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## Molecular Geometry & VSEPR

### Study Guide — Chemical Bonding

Pre-med/IB-style questions on VSEPR: electron domains vs molecular shape, lone pair effects, bond angles, trigonal bipyramidal and octahedral structures, polarity from geometry, and basic hybridization mapping.

70 items — Study Guide with Answers

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1 In VSEPR theory, what counts as ONE electron domain (electron region) around a central atom?



- A Only lone pairs on the central atom
- B Only single bonds to surrounding atoms
- C Any region of electron density: a single bond, multiple bond, or a lone pair ✓
- D Each shared electron counts as one domain
- E Each atom attached to the central atom counts as one domain, regardless of bonding

► **Explanation:** VSEPR counts regions of electron density around the central atom. A single bond, double bond, triple bond, or lone pair each counts as one electron domain. Options A and B are incomplete, D is incorrect because domains are regions not individual electrons, and E ignores lone pairs and multiple bonds.

2 When counting electron domains for VSEPR, a double bond between the central atom and an outer atom counts as:



- A Two electron domains because it contains two shared electron pairs
- B One electron domain because it is one region of electron density ✓
- C Zero electron domains because the electrons are shared
- D Three electron domains because a double bond is 'bigger' than a single bond
- E It depends on electronegativity, not bonding

► **Explanation:** A double bond is still a single region of electron density around the central atom, so it counts as ONE electron domain. A and D are common counting traps; C and E are unrelated to VSEPR domain counting.

3 What is the molecular geometry (shape) of CO<sub>2</sub>?





- A Bent
- B Trigonal planar
- C Tetrahedral
- D Linear ✓**
- E Trigonal pyramidal

► **Explanation:** Carbon has two electron domains in CO<sub>2</sub> (two C=O regions), giving a linear arrangement (180°). Bent and trigonal shapes require 3+ domains; tetrahedral/pyramidal require 4 domains.

4 What is the molecular geometry around carbon in HCN (H–C N)?



- A Bent
- B Trigonal planar
- C Tetrahedral
- D Linear ✓**
- E Seesaw

► **Explanation:** Carbon has two electron domains (one C–H single bond and one C N triple bond counts as one domain), so it is linear. Trigonal planar would require 3 domains; tetrahedral 4; seesaw 5.

5 What is the molecular geometry of BF<sub>3</sub>?



- A Trigonal planar ✓**
- B Trigonal pyramidal
- C Tetrahedral
- D Bent





**E** Linear

► **Explanation:** Boron in  $\text{BF}_3$  has 3 bonding domains and no lone pairs (AX3), giving trigonal planar ( $\sim 120^\circ$ ). Pyramidal and tetrahedral require 4 domains; bent requires a lone pair; linear requires 2 domains.

**6** What is the molecular geometry of  $\text{CH}_4$ ?



**A** Trigonal planar

**B** Tetrahedral ✓

**C** Linear

**D** Trigonal pyramidal

**E** Square planar

► **Explanation:** Carbon has 4 bonding domains and no lone pairs (AX4), giving tetrahedral geometry ( $\sim 109.5^\circ$ ). Trigonal planar needs 3 domains; linear needs 2; pyramidal needs a lone pair; square planar typically comes from 6-domain (octahedral) arrangements.

**7** Which pair correctly describes the electron-domain geometry and the molecular geometry of  $\text{NH}_3$ ?



**A** Electron geometry trigonal planar; molecular geometry trigonal planar

**B** Electron geometry tetrahedral; molecular geometry trigonal pyramidal ✓

**C** Electron geometry trigonal bipyramidal; molecular geometry trigonal pyramidal

**D** Electron geometry tetrahedral; molecular geometry tetrahedral

**E** Electron geometry linear; molecular geometry trigonal pyramidal





► **Explanation:** NH<sub>3</sub> has 4 electron domains (3 bonds + 1 lone pair): electron-domain geometry is tetrahedral, but the molecular geometry (positions of atoms only) is trigonal pyramidal. A and E have wrong domain counts; D ignores the lone pair; C corresponds to 5 domains.

8 Which pair correctly describes the electron-domain geometry and the molecular geometry of H<sub>2</sub>O?



- A Electron geometry linear; molecular geometry linear
- B Electron geometry tetrahedral; molecular geometry bent ✓**
- C Electron geometry trigonal planar; molecular geometry trigonal planar
- D Electron geometry tetrahedral; molecular geometry tetrahedral
- E Electron geometry trigonal planar; molecular geometry bent

► **Explanation:** H<sub>2</sub>O has 4 electron domains (2 bonds + 2 lone pairs): electron-domain geometry tetrahedral, molecular geometry bent. E would fit 3 domains (like SO<sub>2</sub>), not water. D ignores lone pairs.

9 Which repulsion is strongest in VSEPR (largest electron-pair repulsion)?



- A Bonding pair–bonding pair (BP–BP)
- B Bonding pair–lone pair (BP–LP)
- C Lone pair–lone pair (LP–LP) ✓**
- D All repulsions are equal in strength
- E Repulsion depends only on atom size, not on lone pairs

► **Explanation:** Lone pairs occupy more space and repel more strongly: LP–LP > LP–BP > BP–BP. A and B are weaker than LP–LP; D and E contradict the basic VSEPR model.





