Covalent bonding

A Level

Part A Number of bonding electrons

Which of the following molecules contains six bonding electrons?

- H_2S
- NCl_3
- C_2H_4
- SF_6
- CO_2

Part B $\mathrm{P-H}$ and $\mathrm{Cl-H}$ bonds

The $\mathrm{P-H}$ bond energy is the mean (average) of the $\mathrm{H-H}$ and $\mathrm{P-P}$ values. Explain why the $\mathrm{H-Cl}$ bond energy is **not** the mean of the $\mathrm{H-H}$ and $\mathrm{Cl-Cl}$ values.

Some bond energy values are given in the table below:

bond	bond energy/$\mathrm{kJ\,mol^{-1}}$	bond	bond energy/$\mathrm{kJ\,mol^{-1}}$
$\mathrm{H-H}$	436	$\mathrm{H-H}$	436
$\mathrm{P-P}$	208	$\mathrm{Cl-Cl}$	244
$\mathrm{P-H}$	322	$\mathrm{H-Cl}$	431

1 The $\mathrm{Cl-H}$ bond is more polar than the $\mathrm{P-H}$ bond.
2 Cl has a smaller covalent radius than P.
3 P has five valence electrons whereas Cl has seven.

- ○ **1, 2** and **3** are correct
- ○ **1** and **2** only are correct
- ○ **2** and **3** only are correct
- ○ **1** only is correct
- ○ **3** only is correct

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Shapes of molecules and ions

A Level

Part A F_2O

By considering the number of lone and bonding pairs of electrons, predict the shape of F_2O.

Part B H_3O^+

By considering the number of lone and bonding pairs of electrons, predict the shape of H_3O^+.

Part C ClF_4^-

By considering the number of lone and bonding pairs of electrons, predict the shape of ClF_4^-.

Part D SbF_5^{n-}

Antimony, Sb, is in group 15 of the Periodic Table. It forms a series of salts which contain the SbF_5^{n-} anion, the structure of which is a square-based pyramid:

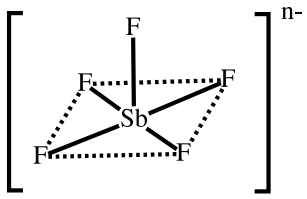

Figure 1: Structure of the SbF_5^{n-} anion

Deduce the total number of electrons around the antimony atom.

Deduce the value of n.

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Dative bond and similar shapes

A Level

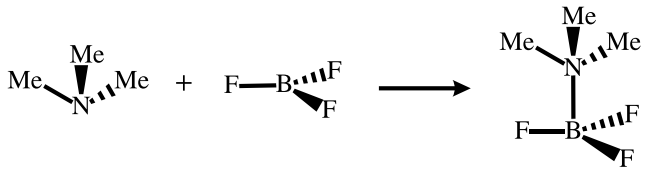
Part A Me_3N and BF_3

Trimethylamine, Me_3N, reacts with boron trifluoride, BF_3, to form a compound of formula Me_3NBF_3.

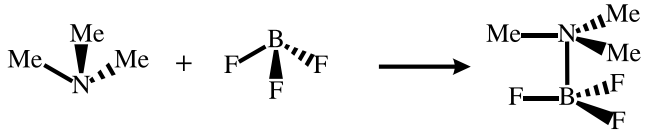
$[Me = CH_3]$

How may this reaction be drawn in terms of the shapes of the reactants and products?

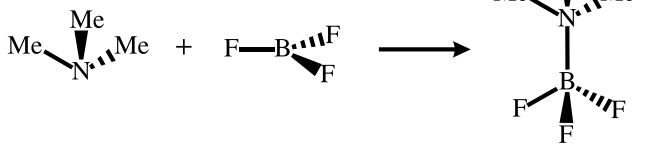
A



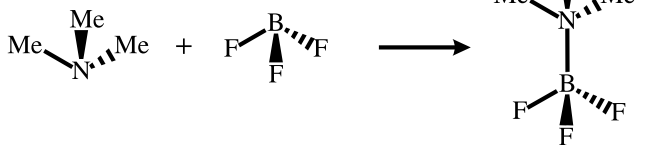
B



C



D



- A
- B
- C
- D

Part B Similar shapes

In which of the following pairs do the molecules have similar shapes?

- BF_3 and NH_3
- CO_2 and SO_2
- $AlCl_3$ and BCl_3
- $AlCl_3$ and PCl_3
- $BeCl_2$ and H_2O

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Part B adapted with permission from UCLES, A-Level Chemistry, June 1993, Paper 4, Question 6

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Shapes and angles

A Level

Part A BCl_3 and PCl_3

Why is the molecule of BCl_3 planar, whereas the molecule of PH_3 is pyramidal?

