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VSEPR: Molecular Geometry, Angles & Exceptions

Printable Flashcards — Pre-Med Chemistry

VSEPR theory, electron domains, AXE notation, ideal bond angles, lone pair effects, trigonal bipyramidal/octahedral shapes, expanded octet exceptions, hybridization, and shapes for 40+ common molecules.

170 cards — Print double-sided, flip on long edge, then cut along dashed lines.

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1

VSEPR in one sentence: what's the point?

2

The 4-step VSEPR workflow (fast and reliable):

3

Electron group (electron domain) means...

4

Trap: double bonds count as 2 electron groups in VSEPR. True or false?

5

Electron geometry vs molecular geometry (what's the clean difference)?

6

Steric number (SN) shortcut =

7

Why does VSEPR care about sigma bonds (not pi bonds) for counting?

8

If a question gives you the shape and asks for steric number, remember:

2

1) Draw Lewis. 2) Count electron groups on central atom. 3) Get electron geometry. 4) Remove lone pairs -> molecular shape.

1

Electron groups around a central atom repel, so they spread out to be as far apart as possible.

4

False.

3

Any region of electron density: single bond, double bond, triple bond, or lone pair.

6

SN = (# of sigma bonds) + (# of lone pairs) on the central atom.

5

Electron geometry counts bonds + lone pairs. Molecular geometry describes the shape made by the atoms only.

8

Steric number is the electron geometry count (bonds + lone pairs).

7

Because the sigma bond is the main direction/region of electron density between atoms.

9

VSEPR counting rule: single, double, and triple bonds each count as {{c1::one}} electron group.

10

VSEPR stands for:

11

2 electron groups -> electron geometry:

12

3 electron groups -> electron geometry:

13

4 electron groups -> electron geometry:

14

5 electron groups -> electron geometry:

15

6 electron groups -> electron geometry:

16

Quick angle set to memorize: linear, trigonal planar, tetrahedral are...

10

Valence Shell Electron Pair Repulsion

9

VSEPR counting rule: single, double, and triple bonds each count as one electron group.

12

Trigonal planar (120°).

11

Linear (180°).

14

Trigonal bipyramidal (90°, 120°, 180°).

13

Tetrahedral (109.5°).

16

180°, 120°, 109.5°.

15

Octahedral (90°, 180°).

17

Electron geometry cheat: 2 -> {{c1::linear}}, 3 -> {{c2::trigonal planar}}, 4 -> {{c3::tetrahedral}}, 5 -> {{c4::trigonal bipyramidal}}, 6 -> {{c5::octahedral}}.

18

Ideal bond angle for a tetrahedral electron geometry:

19

AXE notation: what does it mean?

20

AX2 with no lone pairs gives what molecular shape?

21

AX3 with no lone pairs gives what molecular shape?

22

AX4 with no lone pairs gives what molecular shape?

23

AX3E1 gives what molecular shape?

24

AX2E2 gives what molecular shape?

18

109.5°

17

Electron geometry cheat: 2 -> linear, 3 -> trigonal planar, 4 -> tetrahedral, 5 -> trigonal bipyramidal, 6 -> octahedral.

20

Linear (180°).

19

A = central atom, X = bonded atoms, E = lone pairs on central atom.

22

Tetrahedral (109.5°).

21

Trigonal planar (120°).

24

Bent/V-shaped (~104.5° if it's like H2O).

23

Trigonal pyramidal (~107° if it's like NH3).

25

AX2E1 gives what shape and angle (typical)?

26

AXE quick: AX3E1 = {{c1::trigonal pyramidal}}; AX2E2 = {{c2::bent}}.

27

AXE for water (H2O):

28

Bond angles get smaller when you add lone pairs because...

29

Trap: NH3 has 109.5° because it comes from tetrahedral geometry. True or false?

30

Trap: H2O has a 120° bond angle because it's bent. True or false?

31

Order the angles (largest -> smallest): CH4, NH3, H2O

32

Why does H2O have a smaller angle than NH3 (even though both are 'tetrahedral-based')?

