VSEPR Model

Representations Series

Instructor's Guide

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Developed by the Teaching and Learning Laboratory at MIT
for the Singapore University of Technology and Design

Introduction

When to Use this Video

- In Chem 101, at home or in recitation, after Lecture #15: Lewis structures
- Prior knowledge: experience drawing Lewis structures

Key Information

Duration: 12:12
Narrator: Prof. Cathy Drennan
Materials Needed:
• Molecular Modeling Kit
• Paper
• Pen/pencil

Learning Objectives

After watching this video students will be able to:

- Use the VSEPR model to predict 3D molecular structures from 2D Lewis structures.
- Discuss some of the assumptions and limitations of the VSEPR model.

Motivation

- At a general level, 3D representations are important in engineering and design. The more opportunities students have to practice representing and visualizing in 3D, the better.
- While an experienced chemist may be able to examine a 2D representation of a molecule and mentally translate it to 3D, beginning students are not able to do this as fluidly.
- Students are tempted to memorize VSEPR geometries and bond angles instead of thinking about three-dimensional space. This video emphasizes the use of polyhedra as a tool for imagining the placement of bonded atoms and lone pairs around the central atom. This mental aid keeps students focused on a key assumption of the VSEPR model - that regions of high electron density are spaced as far apart from one another as possible.

Student Experience

It is highly recommended that the video is paused when prompted so that students are able to attempt the activities on their own and then check their solutions against the video.

During the video, students:

- Apply the VSEPR model to predict the three-dimensional shape of molecules.
- Construct molecules having the following geometries: linear, trigonal planar, bent, tetrahedral, trigonal pyramidal, octahedral, and square pyramidal.
- Check their solutions against the video.
- Recognize the primary assumptions and limitations of the VSEPR model.

Video Highlights

This table outlines a collection of activities and important ideas from the video.

Time	Feature	Comments
1:25	VSEPR Model assumptions	The primary assumptions of the VSEPR model are quickly reviewed.
1:55	Linear example: N_2O	
2:45	Trigonal planar example: SO_3	
3:46	Bent example: SO_2	This is the first molecule that students have to construct on their own AND the first example presenting a lone pair on the central atom. Many students will incorrectly predict that the structure of SO_2 is linear because they will ignore or forget to account for the lone pair.
5:18	Tetrahedral example: CH_3Cl	This is the first non-planar molecule that the video asks students to construct. Some students will be tempted to construct a planar molecule only to realize that this does not maximize the distance of the bonding atoms from each other.
6:48	Trigonal pyramid example: NF_3	
8:09	Octahedral example: SF_6	
9:17	Square pyramid: BF_5	

Video Summary

In this video, MIT chemistry professor Cathy Drennan briefly reviews the simplifications and assumptions of the VSEPR model. She walks students through a series of examples to help students translate 2D Lewis structures into 3D molecular geometries using the VSEPR model. Opportunities for pausing the video are provided so that students may construct 3D molecular models alongside the video.

Chem 101 Materials

When appropriate, this guide is accompanied by additional materials to aid in the delivery of some of the following activities and discussions.

Pre-Video Materials

Students should be able to draw Lewis structures before watching this video. The following pre-video activity could be used to reinforce this skill.

1. Draw Lewis structures for the following molecules:

(a) nitrate ion (NO_3^-)

(b) thionyl fluoride (SOF_2)

(c) sulfur dichloride (SCl_2)

(d) hexafluoroantimony anion (SbF_6^-)

(e) iodine pentafluoride (IF_5)

2. Prior to viewing the video, ask students the following questions. Encourage students to discuss the questions with one or two students sitting beside them. Then, ask groups to share their ideas with the whole class.

(a) What information can a Lewis structure give us about a molecule?

(b) What additional information can we get about a molecule by thinking about it in three-dimensions?

3. The VSEPR video motivates the need to think about molecules in three dimensions by using a real-world example of a vitamin binding to a protein. You may also choose to show students the supplemental video clip, "Cancer Therapeutics.m4v", which discusses why knowing the 3D structure of an enzyme that is crucial to the replication of tumor cells can aid in the design of drugs that can inhibit its activity.

Post-Video Materials

Use the following activities to reinforce and extend the concepts in the video.

1. Practice with other VSEPR geometries (Appendix A1-A3)

To give students practice with other VSEPR geometries, project or draw the following Lewis structures on the board. Slides for the following molecules are available. Have students work in groups of two or three to construct the following molecules with a molecule kit:

(a) trimethylamine ($N(CH_3)_3$)

(b) phosphorous pentachloride (PCl_5)

(c) xenon dioxide difluoride (XeO_2F_2)

Use the following questions to promote discussion after watching the video. Encourage students to discuss the questions with one or two students sitting beside them. Then, ask groups to share their ideas with the whole class.

2. Although VSEPR theory predicts that CH_3Cl (chloromethane) will have a tetrahedral structure with bond angles equal to 109.5 degrees, in reality, all of the bond angles are not equivalent in this molecule. Why do you think this is?

Students may find it helpful to construct this molecule with a molecule kit while they are thinking through the problem.

3. What are some of the advantages and disadvantages of the VSEPR model?

4. Which of the following statements about the polarity of XeF_2 is correct?

(a) XeF_2 is non-polar because of the difference in electronegativity between Xe and F.

(b) XeF_2 is polar because of the difference in electronegativity between Xe and F.

(c) XeF_2 is polar because there are lone pairs of electrons on the central atom.

(d) XeF_2 is non-polar because of the shape of the molecule.

