPR Theory" as an introduction to the topic. After this video, the teacher will have a brief class discussion to brainstorm what they will be learning this section of the Bonding Unit. Then, students will watch a video tutorial to learn how to use "Avogadro". Students will have the opportunity to explore this computer software. They will learn some of the most important features of the program such as how to build molecules, use the optimization option, determine the bond angle in a molecule, etc.

Day 2: Students will explore "Avogadro" more in deep by completing a Virtual Lab. They will complete the steps on their lab handout from building the molecule on the computer to drawing a 2-D image of them and determine their molecular shape.

Lesson Closure

At the end of the class period, students must have built all assigned molecules and have filled out the information on their Lab Handout. Any incomplete sections must be done for homework.

Students will complete the slip *"What about today's teaching"*(see attachments), where they will have the opportunity to tell the teacher more about the learning experience that they had with this lesson and how this type of approach can contribute to their academic success.

Assessment (5E – Evaluate)

Pre-Lesson Assessment
Descriptive Title: ___ Class discussion after introduction video.

Post-Introduction Assessment
Descriptive Title: ___ Exit Slip: *What about today's teaching*, Post-Virtual Lab Discussion and VSEPR Theory Quiz

Lesson Summary Assessment
Descriptive Title: ___ Lab Report

Homework
Descriptive Title: ___ Lab Questions must be complete it for homework as well as study for the VSEPR Theory Quiz (this quiz will be administered after the post-lab discussion).

Lesson Extension Activities (5E-Extension)

The teacher may choose to demonstrate to the students how to use "Avogadro" to build molecules with double and triple bonds.

Additional Multimedia Support

1. Avogadro: Molecular Editor and Visualization https://www.gitbook.com/book/ghutchis/avogadro/details

References

1. intro.chem.okstate.edu/1314F97/Chapter9/VSEPR.html
2. Chemistry-Dictionary.com
3. http://avogadro.cc/
4. Avogadro v1.1 Basics of modeling & Optimization Video (https://www.youtube.com/watch?v=fDk3T9aD4bU)
5. Figure 2 courtesy of DiggFreeware.com
6. VSEPR Theory Video: https://www.youtube.com/watch?v=keHS-CASZfc
7. The VSEPR Theory Quiz was modified from an assessment made by Mrs. Roschell Thybulle, HCPS Chemistry Teacher at Steinbrenner High School and former Science Department Head at Freedom H.S.

Attachments:

1. Video: Avogadro v1.1 Basics of modeling & Optimization https://www.youtube.com/watchv=fDk3T9aD4bU
2. Lab Handout: "VSEPR Theory and Molecular Geometry Virtual Lab."
3. Exit Slip: "*What about today's teaching?"*
3. Quiz: "VSEPR Theory Quiz"

Contributors

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ATTACHMENTS

VSEPR Theory & Molecular Geometry Virtual Lab

Directions:

1. Open the software "Avogadro" in your computer/iPad.
2. Build each of the given molecules. After you are done, use the "Auto Optimization" option to "fix" your molecule. Take a picture of each molecule and send it to your teacher by email or Edsby. You can also print them and turn them in with your Lab Report.
3. Fill in the blanks in the following chart. Be neat and write legible. Remember that if you don't complete the chart by the end of the class period, you must do so for homework. Due _____.

Chemical Formula	Name	e^- Count	Lewis Structure	# of Bonding Atoms	# of e^- Lone Pairs	Bond Angle	Name of Molecular Geometry	Molecule's 2-D Drawing
CO_2								
	Boron Trichloride							
PH_3								
H_2O								
	Carbon Tetrachloride							

VSEPR Theory Quiz

Directions: For each of the following molecules, count up the electrons and draw the Lewis Diagram. Next, identify the correct the molecular shape and bond angle.

MOLECULE	e^- Count	LEWIS DIAGRAM	SHAPE/POLAR OR NON-POLAR	BOND ANGLE
1. NH_3			_____ _____	_____
2. SO_4^{-2}			_____ _____	_____
3. CO			_____ _____	_____

4. For what does **VSEPR** stand for? _____

5. What creates the bond angles within a molecule? Explain.

6. a. What type of bond unequally shares electrons? _____

   b. What type of bond equally shares electrons? _____

Exit Slip

Name: _____

Date: _____

Lesson: VSEPR Theory and Molecular Geometry Virtual Lab.

What about today's teaching?

3-Things that you have learned today in class.

2-Things that surprised/engaged you in today's lesson.

1-Question that you still having about today's class or what would you change about today's class.