26

AXE quick: AX3E1 = trigonal pyramidal; AX2E2 = bent.

25

Bent, with angle slightly less than 120°.

28

Lone pairs repel more strongly than bonding pairs and squeeze bonds closer together.

27

AX2E2

30

False.

29

False.

32

H2O has 2 lone pairs, NH3 has 1 lone pair. More lone pairs -> more compression.

31

CH4 (109.5°) > NH3 (~107°) > H2O (~104.5°).

33

Multiple bonds vs single bonds: which repels more (in VSEPR)?

34

Trap: resonance changes the VSEPR shape. True or false?

35

Repulsion strength: lone pair-lone pair $>$ {{c1::lone pair-bond pair}} $>$ bond pair-bond pair.

36

Approximate H-O-H bond angle in water:

37

Trigonal bipyramidal has two types of positions:

38

In trigonal bipyramidal, lone pairs prefer...

39

Trap: in trigonal bipyramidal, lone pairs prefer axial because they're far apart. True or false?

40

AX5 (no lone pairs) shape:

34

Usually false for basic VSEPR.

33

Multiple bonds repel more strongly (they are electron-density heavier).

36

104.5°

35

Repulsion strength: lone pair-lone pair > lone pair-bond pair > bond pair-bond pair.

38

Equatorial positions.

37

Equatorial (3 positions, 120° apart) and axial (2 positions, 180° apart).

40

Trigonal bipyramidal (90°, 120°, 180°).

39

False.

41

AX4E1 (5 domains) shape:

42

AX3E2 (5 domains) shape:

43

AX2E3 (5 domains) shape:

44

Common trap: 'linear always means 2 electron groups'. Fix it:

45

5 domains shapes: AX5 = {{c1::trigonal bipyramidal}}, AX4E1 = {{c2::seesaw}}, AX3E2 = {{c3::T-shaped}}, AX2E3 = {{c4::linear}}.

46

Molecular shape of SF4:

47

AX6 (no lone pairs) shape:

48

AX5E1 (6 domains) shape:

42

T-shaped.

41

Seesaw.

44

Linear molecular shape can also come from 5 domains (AX2E3) or 6 domains (AX2E4).

43

Linear (180°).

46

Seesaw

45

5 domains shapes: AX5 = trigonal bipyramidal, AX4E1 = seesaw, AX3E2 = T-shaped, AX2E3 = linear.

48

Square pyramidal.

47

Octahedral (90°, 180°).

49

AX4E2 (6 domains) shape:

50

Trap: square planar comes from trigonal bipyramidal. True or false?

51

Angles in square planar are ideally...

52

AX2E4 (6 domains) gives what molecular shape?

53

6 domains shapes: AX6 = {{c1::octahedral}}, AX5E1 = {{c2::square pyramidal}}, AX4E2 = {{c3::square planar}}.

54

Molecular shape of XeF4:

55

Expanded octet: which atoms can have more than 8 electrons around them (basic rule)?

56

Trap: nitrogen can make 5 bonds like phosphorus (NF5). True or false?

50

False.

49

Square planar.

52

Linear (180°).

51

90° and 180°.

54

Square planar

53

6 domains shapes: AX6 = octahedral, AX5E1 = square pyramidal, AX4E2 = square planar.

56

False.

55

Period 3 and below (like P, S, Cl, Br, I, Xe).

57

Classic expanded-octet molecules you should recognize fast:

58

Odd-electron molecules (radicals) are an 'octet exception' because...

59

Trap: every stable molecule has a perfect octet around every atom. True or false?

60

Incomplete octet examples you should know:

61

Trap: BF3 must be tetrahedral because boron wants 8 electrons. True or false?

62

Octet exceptions: incomplete octet ({{c1::B, Be}}), expanded octet ({{c2::period 3+}}), odd-electron species ({{c3::radicals}}).

63

VSEPR: CO2 shape and typical bond angle?

