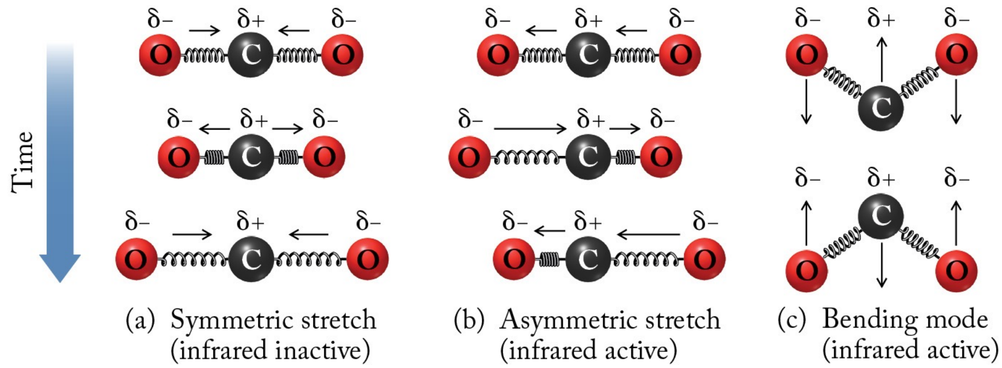
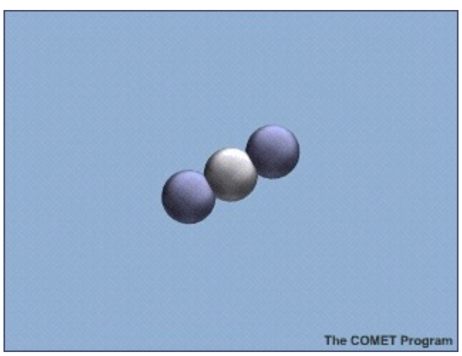
Vibrating Bonds and the Greenhouse Effect

Covalent bonds are not rigid—they vibrate, stretch, and bend.

- As bonds vibrate, the vibrational frequencies of their electric fields match those of infrared radiation.



Vibrating Bonds and the Greenhouse Effect



This symmetric bend in CO_2 is activated by light of wavelength 4.26 µm. [We could find the energy of a photon of this light!]

Why does IR radiation cause bonds to vibrate but not to break?

https://scied.ucar.edu/learning-zone/how-climate-works/carbon-dioxide-absorbs-and-re-emits-infrared-radiation

Water vapor in the atmosphere contributes more to the greenhouse effect than carbon dioxide, yet water vapor is not considered an important factor in global warming. Why might this be?

3

Learning Objectives: VSEPR Theory

- Determine the number of electron domains in a molecule
- Describe molecular shape based on electron domains (through four electron domains or S.N.=4)
- Draw 3D structures of molecules using wedge & dash notation
- Predict molecular geometries and bond angles using the VSEPR theory

4

What is the approximate bond angle in O_3?

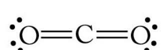
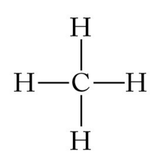
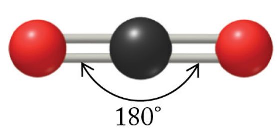
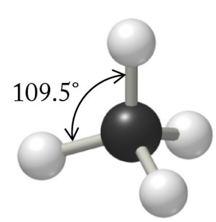
A. 180°
B. 120°
C. 109.5°
D. 107°
E. 104.5°

Think & Solve: 1 min; on your own
Discussion: 30 sec; share and compare
Answer: iClicker, when prompted

5

5

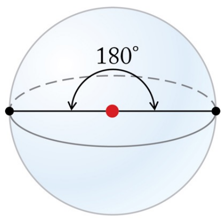
How do chemists describe the three-dimensional shape of molecules?

Compound:	Carbon dioxide	Methane
Molecular formula:	CO_2	CH_4
Lewis structure:		
Ball-and-stick model and bond angles:		

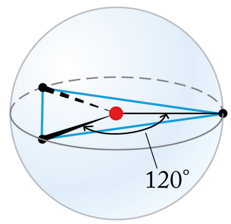
6

What Determines the Shape of a Molecule?

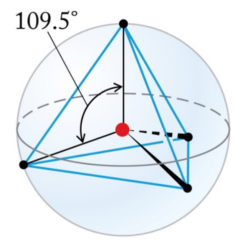
VSEPR: A model that predicts the arrangement of valence electron pairs around a central atom that minimizes their mutual repulsion to produce the lowest energy orientations



Linear



Trigonal planar



Tetrahedral

More molecular models:

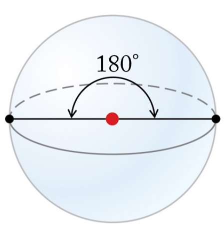
http://www.chemeddl.org/resources/models360/models.php?pubchem=24682

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

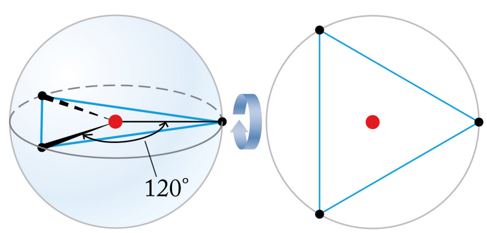
7

Electron Domain Geometry

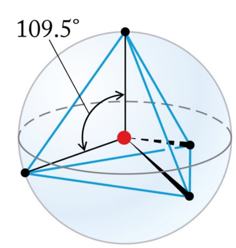
- To determine the electron domain geometry, count the *total* number of lone pairs, single, double, and triple bonds on the central atom.