(e) XeF_2 is polar because of the shape of the molecule.

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Additional Resources

Going Further

Encourage students to use the Chemical Education Digital Library Models 360 website (http://www.chemeddl.org/resources/models360/models.php) to view molecules that they have constructed using their molecule kits and the VSEPR model. Are the bond angles predicted by the VSEPR model in agreement with those listed on the website? If not, why? Students can click on the "Molecular Properties" tab to learn about the calculations that were used to predict the molecular structure.

References

The Chemical Education Digital Library Models 360 website can be used to view molecules in three-dimensions. These structures are computed using more complicated quantum-based models.

- The Chemical Education Digital Library Models 360 website http://www.chemeddl.org/resources/models360/models.php

The following MIT Open CourseWare lectures cover the topics of Lewis structures and the VSEPR model.

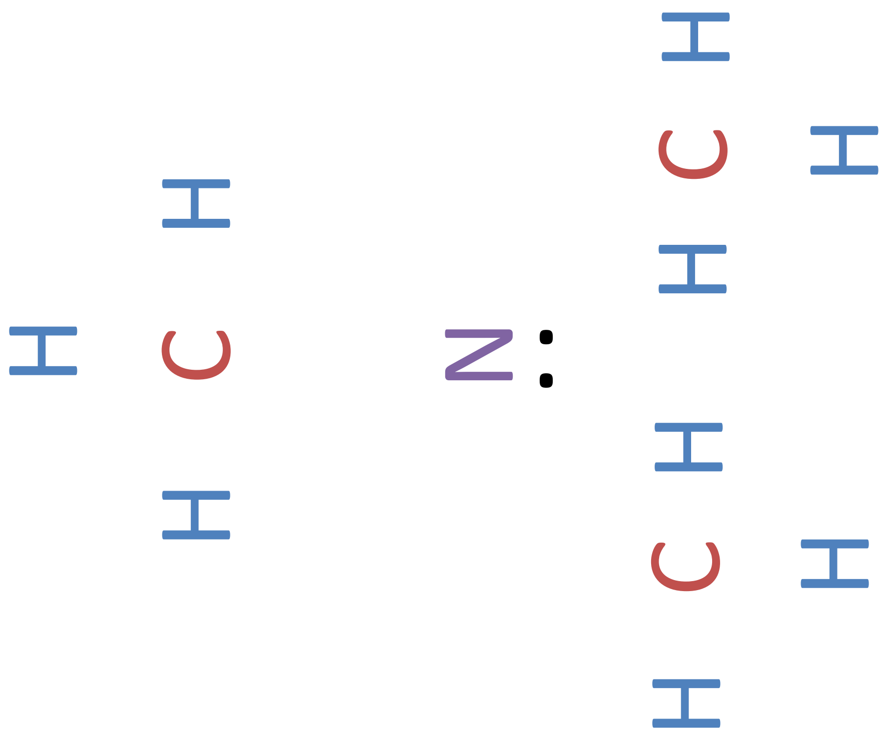
- Drennan, Catherine, and Elizabeth Vogel Taylor. *5.111 Principles of Chemical Science, Fall 2008*. (Massachusetts Institute of Technology: MIT OpenCourseWare), http://ocw.mit.edu (Accessed 22 Dec, 2011). License: Creative Commons BY-NC-SA

  –Video Lectures 10 & 11 are good resources on how to draw Lewis structures.
  –Video Lecture 13 is a good resource on the VSEPR model.

The following papers and journal articles may also be of use when researching student difficulties and best practices in teaching the VSEPR Model.

- Cooper, M., Grove, N., Underwood, S., & Klymkowsky, M. (2010). Lost in Lewis Structures: An Investigation of Student Difficulties in Developing Representational Competence. *Journal of Chemical Education. 87*(8), 869-874.
- McKenna, A., McKenna, J. (1984). Teaching VSEPR Theory. *Journal of Chemical Education. 61*(9), 771-773.

Trimethylamine



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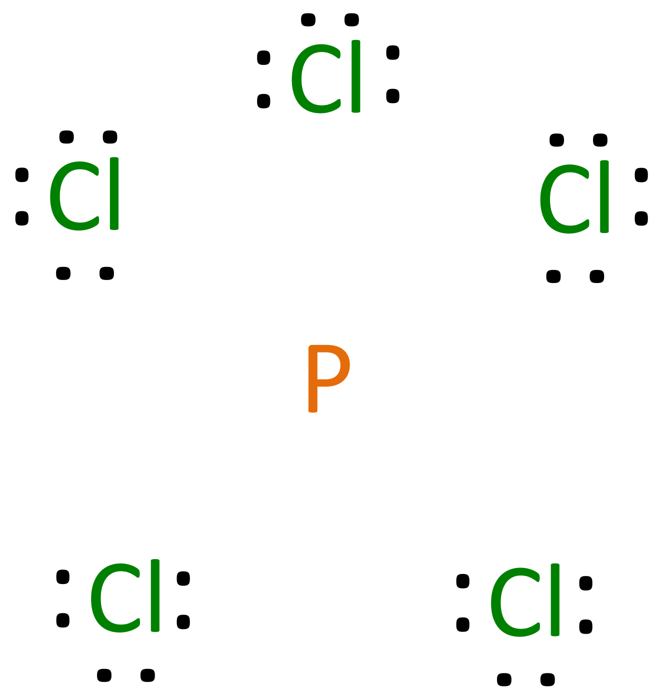
Phosphorous pentachloride



Xenon dioxide difluoride