64

VSEPR: HCN shape and typical bond angle?

58

They have an odd number of electrons, so someone can't complete an octet.

57

PCl5 (5 groups), SF6 (6 groups), XeF4 (6 groups).

60

BeCl2 (Be often has 4 e-), BF3 (B often has 6 e-).

59

False.

62

Octet exceptions: incomplete octet (B, Be), expanded octet (period 3+), odd-electron species (radicals).

61

False.

64

Linear; 180°.

63

Linear; 180°.

65

VSEPR: $BeCl_2$ shape and typical bond angle?

66

VSEPR: BF_3 shape and typical bond angle?

67

VSEPR: SO_3 shape and typical bond angle?

68

VSEPR: NO_3^- shape and typical bond angle?

69

VSEPR: CO_3^{2-} shape and typical bond angle?

70

VSEPR: CH_4 shape and typical bond angle?

71

VSEPR: NH_4^+ shape and typical bond angle?

72

VSEPR: SO_4^{2-} shape and typical bond angle?

66

Trigonal planar; 120°.

65

Linear; 180°.

68

Trigonal planar; 120°.

67

Trigonal planar; 120°.

70

Tetrahedral; 109.5°.

69

Trigonal planar; 120°.

72

Tetrahedral; 109.5°.

71

Tetrahedral; 109.5°.

73

VSEPR: $ClO4^-$ shape and typical bond angle?

74

VSEPR: NH3 shape and typical bond angle?

75

VSEPR: PF3 shape and typical bond angle?

76

VSEPR: H2O shape and typical bond angle?

77

VSEPR: OF2 shape and typical bond angle?

78

VSEPR: SO2 shape and typical bond angle?

79

VSEPR: O3 shape and typical bond angle?

80

VSEPR: PCl5 shape and typical bond angle?

74

Trigonal pyramidal; ~107°.

73

Tetrahedral; 109.5°.

76

Bent; ~104.5°.

75

Trigonal pyramidal; ~107°.

78

Bent; <120° (about 119°).

77

Bent; ~103° (smaller than water).

80

Trigonal bipyramidal; 90°/120°/180°.

79

Bent; <120°.

81

VSEPR: SF4 shape and typical bond angle?

82

VSEPR: ClF3 shape and typical bond angle?

83

VSEPR: XeF2 shape and typical bond angle?

84

VSEPR: I^{3-} shape and typical bond angle?

85

VSEPR: SF6 shape and typical bond angle?

86

VSEPR: BrF5 shape and typical bond angle?

87

VSEPR: XeF4 shape and typical bond angle?

88

Shape of CO2:

82

T-shaped; ~90° (distorted).

81

Seesaw; <90° and <120° (distorted).

84

Linear; 180°.

83

Linear; 180°.

86

Square pyramidal; ~90° (distorted).

85

Octahedral; 90°/180°.

88

Linear

87

Square planar; 90°/180°.

89

Bond angle in CO2:

90

Shape of BF3:

91

Ideal bond angle in BF3:

92

Shape of CH4:

93

Ideal bond angle in CH4:

94

Shape of NH3:

95

Approximate H-N-H angle in NH3:

96

Shape of H2O:

90

Trigonal planar

89

180°

92

Tetrahedral

91

120°

94

Trigonal pyramidal

93

109.5°

96

Bent

95

~107°

97

Approximate H-O-H angle in H_2O:

98

Shape of PCl_5:

99

Shape of SF_6:

100

Shape of XeF_4:

101

Shape of XeF_2:

102

CO_2 has two double bonds. Electron geometry is... and molecular geometry is...

103

SO_2: electron geometry vs molecular geometry?

104

NH_3: electron geometry vs molecular geometry?

98

Trigonal bipyramidal

97

~104.5°

100

Square planar

99

Octahedral

102

Electron geometry: linear.
Molecular geometry: linear.

101

Linear

104

Electron geometry: tetrahedral.
Molecular geometry: trigonal pyramidal.