10 Which order of bond angles is generally correct?



- A  $\text{H}_2\text{O} > \text{NH}_3 > \text{CH}_4$
- B  $\text{CH}_4 > \text{NH}_3 > \text{H}_2\text{O}$  ✓**
- C  $\text{NH}_3 > \text{CH}_4 > \text{H}_2\text{O}$
- D  $\text{CH}_4 > \text{H}_2\text{O} > \text{NH}_3$
- E All are exactly  $109.5^\circ$

► **Explanation:** All have tetrahedral electron geometry, but lone pairs compress angles:  $\text{CH}_4$  (no lone pairs,  $109.5^\circ$ )  $>$   $\text{NH}_3$  (one lone pair,  $\sim 107^\circ$ )  $>$   $\text{H}_2\text{O}$  (two lone pairs,  $\sim 104.5^\circ$ ).

11  $\text{NH}_3$  has a bond angle slightly less than  $109.5^\circ$  mainly because:



- A Nitrogen has too few protons to make tetrahedral geometry
- B A lone pair on nitrogen repels bonding pairs more strongly, compressing the H–N–H angle ✓**
- C Hydrogen atoms repel each other less than electron pairs do
- D  $\text{NH}_3$  is linear, so the angle must be near  $180^\circ$
- E The N–H bonds are ionic, so angles are not defined

► **Explanation:** The electron geometry is tetrahedral, but the lone pair takes more space and increases repulsion toward bonding pairs, reducing the H–N–H bond angle. Other choices confuse geometry, bonding type, or basic VSEPR principles.

12 Which molecule has trigonal planar electron-domain geometry but a bent molecular shape?



- A  $\text{CO}_2$





- B BF<sub>3</sub>
- C SO<sub>3</sub>
- D SO<sub>2</sub> ✓
- E CH<sub>4</sub>

► **Explanation:** SO<sub>2</sub> has 3 electron domains around S (2 bonding regions + 1 lone pair): electron geometry trigonal planar, molecular shape bent. CO<sub>2</sub> is linear (2 domains). BF<sub>3</sub> and SO<sub>3</sub> are trigonal planar with no lone pairs. CH<sub>4</sub> is tetrahedral.

13 Which statement about SO<sub>3</sub> is correct (treating it with VSEPR/resonance)?



- A SO<sub>3</sub> is bent and polar because sulfur has one lone pair
- B SO<sub>3</sub> is trigonal planar and nonpolar because the three S–O bond dipoles cancel by symmetry ✓
- C SO<sub>3</sub> is tetrahedral because sulfur forms three double bonds
- D SO<sub>3</sub> is linear because it has three oxygen atoms
- E SO<sub>3</sub> must be square planar because it has 3 electron domains

► **Explanation:** SO<sub>3</sub> has 3 electron domains around sulfur (three bonding regions, no lone pair on S in the simplest VSEPR count), giving trigonal planar geometry; its symmetric shape cancels dipoles so it is nonpolar. Bent requires a lone pair; tetrahedral requires 4 domains.

14 What is the molecular geometry of the nitrate ion, NO<sub>3</sub><sup>−</sup>?



- A Trigonal planar ✓
- B Trigonal pyramidal
- C Bent (tetrahedral electron geometry)
- D Linear





**E** T-shaped

► **Explanation:** In  $\text{NO}_3^-$ , nitrogen has 3 electron domains (three bonding regions via resonance) and no lone pair on N, so it is trigonal planar. Pyramidal would require a lone pair; bent/tetrahedral would require 4 domains.

**15** What is the molecular geometry of the nitrite ion,  $\text{NO}_2^-$ ?



**A** Linear

**B** Trigonal planar

**C** Bent (with trigonal planar electron geometry) ✓

**D** Tetrahedral

**E** Square planar

► **Explanation:**  $\text{NO}_2^-$  has 3 electron domains around N (2 bonding regions + 1 lone pair): electron geometry trigonal planar, molecular shape bent. Linear would require only 2 domains; trigonal planar would require no lone pair.

**16** What is the molecular geometry of the carbonate ion,  $\text{CO}_3^{2-}$ ?



**A** Tetrahedral

**B** Trigonal planar ✓

**C** Bent

**D** Trigonal pyramidal

**E** Linear





► **Explanation:** Carbon in  $\text{CO}_3^{2-}$  has 3 electron domains (three bonding regions through resonance) and no lone pairs on C, so the geometry is trigonal planar. Tetrahedral requires 4 domains; bent/pyramidal require lone pairs.

17 What is the molecular geometry of  $\text{PCl}_5$ ?



- A Tetrahedral
- B Trigonal bipyramidal ✓**
- C Square pyramidal
- D Octahedral
- E Seesaw

► **Explanation:**  $\text{PCl}_5$  has 5 bonding domains and no lone pairs (AX5), giving trigonal bipyramidal geometry. Seesaw would require one lone pair; square pyramidal and octahedral involve 6 domains.

18 In an ideal trigonal bipyramidal molecule like  $\text{PF}_5$ , what is the bond angle between two equatorial bonds?



- A  $90^\circ$
- B  $109.5^\circ$
- C  $120^\circ$  ✓**
- D  $180^\circ$
- E  $60^\circ$

► **Explanation:** Trigonal bipyramidal has three equatorial positions separated by  $120^\circ$ .  $90^\circ$  applies to axial-equatorial, and  $180^\circ$  applies to axial-axial.