Linear



Trigonal planar

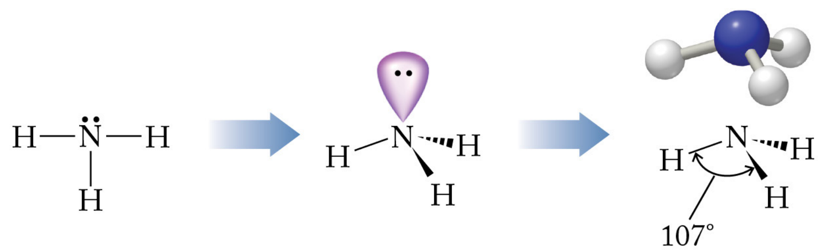


Tetrahedral

8

Molecular Shape: 3 Steps

1) Draw the best Lewis structure.
2) Determine the electron domain geometry by counting electron domains.
3) Use the arrangement of the ***bonded atoms*** to determine the ***molecular geometry (shape)***.



(a) Lewis structure (b) Tetrahedral electron domain geometry (c) Trigonal pyramidal molecular geometry

9

Draw the best Lewis structure for OCS. What is the O-C-S bond angle? How do you know?

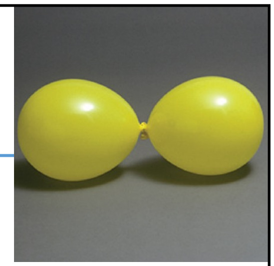
A. 180°
B. 120°
C. 109.5°
D. 90°

Think & Solve: 1 min; on your own
Discuss: 30 sec; share and compare
Answer: iClicker, when prompted

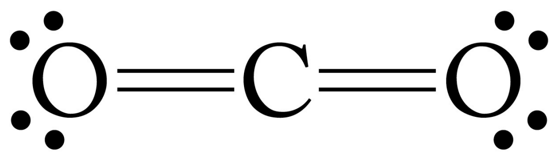
10

10

Linear Electron Domain Geometry: Single Molecular Shape (Linear)



- In the linear electron domain geometry, there is only one molecular geometry: linear.
- **Note:** If there are only two atoms in the molecule, the molecule will be linear no matter what number of pairs around an atom.



11

Recall the best Lewis structure for nitrite, NO_2^-. What is the approximate O-N-O bond angle? How do you know?

A. 180°
B. 120°
C. 109.5°
D. 90°

Think & Solve: 1 min; on your own
Discussion: 30 sec; share and compare
Answer: iClicker, when prompted

12

12

Trigonal Planar Electron Domain Geometry: 2 Molecular Shapes

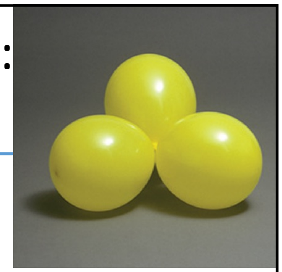
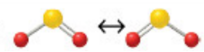


TABLE 5.1 Electron-Pair Geometries and Molecular Geometries

SN = 3	Electron-Pair Geometry	No. of Bonded Atoms	No. of Lone Pairs	Molecular Geometry	Theoretical Bond Angles	Example	
	Trigonal planar	3	0	Trigonal planar	120°	CH_2O	
	Trigonal planar	2	1	Bent (angular)	<120°	SO_2	

SN = # electron domains around central atom

13

What is the molecular shape of NO_3-?

A. Linear
B. Trigonal Planar
C. Bent
D. Tetrahedral

Follow-up: what is the name of this ion?
(Hint: learn Table 4.4)

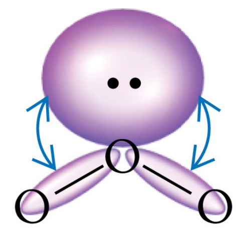
Think & Solve: 2 min; on your own
Discuss: 30 sec; share and compare

14

14

Draw NO_3- and compare to ozone, O_3, shown below.

- Nonbonding pairs are physically *larger* than bonding pairs. [Why?] Therefore, their *repulsions* are greater; this tends to compress bond angles.



O—O—O bond angle = 117°

15

Draw the best Lewis structure for methane, CH_4. What is the H-C-H bond angle?