103

Electron geometry: trigonal planar. Molecular geometry: bent.

105

H2O: electron geometry vs molecular geometry?

106

Trap: if the molecule is bent, electron geometry must be trigonal planar. True or false?

107

How do you tell which 'bent' you have (AX2E1 vs AX2E2)?

108

Trap: $NO3^-$ is trigonal pyramidal because it has 3 oxygens. True or false?

109

Trap: $CO3^{2-}$ is tetrahedral because it has 3 oxygens and a charge. True or false?

110

Trap: $SO4^{2-}$ is trigonal planar because sulfur is in the middle. True or false?

111

NH3: electron geometry {{c1::tetrahedral}}, molecular geometry {{c2::trigonal pyramidal}}.

112

SO2 molecular geometry:

106

False.

105

Electron geometry: tetrahedral.
Molecular geometry: bent.

108

False.

107

Count total electron groups on the central atom (bonds + lone pairs).

110

False.

109

False.

112

Bent

111

NH3: electron geometry tetrahedral, molecular geometry trigonal pyramidal.

113

Why is CH4 tetrahedral, not square planar?

114

Why is BF3 trigonal planar, not tetrahedral?

115

Why is CO2 linear, even
though it has 2 double bonds?

116

Why do lone pairs compress
bond angles (real reason)?

117

Why do trigonal bipyramidal
lone pairs go equatorial?

118

Why is XeF2 linear even though
xenon has 5 electron groups?

119

Why is XeF4 square planar instead of tetrahedral?

120

If you ever forget a shape,
what's the 'always works' move?

114

Boron has only 3 electron groups (3 bonds, no lone pair).

113

Because 4 electron groups spread out in 3D to minimize repulsion (tetrahedral is best).

116

Lone pairs sit closer to the central atom and take up more space, so they push bonding pairs together.

115

Because carbon still has only 2 electron groups, so they go opposite (180°).

118

Because the 3 lone pairs take equatorial spots, leaving 2 bonds opposite (axial).

117

Equatorial positions have fewer 90° interactions, so repulsion is lower.

120

Count electron groups and match them to the 2-3-4-5-6 electron geometry table.

119

Because it has 6 electron groups total; electron geometry is octahedral, and 2 lone pairs sit opposite.

121

Hybridization shortcut: steric number 2 ->

122

Hybridization shortcut: steric number 3 ->

123

Hybridization shortcut: steric number 4 ->

124

Hybridization shortcut: steric number 5 ->

125

Hybridization shortcut: steric number 6 ->

126

Trap: double bonds change hybridization count by adding a domain. True or false?

127

Hybridization of carbon in CO2:

128

Hybridization of boron in BF3:

122

sp2.

121

sp.

124

sp3d.

123

sp3.

126

False.

125

sp3d2.

128

sp2

127

sp

129

Hybridization of oxygen in H2O:

130

Steric number -> hybridization:
2={{c1::sp}}, 3={{c2::sp2}}, 4={{c3::sp3}},
5={{c4::sp3d}}, 6={{c5::sp3d2}}.

131

In VSEPR, you should count
electron groups around which atom?

132

Trap: hydrogen can be the central
atom in H2O2. True or false?

133

How to pick the central atom
quickly (most of the time)?

134

Trap: the central atom is always the one
written first in the formula. True or false?

135

When counting electron
groups, a lone pair counts as...

136

Trap: if you can't see a lone pair in the
formula, it doesn't exist. True or false?

130

Steric number -> hybridization: 2=sp, 3=sp2, 4=sp3, 5=sp3d, 6=sp3d2.

129

sp3

132

False.

131

The central atom (usually the least electronegative, not H).

134

False.

133

The least electronegative atom (except H).

136

False.

135

One electron group.

137

Quick: central carbon in carbonate ($CO3^{2-}$) has how many electron groups?

138

Quick: central sulfur in sulfate ($SO4^{2-}$) has how many electron groups?

139

Quick: central sulfur in SO2 has how many electron groups?