**19** In trigonal bipyramidal electron geometry, lone pairs usually occupy equatorial positions because:

- A** Equatorial positions have fewer  $90^\circ$  interactions than axial positions ✓
- B** Equatorial positions always have stronger bonds than axial positions
- C** Axial positions do not allow lone pairs
- D** Equatorial positions are closer to the nucleus
- E** Lone pairs prefer  $180^\circ$  angles only

► **Explanation:** Equatorial placement minimizes high-repulsion  $90^\circ$  interactions: an equatorial domain has 2 such interactions, while an axial domain has 3. Other options invent rules not in VSEPR.



**20**  $\text{SF}_4$  has one lone pair on sulfur (AX<sub>4</sub>E). What is its molecular geometry and where is the lone pair located in the trigonal bipyramidal arrangement?

- A** Tetrahedral; lone pair is axial
- B** Seesaw; lone pair is equatorial ✓
- C** Trigonal planar; lone pair is equatorial
- D** Square planar; lone pair is axial
- E** T-shaped; lone pair is axial

► **Explanation:** AX<sub>4</sub>E corresponds to a trigonal bipyramidal electron geometry with one equatorial lone pair, giving a seesaw molecular shape. T-shaped is AX<sub>3</sub>E<sub>2</sub>, not AX<sub>4</sub>E. Tetrahedral would require 4 domains total.



**21**  $\text{ClF}_3$  has the formula AX<sub>3</sub>E<sub>2</sub> around chlorine. What is its molecular geometry (shape)?

- A** Trigonal planar





- B Trigonal pyramidal
- C T-shaped ✓**
- D Seesaw
- E Octahedral

► **Explanation:** AX<sub>3</sub>E<sub>2</sub> means 5 electron domains (trigonal bipyramidal electron geometry) with two equatorial lone pairs, leaving three bonds arranged in a T-shape. Seesaw is AX<sub>4</sub>E; trigonal pyramidal is AX<sub>3</sub>E with 4 domains.

22 Which statement correctly describes XeF<sub>2</sub>?



- A XeF<sub>2</sub> is bent because xenon has two lone pairs
- B XeF<sub>2</sub> is linear with trigonal bipyramidal electron geometry (AX<sub>2</sub>E<sub>3</sub>) ✓**
- C XeF<sub>2</sub> is trigonal planar because it has three electron domains
- D XeF<sub>2</sub> is tetrahedral because xenon has four electron domains
- E XeF<sub>2</sub> is square planar because it has six electron domains

► **Explanation:** XeF<sub>2</sub> has 5 electron domains (2 bonding + 3 lone pairs). The three lone pairs occupy equatorial positions, leaving a linear molecular shape. Bent would require 3 or 4 domains with lone pairs arranged differently.

23 The ion I<sub>3</sub><sup>-</sup> is best described as:



- A Bent with two lone pairs on the central iodine
- B Linear with three lone pairs on the central iodine (AX<sub>2</sub>E<sub>3</sub>) ✓**
- C Trigonal planar with one lone pair on the central iodine
- D Tetrahedral because there are three iodine atoms





- E** Octahedral because it is an ion

► **Explanation:**  $\text{I}_3^-$  has 5 electron domains around the central I (2 bonding + 3 lone pairs), giving trigonal bipyramidal electron geometry and a linear molecular geometry. Other options mismatch domain counts or confuse ion charge with geometry.

**24** What is the molecular geometry of  $\text{SF}_6$ ?



- A** Trigonal bipyramidal
- B** Octahedral ✓
- C** Square planar
- D** Seesaw
- E** Trigonal pyramidal

► **Explanation:**  $\text{SF}_6$  has 6 bonding domains and no lone pairs (AX6), giving octahedral geometry ( $90^\circ$  and  $180^\circ$  angles). Trigonal bipyramidal is for 5 domains; square planar requires lone pairs.

**25** What is the molecular geometry of  $\text{BrF}_5$  (AX5E)?



- A** Trigonal bipyramidal
- B** Square pyramidal ✓
- C** Square planar
- D** Octahedral
- E** Seesaw

► **Explanation:**  $\text{BrF}_5$  has 6 electron domains (5 bonds + 1 lone pair), so electron geometry is octahedral but the molecular geometry is square pyramidal. Octahedral would require 6 bonds and no lone pairs.





26 What is the molecular geometry of XeF<sub>4</sub> (AX<sub>4</sub>E<sub>2</sub>)?



- A Tetrahedral
- B Square planar ✓
- C Trigonal planar
- D Trigonal bipyramidal
- E Square pyramidal

► **Explanation:** XeF<sub>4</sub> has 6 electron domains (4 bonds + 2 lone pairs): octahedral electron geometry. The two lone pairs occupy opposite positions, leaving four bonds in a square plane → square planar shape.