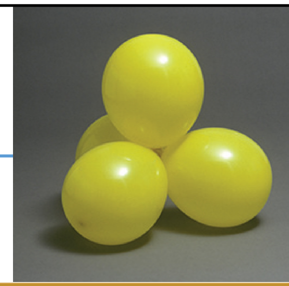
A. 180°
B. 120°
C. 109.5°
D. 90°

Think & Solve: 1 min; on your own
Discuss: 30 sec; share and compare
Answer: iClicker, when prompted

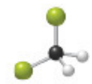
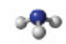
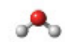
16

16

Tetrahedral Electron Domain Geometry: 3 Shapes



SN = 4

Tetrahedral	4	0	Tetrahedral	109.5°	CH_2Cl_2	
Tetrahedral	3	1	Trigonal pyramidal	<109.5°	NH_3	
Tetrahedral	2	2	Bent (angular)	<109.5°	H_2O	

SN = # electron domains around central atom

17

What is the angle between the hydrogens in NH_3 (the H-N-H bond angle)? Draw the 3D structure using wedge & dash notation.

A. 109.5^o
B. A bit > 109.5^o
C. A bit < 109.5^o
D. 90^o

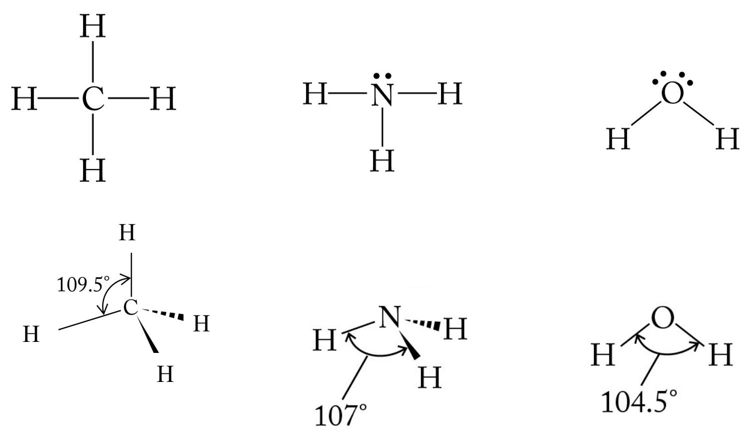
Think & Solve: 1 min; on your own
Discuss: 30 sec; share and compare
Answer: iClicker, when prompted

18

18

Nonbonding Pairs and Bond Angle

- Nonbonding pairs are physically *larger* than bonding pairs. [Why?] Therefore, their *repulsions* are greater; this tends to compress bond angles.

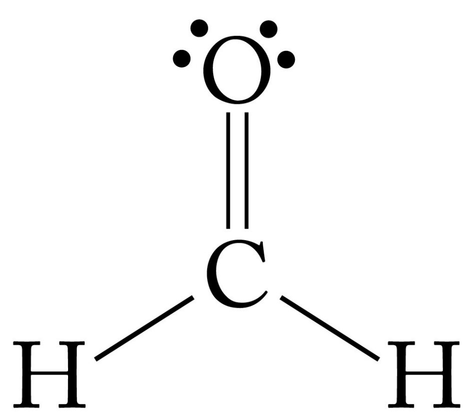


Note wedge & dash structure

19

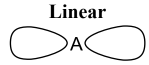
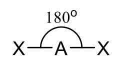
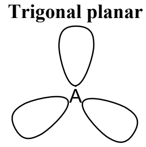
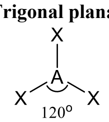
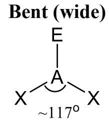
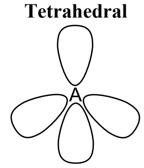
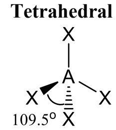
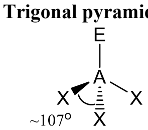
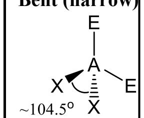
Multiple Bonds and Bond Angles

- Double and triple bonds have *larger* electron domains than single bonds.
- They exert a greater *repulsive* force than single bonds, making their bond angles greater.
- HCO angle > HCH angle in formaldehyde, right, as a result



20

Know this (**All of it!!**)

Total # of electron domains	Electron domain geometry	# of nonbonding domains (E)		
		0	1	2
2	**Linear**  sp hybridization	**Linear**  AX_2 Ex: CO_2	←**Molecular shape** ←**Structure** ←**Generic formula** ←**Example molecule**	
3	**Trigonal planar**  sp^2 hybridization	**Trigonal planar**  AX_3 Ex: CH_2O	**Bent (wide)**  AX_2E Ex: O_3	
4	**Tetrahedral**  sp^3 hybridization	**Tetrahedral**  AX_4 Ex: $CHCl_3$	**Trigonal pyramidal**  AX_3E Ex: NH_3	**Bent (narrow)**  AX_2E_2 Ex: H_2O

Exam-type question: Draw the best Lewis structure for each of the following molecules and determine the electron domain geometry and molecular shape:

1. SO_3

2. H_3O^+

Think & Solve: 4 min; on your own
Discuss: 30 sec; share and compare
Answer: iClicker, when prompted