140

Number of electron groups around nitrogen in NH3:

141

Ideal bond angle in linear geometry:

142

Ideal bond angle in trigonal planar geometry:

143

Ideal bond angle in tetrahedral geometry:

144

Angles present in trigonal bipyramidal geometry:

138

4.

137

3.

140

4

139

3 (2 bonds + 1 lone pair).

142

120°

141

180°

144

90°, 120°, 180°

143

109.5°

145

Angles present in octahedral geometry:

146

Real molecules vs ideal angles: why are angles sometimes 'not exactly' the ideal ones?

147

Largest to smallest (tetrahedral-based): CH4 ({{c1::109.5}}) > NH3 ({{c2::~107}}) > H2O ({{c3::~104.5}}).

148

Shape name for AX3E2 (5 electron groups):

149

Shape name for AX4E2 (6 electron groups):

150

Common mix-up: trigonal planar vs trigonal pyramidal. Quick difference?

151

Common mix-up: tetrahedral vs square planar. Quick difference?

152

Common mix-up: seesaw vs tetrahedral. Why isn't SF4 tetrahedral?

146

Because lone pairs and different bond types change repulsions and distort the ideal geometry.

145

90°, 180°

148

T-shaped

147

Largest to smallest (tetrahedral-based): CH4 (109.5) > NH3 (~107) > H2O (~104.5).

150

Trigonal planar has 0 lone pairs (AX3). Trigonal pyramidal has 1 lone pair (AX3E1).

149

Square planar

152

SF4 has 5 electron groups (4 bonds + 1 lone pair) -> trigonal bipyramidal electron geometry -> seesaw.

151

Tetrahedral is 4 domains total. Square planar is 6 domains total (AX4E2).

153

Common mix-up: T-shaped vs trigonal planar. Why isn't ClF3 trigonal planar?

154

Common mix-up: XeF2 vs CO2. Both are linear, but the electron geometry is...

155

If a question says 'linear but has 5 electron groups', what AXE must it be?

156

If a question says 'square planar', what electron geometry is hiding behind it?

157

Shape confusion fix: trigonal pyramidal = AX3{{c1::E1}}; trigonal planar = AX3{{c2::E0}}.

158

VSEPR: NO_2^- (around central N) shape and angle?

159

VSEPR: NO_2^+ (around central N) shape and angle?

160

VSEPR: NH_2^- (around central N) shape and angle?

154

CO2: 2 domains (linear electron geometry). XeF2: 5 domains (trigonal bipyramidal electron geometry).

153

ClF3 has 5 electron groups (3 bonds + 2 lone pairs) -> trigonal bipyramidal electron geometry -> T-shaped.

156

Octahedral.

155

AX2E3.

158

Bent; <120°.

157

Shape confusion fix: trigonal pyramidal = AX3E1; trigonal planar = AX3E0.

160

Bent; <109.5°.

159

Linear; 180°.

161

VSEPR: $H3O^{+}$ (around central O) shape and angle?

162

VSEPR: SO4 (around central S) shape and angle?

163

VSEPR: $ClO3^{-}$ (around central Cl) shape and angle?

164

VSEPR: PCl3 (around central P) shape and angle?

165

VSEPR: COCl2 (phosgene) (around central C) shape and angle?

166

VSEPR: CH2O (formaldehyde) (around central C) shape and angle?

167

VSEPR: C2H4 (each C) (around central C) shape and angle?

168

VSEPR: C2H2 (each C) (around central C) shape and angle?

162

Tetrahedral; 109.5°.

161

Trigonal pyramidal; <109.5°.

164

Trigonal pyramidal; <109.5°.

163

Trigonal pyramidal; <109.5°.

166

Trigonal planar; ~120°.

165

Trigonal planar; ~120°.

168

Linear; 180°.

167

Trigonal planar; ~120°.

169

Shape of NO_3^- (nitrate):

170

Shape of SO_4^{2-} (sulfate):

170

Tetrahedral

169

Trigonal planar