27 In XeF<sub>4</sub>, the two lone pairs on xenon are arranged:



- A Adjacent in the square plane
- B Opposite each other (trans) in an octahedral arrangement ✓
- C Both in axial positions of a trigonal bipyramidal arrangement
- D On different atoms, not on xenon
- E Randomly; VSEPR cannot predict lone pair positions

► **Explanation:** XeF<sub>4</sub> has octahedral electron geometry. Placing the two lone pairs opposite each other minimizes lone pair–lone pair repulsion. Adjacent placement increases repulsion, and trigonal bipyramidal is the wrong electron geometry (needs 5 domains).

28 Which molecule is nonpolar mainly because its molecular geometry causes bond dipoles to cancel?





- A NH<sub>3</sub>
- B H<sub>2</sub>O
- C SF<sub>4</sub>
- D XeF<sub>4</sub> ✓**
- E CH<sub>2</sub>Cl<sub>2</sub>

► **Explanation:** XeF<sub>4</sub> is square planar and symmetric, so the four Xe–F bond dipoles cancel. NH<sub>3</sub> and H<sub>2</sub>O are polar due to lone-pair shapes, SF<sub>4</sub> is polar (seesaw), and CH<sub>2</sub>Cl<sub>2</sub> is tetrahedral but not symmetric enough to cancel.

29 Which molecule is expected to be polar?



- A CO<sub>2</sub>
- B BF<sub>3</sub>
- C SF<sub>6</sub>
- D CCl<sub>4</sub>
- E SF<sub>4</sub> ✓**

► **Explanation:** SF<sub>4</sub> is seesaw (asymmetric), so its bond dipoles do not cancel → polar. CO<sub>2</sub> is linear symmetric; BF<sub>3</sub> is trigonal planar symmetric; SF<sub>6</sub> and CCl<sub>4</sub> are highly symmetric (octahedral and tetrahedral) so dipoles cancel.

30 What is the hybridization of the central carbon in CO<sub>2</sub> using the basic electron-domain model?



- A sp ✓**
- B sp<sup>2</sup>
- C sp<sup>3</sup>





- D sp3d
- E sp3d2

► **Explanation:** CO<sub>2</sub> has 2 electron domains around carbon (two double bonds count as two domains total), corresponding to linear geometry and sp hybridization. sp<sup>2</sup> would require 3 domains; sp<sup>3</sup> requires 4.

**31** What is the hybridization of boron in BF<sub>3</sub> in the basic VSEPR/hybridization model?



- A sp
- B sp<sup>2</sup> ✓
- C sp<sup>3</sup>
- D sp<sup>3</sup>d
- E sp<sup>3</sup>d<sup>2</sup>

► **Explanation:** BF<sub>3</sub> has 3 electron domains around B (3 bonds, no lone pairs) → trigonal planar → sp<sup>2</sup>. sp is for 2 domains; sp<sup>3</sup> is for 4.

**32** What is the hybridization of nitrogen in NH<sub>3</sub> in the basic model?



- A sp
- B sp<sup>2</sup>
- C sp<sup>3</sup> ✓
- D sp<sup>3</sup>d
- E sp<sup>3</sup>d<sup>2</sup>





► **Explanation:**  $\text{NH}_3$  has 4 electron domains (3 bonds + 1 lone pair)  $\rightarrow$  tetrahedral electron geometry  $\rightarrow$   $\text{sp}^3$ .  $\text{sp}^2$  would correspond to 3 domains (trigonal planar electron geometry).

**33** Using the common high-school hybridization mapping, what hybridization is assigned to sulfur in  $\text{SF}_6$ ?



- A  $\text{sp}$
- B  $\text{sp}^2$
- C  $\text{sp}^3$
- D  $\text{sp}^3\text{d}$
- E  $\text{sp}^3\text{d}^2$  ✓

► **Explanation:**  $\text{SF}_6$  has 6 electron domains (6 S–F bonds)  $\rightarrow$  octahedral electron geometry, commonly mapped to  $\text{sp}^3\text{d}^2$  in introductory models. The other hybridizations correspond to fewer electron domains.

**34** In the basic hybridization mapping,  $\text{sp}^3\text{d}$  hybridization corresponds to a central atom with:



- A 2 electron domains (linear)
- B 3 electron domains (trigonal planar)
- C 4 electron domains (tetrahedral)
- D 5 electron domains (trigonal bipyramidal) ✓
- E 6 electron domains (octahedral)

► **Explanation:** In the standard introductory mapping:  $2 \rightarrow \text{sp}$ ,  $3 \rightarrow \text{sp}^2$ ,  $4 \rightarrow \text{sp}^3$ ,  $5 \rightarrow \text{sp}^3\text{d}$  (trigonal bipyramidal electron geometry),  $6 \rightarrow \text{sp}^3\text{d}^2$  (octahedral).





35 How many electron domains are around sulfur in SO<sub>2</sub> (according to VSEPR counting)?



- A 2
- B 3 ✓
- C 4
- D 5
- E 6

► **Explanation:** SO<sub>2</sub> has two bonding regions (each S–O bond counts as one domain, despite resonance) plus one lone pair on sulfur in the usual Lewis/VSEPR picture → 3 electron domains. Two domains would be linear; 4 would imply tetrahedral electron geometry.

