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Progressive Science Initiative

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AP Chemistry



Unit 4: Presentation C
Molecular Shapes and
Dipole Moments

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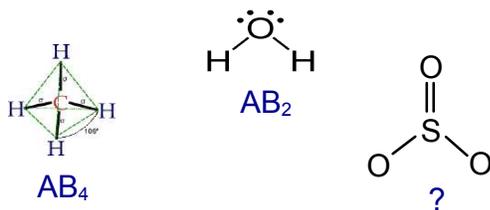
Chemical Bonding



Water's bent shape gives rise to its properties such as having an unusually high boiling point for a molecule so small.

Molecular Shape and VSEPR Theory

The "AB" system can be used to determine the molecular shape by tracking how many atoms and unbonded pairs are attached to an atom.



Molecular Shape and VSEPR Theory

The molecular shape is determined by the number of bonded and unbonded pairs of electrons around an atom.

A molecule will arrange its atoms and bonds to minimize the repulsions between electron pairs.



In methane (CH_4), the molecule adopts a 3D tetrahedral arrangement to minimize repulsions.



In water (H_2O), the un-bonded electrons repel more strongly than the bonded electrons resulting in a bent configuration with a reduced bond angle compared to methane.

***Note: Un-bonded electrons repel more strongly as they have no nuclei to reduce or shield their charge.

Molecular Shape and VSEPR Theory

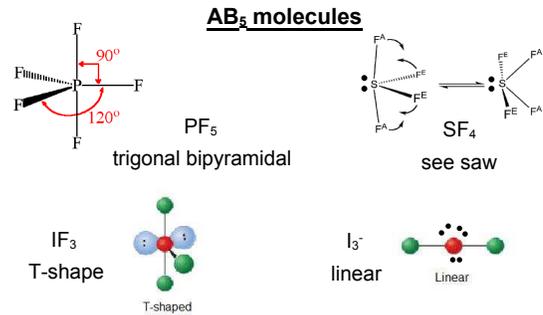
Basic Molecular Shapes

"AB" Designation	# of unbonded pairs of electrons on "A" atom	Shape	Bond Angles	Example
AB_2	0	Linear	180	$\text{O}=\text{C}=\text{O}$
AB_3	0	trigonal planar	120	CO_3^{2-}
AB_4	0	tetrahedral	109.5	CH_4
AB_5	0	trigonal bipyramidal	90, 120, 180	PF_5
AB_6	0	octahedral	90, 180	SF_6

***Note: Pi bonds act with the sigma bonds to contribute to the repulsions that result in the molecular shape, however they do not act as a separate constituent around the "A" atom.

Molecular Shape and VSEPR Theory

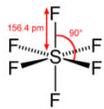
Unbonded pairs contribute to the shape of the molecule as well, most often shrinking the bond angles as they repel more strongly than bonded pairs.



Molecular Shape and VSEPR Theory

Unbonded pairs contribute to the shape of the molecule as well, most often shrinking the bond angles as they repel more strongly than bonded pairs.

AB₆ molecules



SF₆
octahedral



XeCl₄
square planar



ClF₅
square pyramidal

1

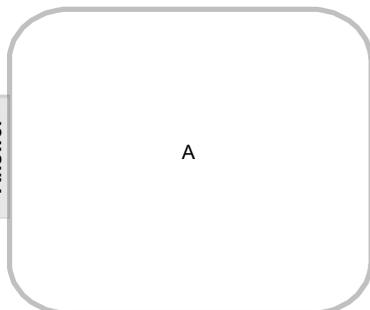
- I only
- II only
- III only
- I and II only
- II and III only

- I. XeO₂F₂
- II. IBr₃
- III. SeH₂

1

- I only
- II only
- III only
- I and II only
- II and III only

Answer



2

- I only
- II only
- III only
- II and III only
- I, II, and III

- I. CH₄, PCl₃, SF₅
- II. XeF₂, H₂O, XeF₄
- III. NO₃⁻, NO₂⁻, CH₄

2

- I only
- II only
- III only
- II and III only
- I, II, and III

I. CH_4 , PCl_3 , SF_5

II

III

Answer

E

3

- BeCl_2
- SeH_2
- SCl_2
- OH_2
- All have a bent shape

3

- BeCl_2
- SeH_2
- SCl_2
- OH_2
- All have a bent shape

Answer

A

4

- C_2H_4
- PH_3
- SiH_4
- PF_5
- SeCl_6

4

- C_2H_4
- PH_3
- SiH_4
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Answer