- The boron atom has no d-orbitals available for bonding.
- The boron atom in BCl_3 has six electrons in its valency shell, whereas the phosphorus atom in PH_3 has eight.
- The repulsion between chlorine atoms is greater than that between hydrogen atoms,
- The covalent radius of phosphorus is greater than that of boron.
- The covalent radius of chlorine is greater than that of hydrogen.

Part B NH_3

In the ammonia molecule, what is the approximate value of the $H-N-H$ bond angle?

- 180°
- 120°
- 107°
- 90°
- 60°

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Part B adapted with permission from OCSEB, A-Level Chemistry, June 1994, Paper 1, Question 1

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Shape of ozone

A Level
C C C

Part A O_3

Predict the shape of the ozone molecule O_3.

Part B

How many lone pairs of electrons are in O_3?

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Part B created for isaacphysics.org by Robert Less

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Bond angles

A Level

Part A Methane, ammonia and water

The bond lengths and bond angles in the molecules of methane, ammonia and water may be represented as follows:

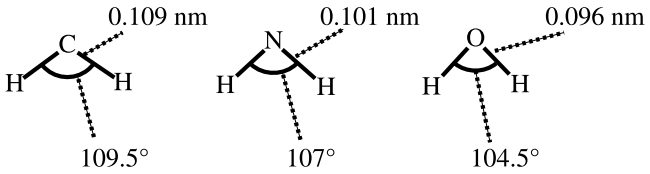

Figure 1: Shapes of molecules of methane, ammonia and water.

What causes this trend in the bond angles shown, according to valence shell electron pair repulsion theory?

1 increasing repulsion between hydrogen atoms as the bond length decreases
2 the number of non-bonding electron pairs in the molecule
3 a nonbonding electron pair having a greater repulsive force than a bonding electron pair

- **1, 2** and **3** are correct
- **1** and **2** only are correct
- **2** and **3** only are correct
- **1** only is correct
- **3** only is correct

Part B SO_3^{2-}

The SO_3^{2-} ion may be represented as (geometry not necessarily representative):

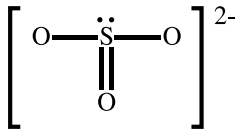

Figure 2: SO_3^{2-} ion

What is the $O-S-O$ bond angle?

- $90°$ exactly
- about $107°$
- about $109.5°$
- $120°$ exactly

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Shape of $SnCl_2$

A Level

Which of the following structures represents the gaseous $SnCl_2$ molecule? The orbital lobe represents a lone (unshared) pair of electrons.

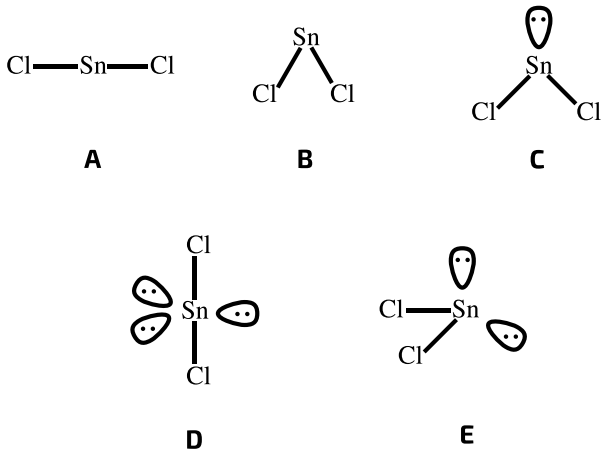

Figure 1: Possible shapes of $SnCl_2$

- A
- B
- C
- D
- E

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Shapes of fluorides

A Level

For each of the following, enter a one to two word answer, using appropriate shape of molecule terminology, e.g. "linear".

Part A BF_3

Describe the shape of BF_3.

Part B CF_4

Describe the shape of CF_4.

Part C NF_3

Describe the shape of NF_3.

Part D SF_6

Describe the shape of SF_6.

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Shapes of halide compounds

A Level
C C C

For each of the following, deduce the shape of the molecules and enter a one to two word answer, using appropriate shape of molecule terminology, e.g. "linear".

Part A BBr_3

Deduce the shape of of BBr_3.

Part B PF_3

Deduce the shape of of PF_3.

Part C SF_4

Deduce the shape of SF_4.

Part D IF_5

Deduce the shape of IF_5.

Part E $AlCl_3$ **and** Cl^-

Predict the shape of the species formed from the reaction of $AlCl_3$ with Cl^-.

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Shapes of xenon compounds

A Level

C C C

For each of the following, deduce the shape of the molecules and enter a one to two word answer, using appropriate shape of molecule terminology, e.g. "linear".

Part A XeF_2

Describe the shape of XeF_2.

Part B $XeOF_2$

Describe the shape of $XeOF_2$.

Part C XeO_4

Describe the shape of XeO_4.

Part D XeF_4

Describe the shape of XeF_4.

Part E $XeOF_4$

Describe the shape of $XeOF_4$.

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