36 What is the geometry around each carbon atom in ethene, C<sub>2</sub>H<sub>4</sub> (H<sub>2</sub>C=CH<sub>2</sub>)?



- A Tetrahedral (sp<sup>3</sup>)
- B Trigonal planar (sp<sup>2</sup>) ✓
- C Linear (sp)
- D Trigonal bipyramidal (sp<sup>3</sup>d)
- E Octahedral (sp<sup>3</sup>d<sup>2</sup>)

► **Explanation:** Each carbon in ethene has 3 electron domains (two C–H bonds and one C=C bond region), giving trigonal planar geometry and sp<sup>2</sup> hybridization. Tetrahedral would require 4 domains.

37 What is the geometry around each carbon atom in ethyne, C<sub>2</sub>H<sub>2</sub> (HC≡CH)?



- A Trigonal planar (sp<sup>2</sup>)
- B Tetrahedral (sp<sup>3</sup>)





- C Linear (sp) ✓
- D Seesaw (sp<sup>3</sup>d)
- E Square planar

► **Explanation:** Each carbon has 2 electron domains (one C–H bond and one C C bond region), so geometry is linear and hybridization sp. Trigonal planar needs 3 domains; tetrahedral needs 4.

**38** In ethanol (CH<sub>3</sub>CH<sub>2</sub>OH), what is the approximate molecular geometry around the oxygen atom?



- A Linear
- B Trigonal planar
- C Bent (from tetrahedral electron geometry) ✓
- D Trigonal pyramidal
- E Octahedral

► **Explanation:** Oxygen in an alcohol typically has 4 electron domains (2 bonds + 2 lone pairs), giving tetrahedral electron geometry and a bent molecular shape. Linear/trigonal planar would require fewer domains.

**39** CO<sub>2</sub> has polar C=O bonds, yet the molecule is nonpolar. The best explanation is:



- A Oxygen is not electronegative enough to make a dipole
- B CO<sub>2</sub> is linear, so the two equal bond dipoles cancel ✓
- C Double bonds cannot be polar
- D Carbon has no valence electrons, so it cannot be polar
- E CO<sub>2</sub> is nonpolar because it has no lone pairs on oxygen





► **Explanation:** The molecule is linear and symmetric: the two C=O bond dipoles point in opposite directions with equal magnitude, so they cancel. A, C, and D are false statements; E is irrelevant because polarity depends on overall dipole cancellation, not simply on lone pairs.

40 Which molecule has a net dipole moment (is polar)?

- A CO<sub>2</sub>
- B BF<sub>3</sub>
- C SO<sub>3</sub>
- D SF<sub>6</sub>
- E SO<sub>2</sub> ✓

► **Explanation:** SO<sub>2</sub> is bent, so its S–O bond dipoles do not cancel → polar. CO<sub>2</sub> (linear), BF<sub>3</sub> and SO<sub>3</sub> (trigonal planar symmetric), and SF<sub>6</sub> (octahedral symmetric) are nonpolar by symmetry.



41 Which statement about BF<sub>3</sub> is correct?

- A BF<sub>3</sub> is polar because B–F bonds are polar
- B BF<sub>3</sub> is nonpolar because trigonal planar symmetry cancels the three bond dipoles ✓
- C BF<sub>3</sub> is bent because boron has a lone pair
- D BF<sub>3</sub> is linear because boron forms three bonds
- E BF<sub>3</sub> is square planar because fluorine has lone pairs

► **Explanation:** BF<sub>3</sub> is trigonal planar (AX<sub>3</sub>) and symmetric, so bond dipoles cancel, making it nonpolar. A ignores vector cancellation; C is wrong (B has no lone pair here); D and E describe incorrect geometries.





42 What is the geometry around carbon in formaldehyde,  $\text{CH}_2\text{O}$  ( $\text{H}_2\text{C}=\text{O}$ )?



- A Tetrahedral
- B Trigonal planar ✓**
- C Linear
- D Trigonal pyramidal
- E Octahedral

► **Explanation:** The carbon has 3 electron domains (two C–H single bonds and one C=O double bond region), giving trigonal planar geometry. Tetrahedral would require 4 domains.

43 What is the molecular geometry of  $\text{NH}_4^+$  (ammonium)?



- A Trigonal pyramidal
- B Tetrahedral ✓**
- C Square planar
- D Bent
- E Linear

► **Explanation:**  $\text{NH}_4^+$  has 4 bonding domains and no lone pairs on nitrogen ( $\text{AX}_4$ ), giving tetrahedral geometry ( $\sim 109.5^\circ$ ). Trigonal pyramidal would require a lone pair ( $\text{NH}_3$ ).

44 What is the molecular geometry of  $\text{H}_3\text{O}^+$  (hydronium)?



- A Trigonal planar
- B Tetrahedral





- C Trigonal pyramidal ✓
- D Bent
- E Linear

► **Explanation:**  $\text{H}_3\text{O}^+$  has 4 electron domains around oxygen (3 bonds + 1 lone pair): tetrahedral electron geometry and trigonal pyramidal molecular geometry. Tetrahedral molecular geometry would require no lone pairs.

45 What is the molecular geometry of sulfate,  $\text{SO}_4^{2-}$ , around sulfur?



- A Trigonal planar
- B Tetrahedral ✓
- C Square planar
- D Trigonal pyramidal
- E Octahedral

► **Explanation:** Sulfate has 4 bonding regions around sulfur (four S–O bonds in the VSEPR count) and no lone pair counted on S, giving tetrahedral geometry. Trigonal planar needs 3 domains; octahedral needs 6.