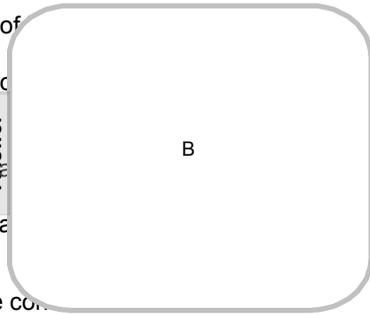
A

5

- Only the number of bonded e- pairs around atom
- Only the number of un-bonded and bonded e- pairs around the atom
- Only the atomic radii of atoms
- Only the atomic radii and bonded e- pairs around the atom
- None of these are correct

5

- Only the number of
- Only the number of
- Only the atomic
- Only the atomic radius
- None of these are correct

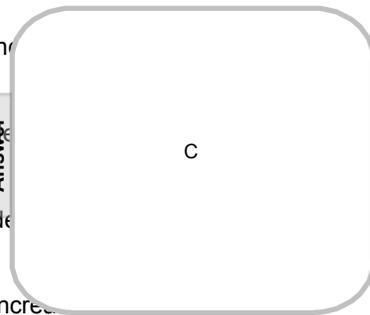


6

- The bond angle increases due to the decreased repulsions
- The bond angle decreases due to the decreased repulsions
- The bond angle decreases due to the increased repulsions
- The bond angle increases due to the increased repulsions

6

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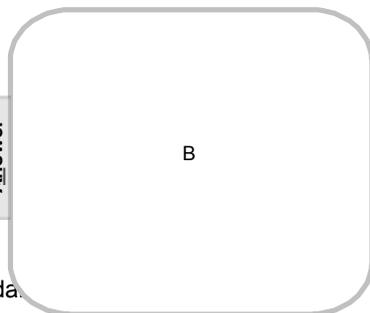


7

- bent
- trigonal planar
- trigonal pyramidal
- see-saw
- trigonal bipyramidal

7

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Molecular Polarity

Molecules in which the electrons are not evenly distributed experience a dipole moment when in an electric field and are said to be polar.

Two factors contribute to the polarity of a molecule:

Polarity of bonds

Polar bonds are necessary for a molecule to be polar but do not guarantee polarity.

Symmetry

To be polar a molecule must be asymmetrical to ensure an uneven distribution of electrons.

Molecular Polarity

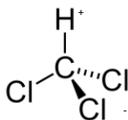
Certain shapes are asymmetrical in nature due to unbonded electrons and can, therefore, result in polar molecules.

Asymmetrical Shapes

Bent, Trigonal pyramidal

T-Shape, See-saw, Square pyramidal

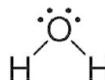
Asymmetry and polarity can also result from a heterogenous group of atoms attached to the central atom thereby creating asymmetrical differences in electronegativity. CHCl_3 is a classic example.



Molecular Polarity

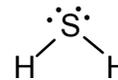
If the molecule is asymmetrical, the more polar the bonds, the more polar the molecule

H_2O



Dipole moment = 1.85 D

H_2S



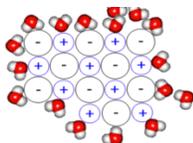
Dipole moment = 0.97 D

Both molecules are asymmetrical and exhibit a dipole moment but water's dipole moment is significantly higher than hydrogen sulfide due to the greater electronegativity difference between O and H.

Molecular Polarity

Polarity influences solubility. Polar solutes are more soluble/miscible in polar solvents and non-polar solutes are more soluble in non-polar solvents.

Since water is a polar molecule, it is an excellent solvent for polar solutes such as ethanol ($\text{C}_2\text{H}_5\text{OH}$), soluble ionic salts (NaCl , K_3PO_4 , etc), or polar gases like ammonia (NH_3).



Molecular Polarity

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Many pigments used to create color in paints are non-polar and require a non-polar solvent such as hexane (C_6H_{14}) to dissolve.

