# Covalent bonding

A Level

## Part A Number of bonding electrons

Which of the following molecules contains six bonding electrons?

- $NCl_3$
- $C_2H_4$
- $SF_6$
- $H_2S$
- $CO_2$

## 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** $\mathrm{Cl}$ has a smaller covalent radius than $\mathrm{P}$.
**3** $\mathrm{P}$ has five valence electrons whereas $\mathrm{Cl}$ 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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Part A adapted with permission from UCLES, A-Level Chemistry, November 1992, Paper 4, Question 5;
Part B adapted with permission from UCLES, A-Level Chemistry, June 1991, Paper 2, Question 2

# 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 $\mathrm{SbF_5}^{n-}$

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

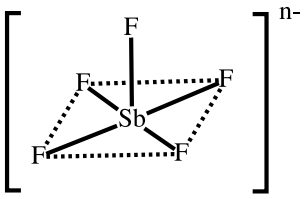



**Figure 1:** Structure of the $\mathrm{SbF_5}^{n-}$ anion

Deduce the total number of electrons around the antimony atom.

Deduce the value of $n$.

Adapted with permission from UCLES, A-Level Chemistry, June 1991, Paper 3, Question 2

# Dative bond and similar shapes

A Level

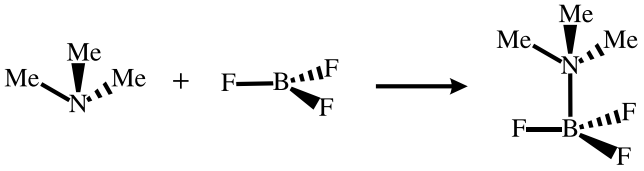
## Part A $Me_3N$ and $BF_3$

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

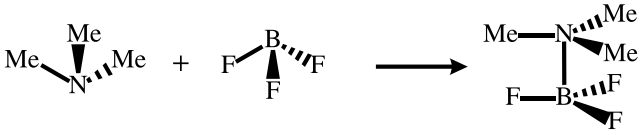
$[Me = CH_3]$

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

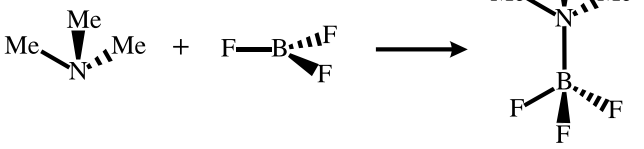
**A**



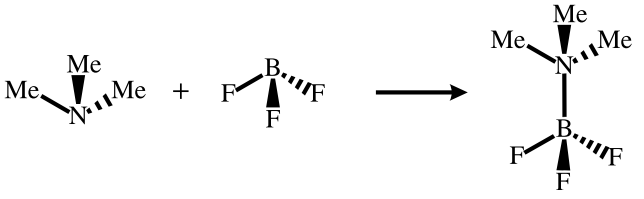

**B**




**C**




**D**




- A
- B
- C
- D

## Part B Similar shapes

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

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

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Part A adapted with permission from UCLES, A-Level Chemistry, June 1995, Paper 4, Question 3;
Part B adapted with permission from UCLES, A-Level Chemistry, June 1993, Paper 4, Question 6

# 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?

- $180^\circ$
- $120^\circ$
- $107^\circ$
- $90^\circ$
- $60^\circ$

Part A adapted with permission from UCLES, A-Level Chemistry, June 1991, Paper 3, Question 4;
Part B adapted with permission from OCSEB, A-Level Chemistry, June 1994, Paper 1, Question 1

# Shape of ozone

A Level

## Part A $O_3$

Predict the shape of the ozone molecule $O_3$.

## Part B

How many lone pairs of electrons are in $O_3$?

Part A adapted with permission from UCLES, A-Level Chemistry, November 1995, Paper 1, Question 5;
Part B created for isaacphysics.org by Robert Less

# 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:

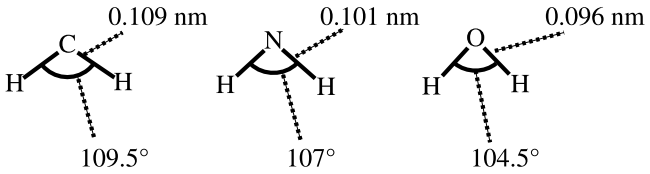


**Figure 1:** Shapes of molecules of methane, ammonia and water.

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):

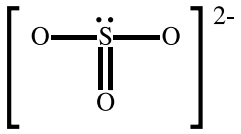


**Figure 2:** $SO_3^{2-}$ ion

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

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

Part A adapted with permission from UCLES, A-Level Chemistry, June 1992, Paper 4, Question 31;
Part B adapted with permission from UCLES, A-Level Chemistry, November 1993, Paper 4, Question 2

# 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.

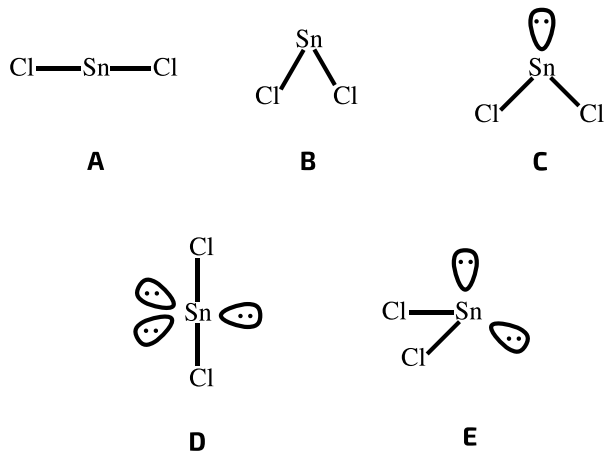


**Figure 1:** Possible shapes of $SnCl_2$

- A
- B
- C
- D
- E

Adapted with permission from UCLES, A-Level Chemistry, November 1991, Paper 1, Question 5

# 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 $SF_6$.

Part A adapted with permission from UCLES, A-Level Chemistry, November 1995 , Paper 1, Question 1

# Shapes of halide compounds

A Level

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** $\mathrm{BBr_3}$

Deduce the shape of of $\mathrm{BBr_3}$.

**Part B** $\mathrm{PF_3}$

Deduce the shape of of $\mathrm{PF_3}$.

**Part C** $\mathrm{SF_4}$

Deduce the shape of $\mathrm{SF_4}$.

**Part D** $\mathrm{IF_5}$

Deduce the shape of $\mathrm{IF_5}$.

**Part E** $\mathrm{AlCl_3}$ **and** $\mathrm{Cl^-}$

Predict the shape of the species formed from the reaction of $\mathrm{AlCl_3}$ with $\mathrm{Cl^-}$.

Adapted with permission from OCSEB, STEP Chemistry, Jun 1998, Question 4

# Shapes of xenon compounds

A Level

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** $\mathrm{XeF_2}$

Describe the shape of $\mathrm{XeF_2}$.

**Part B** $\mathrm{XeOF_2}$

Describe the shape of $\mathrm{XeOF_2}$.

**Part C** $\mathrm{XeO_4}$

Describe the shape of $\mathrm{XeO_4}$.

**Part D** $\mathrm{XeF_4}$

Describe the shape of $\mathrm{XeF_4}$.

**Part E** $\mathrm{XeOF_4}$

Describe the shape of $\mathrm{XeOF_4}$.

Part A adapted with permission from OCR, STEP Chemistry, June 1999, Question 5