46 What is the molecular geometry of phosphate,  $\text{PO}_4^{3-}$ , around phosphorus?



- A Linear
- B Trigonal planar
- C Tetrahedral ✓
- D Trigonal pyramidal
- E Octahedral





► **Explanation:** Phosphate has 4 electron domains (four P–O bonding regions) around P, giving tetrahedral geometry. Trigonal pyramidal would require a lone pair on P with 4 domains total (AX3E), which phosphate does not have in the standard picture.

47 What is the molecular geometry of  $\text{PCl}_3$ ?



- A Trigonal planar
- B Trigonal pyramidal ✓**
- C Tetrahedral
- D Linear
- E T-shaped

► **Explanation:**  $\text{PCl}_3$  has 4 electron domains (3 bonds + 1 lone pair) giving tetrahedral electron geometry and trigonal pyramidal molecular shape. Trigonal planar would require no lone pair and 3 domains.

48 What is the molecular geometry of  $\text{BeCl}_2$  (in the gas phase, as treated by VSEPR)?



- A Bent
- B Linear ✓**
- C Trigonal planar
- D Tetrahedral
- E Square planar

► **Explanation:** Beryllium has two bonding domains and no lone pairs (AX2) in  $\text{BeCl}_2$ , giving linear geometry ( $180^\circ$ ). Bent requires a lone pair.





49 Which pair correctly describes the electron-domain geometry and molecular geometry of ozone,  $O_3$ , around the central oxygen?



- A Electron geometry linear; molecular geometry linear
- B Electron geometry trigonal planar; molecular geometry bent ✓**
- C Electron geometry tetrahedral; molecular geometry bent
- D Electron geometry trigonal planar; molecular geometry trigonal planar
- E Electron geometry trigonal bipyramidal; molecular geometry linear

► **Explanation:** The central O in  $O_3$  has 3 electron domains (2 bonding regions + 1 lone pair), giving trigonal planar electron geometry and a bent molecular shape. Tetrahedral would require 4 domains; trigonal planar molecular shape would require no lone pair.

50 In formaldehyde ( $H_2C=O$ ), which bond angle is expected to be larger, and why?



- A  $H-C-H$  is larger, because H atoms repel more strongly than O does
- B  $O-C-H$  is larger, because the  $C=O$  double bond region repels more strongly than a single bond region ✓**
- C  $H-C-H$  is larger, because a double bond counts as two domains
- D  $O-C-H$  is smaller, because oxygen pulls bonding electrons away and increases repulsion
- E All angles must be exactly  $120^\circ$  in any trigonal planar molecule

► **Explanation:** Around carbon,  $CH_2O$  is trigonal planar, but electron density is not evenly distributed: the  $C=O$  region is more electron-dense and repels more, expanding adjacent angles ( $O-C-H$ ) and compressing  $H-C-H$ . C is wrong because double bonds still count as one domain. E ignores real distortions.





51 Which statement best describes  $\text{CH}_2\text{Cl}_2$ ?



- A  $\text{CH}_2\text{Cl}_2$  is trigonal planar and nonpolar
- B  $\text{CH}_2\text{Cl}_2$  is tetrahedral around carbon and polar because bond dipoles do not cancel**
- C  $\text{CH}_2\text{Cl}_2$  is linear and polar
- D  $\text{CH}_2\text{Cl}_2$  is tetrahedral and nonpolar because tetrahedral molecules always cancel dipoles
- E  $\text{CH}_2\text{Cl}_2$  is square planar because it has four bonds

► **Explanation:** Carbon has 4 bonding domains → tetrahedral. Because substituents are not all identical (two H and two Cl), dipoles do not cancel completely, so the molecule is polar. D is a common trap: tetrahedral symmetry cancels only when all four substituents are arranged symmetrically (e.g.,  $\text{CCl}_4$ ).

52 Which molecule has all its bonded atoms in a single plane around the central atom (planar around the central atom)?



- A  $\text{CH}_4$
- B  $\text{NH}_3$
- C  $\text{BF}_3$  ✓**
- D  $\text{SF}_4$
- E  $\text{H}_2\text{O}$

► **Explanation:**  $\text{BF}_3$  is trigonal planar, so all three B–F bonds lie in the same plane.  $\text{CH}_4$  is tetrahedral (3D),  $\text{NH}_3$  is pyramidal,  $\text{SF}_4$  is seesaw (3D), and  $\text{H}_2\text{O}$  is bent with tetrahedral electron geometry (not planar trigonal arrangement).

53 What is the electron-domain geometry around bromine in  $\text{BrF}_5$ ?



- A Trigonal planar





- B Tetrahedral
- C Trigonal bipyramidal
- D Octahedral ✓
- E Square planar

► **Explanation:** BrF<sub>5</sub> has 6 electron domains (5 bonding + 1 lone pair), which corresponds to octahedral electron-domain geometry. Square planar is a molecular geometry that results from 6 domains with 2 lone pairs, not 1.