Many molecules have non-polar and polar regions and require an "amphipathic" solvent that also shares those qualities.

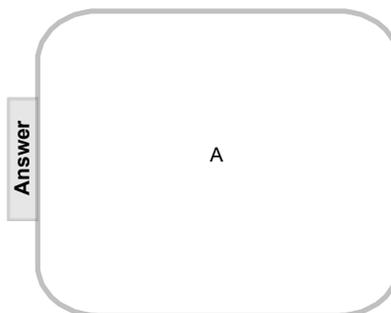
Acetone (CH_3COCH_3) is an excellent choice for these applications.

9

- NH₃
- PH₃
- BF₃
- CH₄
- OF₂

9

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- PH₃
- BF₃
- CH₄
- OF₂

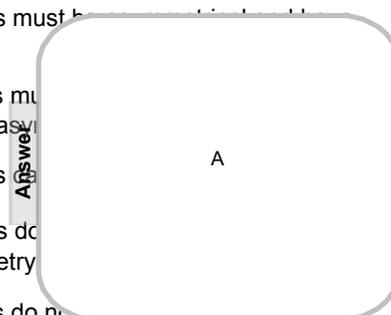


10

- Polar molecules must be asymmetrical and have polar bonds
- Polar molecules must have polar bonds and can be symmetrical or asymmetrical
- Polar molecules cannot have polar bonds
- Polar molecules do not require polar bonds but do require asymmetry
- Polar molecules do not require polar bonds or asymmetry

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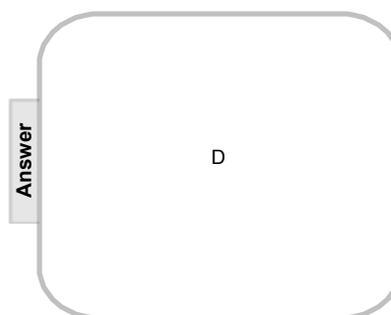


11

- C₂H₂
- SiH₄
- I₂
- CH₂F₂
- CO₂

11

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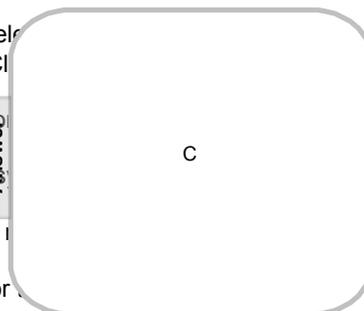


12

- There is a small electronegativity difference between C and Cl
- The bonds are non-polar
- The molecule is symmetrical
- The atoms in the molecule are small
- The IR spectra for the molecule has few peaks

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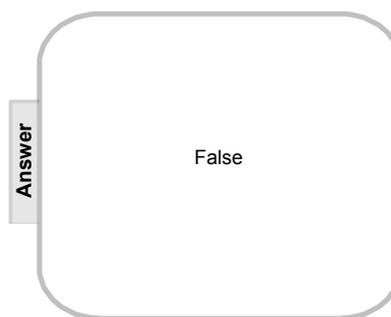


13

- True
- False

13

- True
- False

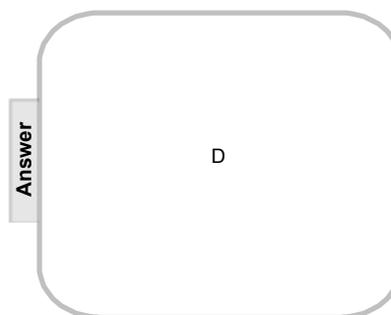


14

- C₈H₁₈
- BeCl₂
- CO₂
- HCN
- H₂S

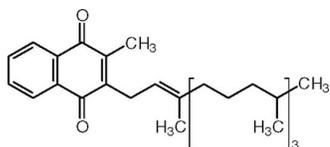
14

- C₈H₁₈
- BeCl₂
- CO₂
- HCN
- H₂S



Application

Fat soluble vitamins dissolve best in non-polar solvents such as bile salts released from the liver. The structure for vitamin K is below. Do you think it is a fat soluble or water soluble vitamin?

**Application**

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Answer

Vitamin K is mostly nonpolar,
so it is fat soluble

In the next section we will examine the forces that exist between these molecules and how the strength and types of these forces influence the properties of these molecules....see you there!