54 A central atom has VSEPR type AX<sub>2</sub>E<sub>3</sub>. What is the molecular geometry?



- A Bent
- B Trigonal planar
- C Linear ✓
- D Seesaw
- E Square planar

► **Explanation:** AX<sub>2</sub>E<sub>3</sub> means 5 electron domains (trigonal bipyramidal electron geometry) with three lone pairs in equatorial positions, leaving two bonds opposite each other → linear molecular geometry.

55 How many lone pairs are on the central xenon atom in XeF<sub>2</sub> (in the VSEPR model)?



- A 0
- B 1
- C 2
- D 3 ✓





E 4

► **Explanation:** XeF<sub>2</sub> is AX<sub>2</sub>E<sub>3</sub>: two bonding pairs and three lone pairs on xenon, totaling five electron domains. This leads to linear molecular geometry after lone pairs occupy equatorial positions.

56 Which molecule has the same molecular geometry as CO<sub>2</sub>?



- A H<sub>2</sub>O
- B NH<sub>3</sub>
- C SO<sub>2</sub>
- D BeCl<sub>2</sub> ✓
- E CH<sub>4</sub>

► **Explanation:** CO<sub>2</sub> is linear. BeCl<sub>2</sub> is also linear in the VSEPR model (AX<sub>2</sub>). H<sub>2</sub>O and SO<sub>2</sub> are bent due to lone pairs; NH<sub>3</sub> is pyramidal; CH<sub>4</sub> is tetrahedral.

57 Which molecule has the same electron-domain geometry as CH<sub>4</sub> but a different molecular geometry?



- A BF<sub>3</sub>
- B CO<sub>2</sub>
- C NH<sub>3</sub> ✓
- D PCI<sub>5</sub>
- E SF<sub>6</sub>

► **Explanation:** CH<sub>4</sub> has tetrahedral electron geometry (4 domains). NH<sub>3</sub> also has 4 electron domains (tetrahedral electron geometry) but its molecular geometry is trigonal pyramidal because one domain is a lone pair. The others have different domain counts/geometries.





58 Which species has a bond angle closest to  $109.5^\circ$  (ideal tetrahedral)?



- A  $\text{NH}_4^+$  ✓
- B  $\text{BF}_3$
- C  $\text{CO}_2$
- D  $\text{SO}_2$
- E  $\text{ClF}_3$

► **Explanation:**  $\text{NH}_4^+$  is tetrahedral with no lone pairs on nitrogen, so angles are closest to  $109.5^\circ$ .  $\text{BF}_3$  is  $120^\circ$ ,  $\text{CO}_2$  is  $180^\circ$ ,  $\text{SO}_2$  is  $<120^\circ$  (bent), and  $\text{ClF}_3$  has  $\sim 90^\circ/180^\circ$  patterns (T-shaped).

59 Why is the H–O–H bond angle in water smaller than the H–N–H bond angle in ammonia?



- A Water is linear but ammonia is bent
- B Oxygen has two lone pairs, causing stronger repulsions that compress the bond angle more than in  $\text{NH}_3$  (one lone pair) ✓
- C Nitrogen cannot form tetrahedral electron geometry
- D Hydrogen atoms repel each other less when attached to oxygen
- E Water has more bonds than ammonia, so angles must be smaller

► **Explanation:** Both have tetrahedral electron geometry, but  $\text{H}_2\text{O}$  has two lone pairs (strong LP–LP and LP–BP repulsions), compressing the H–O–H angle more than  $\text{NH}_3$ , which has only one lone pair. Other options misdescribe shapes or invent rules.





60 NF3 has a smaller F–N–F bond angle than NH3 has for H–N–H. Which explanation best matches the VSEPR reasoning taught at high-school level?



- A Fluorine is larger than hydrogen, so it always increases bond angles
- B Highly electronegative F pulls bonding electron density away from N, reducing bonding-pair repulsion near N and compressing the bond angle ✓**
- C NF3 is trigonal planar while NH3 is trigonal pyramidal
- D NF3 has no lone pair while NH3 does
- E Bond angles depend only on molar mass

► **Explanation:** In both NF3 and NH3, nitrogen has 4 electron domains (AX3E) and trigonal pyramidal shape. But electronegative F pulls bonding electrons away from N, decreasing bond-pair repulsion close to N, giving a smaller angle than in NH3. Options C and D are false structural claims; A and E are oversimplifications.

61 Which molecule has the larger H–X–H bond angle?



- A H2S
- B H2O ✓**
- C They are equal because both have two lone pairs
- D Cannot be compared without knowing the pressure
- E H2S is larger because sulfur is bigger

► **Explanation:** Both are bent (AX2E2), but H2O has a significantly larger bond angle (~104.5°) than H2S (~92°). Down the group, bonding tends to use orbitals closer to p-character and the angle approaches 90°. Size alone does not guarantee a larger angle.





62 In a simple VSEPR model, the chlorate ion  $\text{ClO}_3^-$  is treated as having 4 electron domains around Cl (3 bonding regions + 1 lone pair). What is its molecular geometry?

- A Trigonal planar
- B Trigonal pyramidal ✓
- C Tetrahedral
- D Bent
- E Linear

► **Explanation:** With 4 electron domains, the electron geometry is tetrahedral. With 3 bonded atoms and 1 lone pair (AX<sub>3</sub>E), the molecular shape is trigonal pyramidal. Trigonal planar would require 3 domains and no lone pair.



63 What is the geometry around carbon in phosgene,  $\text{COCl}_2$  ( $\text{O}=\text{CCl}_2$ )?

- A Tetrahedral
- B Trigonal planar ✓
- C Linear
- D Trigonal pyramidal
- E Seesaw

► **Explanation:** Carbon has 3 electron domains (one C=O region and two C–Cl single bonds) giving trigonal planar geometry. Tetrahedral would require 4 domains; linear needs 2.



64 Which molecule is nonpolar because its tetrahedral geometry is perfectly symmetric with identical outer atoms?





- A CH<sub>2</sub>Cl<sub>2</sub>
- B CHCl<sub>3</sub>
- C CCl<sub>4</sub> ✓
- D NH<sub>3</sub>
- E H<sub>2</sub>O

► **Explanation:** CCl<sub>4</sub> is tetrahedral and fully symmetric (four identical C–Cl bonds), so dipoles cancel and it is nonpolar. CH<sub>2</sub>Cl<sub>2</sub> and CHCl<sub>3</sub> are tetrahedral but not symmetric enough; NH<sub>3</sub> and H<sub>2</sub>O have lone-pair shapes that are polar.

**65** Which molecule has octahedral electron-domain geometry but square planar molecular geometry?



- A SF<sub>6</sub>
- B BrF<sub>5</sub>
- C XeF<sub>4</sub> ✓
- D PCl<sub>5</sub>
- E SF<sub>4</sub>

► **Explanation:** XeF<sub>4</sub> has 6 electron domains (octahedral electron geometry) with 2 lone pairs placed opposite, leaving a square planar arrangement of four bonds. SF<sub>6</sub> is octahedral molecular geometry (no lone pairs). BrF<sub>5</sub> is square pyramidal (one lone pair).

**66** A central atom has 6 electron domains: 4 bonding pairs and 2 lone pairs. If the lone pairs occupy opposite positions, what is the molecular geometry?



- A Tetrahedral
- B Square planar ✓





- C Square pyramidal
- D Trigonal bipyramidal
- E Seesaw

► **Explanation:** Six domains means octahedral electron geometry. With 2 lone pairs opposite each other, the four bonds lie in one plane forming a square → square planar molecular geometry. Square pyramidal is AX<sub>5</sub>E, not AX<sub>4</sub>E<sub>2</sub>.

**67** A central atom has 5 electron domains: 3 bonding pairs and 2 lone pairs (AX<sub>3</sub>E<sub>2</sub>). What is the molecular geometry?



- A Trigonal planar
- B Trigonal pyramidal
- C T-shaped ✓
- D Seesaw
- E Square planar

► **Explanation:** Five domains corresponds to trigonal bipyramidal electron geometry. With two lone pairs, they occupy equatorial positions, leaving three bonds arranged in a T-shape (AX<sub>3</sub>E<sub>2</sub>). Seesaw is AX<sub>4</sub>E.

**68** A central atom has 4 electron domains: 2 bonding pairs and 2 lone pairs (AX<sub>2</sub>E<sub>2</sub>). What is the molecular geometry?



- A Linear
- B Bent ✓
- C Trigonal planar
- D Tetrahedral
- E Trigonal pyramidal





► **Explanation:** Four domains means tetrahedral electron geometry. With 2 bonded atoms and 2 lone pairs, the molecular geometry is bent (like H<sub>2</sub>O). Linear would require 2 domains and no lone pairs.

**69** Which statement about CH<sub>3</sub><sup>+</sup> and CH<sub>3</sub><sup>-</sup> is correct (VSEPR/basic hybridization model)?



- A** CH<sub>3</sub><sup>+</sup> is trigonal planar; CH<sub>3</sub><sup>-</sup> is trigonal pyramidal ✓
- B** CH<sub>3</sub><sup>+</sup> is trigonal pyramidal; CH<sub>3</sub><sup>-</sup> is trigonal planar
- C** Both are tetrahedral because carbon always makes 4 bonds
- D** Both are linear because they have only one carbon
- E** Neither has a defined shape because they are charged

► **Explanation:** CH<sub>3</sub><sup>+</sup> has 3 bonding domains and no lone pair on carbon (electron-deficient), giving trigonal planar. CH<sub>3</sub><sup>-</sup> has 3 bonds plus one lone pair (4 domains), giving tetrahedral electron geometry and trigonal pyramidal molecular shape. Charge alone does not remove geometry.

**70** Which species has 5 electron domains around its central atom and NO lone pairs on the central atom?



- A** PF<sub>5</sub> ✓
- B** SF<sub>4</sub>
- C** ClF<sub>3</sub>
- D** XeF<sub>2</sub>
- E** BrF<sub>5</sub>

► **Explanation:** PF<sub>5</sub> is AX<sub>5</sub> (5 bonding domains, 0 lone pairs) → trigonal bipyramidal. SF<sub>4</sub> is AX<sub>4</sub>E, ClF<sub>3</sub> is AX<sub>3</sub>E<sub>2</sub>, XeF<sub>2</sub> is AX<sub>2</sub>E<sub>3</sub>, and BrF<sub>5</sub> is AX<sub>5</sub>E (6 domains total).

