

Topic 14: Chemical bonding and structure

7 hours

Essential idea: Larger structures and more in-depth explanations of bonding systems often require more sophisticated concepts and theories of bonding.

14.1 Further aspects of covalent bonding and structure

Nature of science:

Principle of Occam's razor—bonding theories have been modified over time. Newer theories need to remain as simple as possible while maximizing explanatory power, for example the idea of formal charge. (2.7)

Understandings:

- Covalent bonds result from the overlap of atomic orbitals. A sigma bond (σ) is formed by the direct head-on/end-to-end overlap of atomic orbitals, resulting in electron density concentrated between the nuclei of the bonding atoms. A pi bond (π) is formed by the sideways overlap of atomic orbitals, resulting in electron density above and below the plane of the nuclei of the bonding atoms.
- Formal charge (FC) can be used to decide which Lewis (electron dot) structure is preferred from several. The FC is the charge an atom would have if all atoms in the molecule had the same electronegativity. $FC = (\text{Number of valence electrons}) - \frac{1}{2}(\text{Number of bonding electrons}) - (\text{Number of non-bonding electrons})$. The Lewis (electron dot) structure with the atoms having FC values closest to zero is preferred.
- Exceptions to the octet rule include some species having incomplete octets and expanded octets.
- Delocalization involves electrons that are shared by/between all atoms in a molecule or ion as opposed to being localized between a pair of atoms.
- Resonance involves using two or more Lewis (electron dot) structures to represent a particular molecule or ion. A resonance structure is one of two or more alternative Lewis (electron dot) structures for a molecule or ion that cannot be described fully with one Lewis (electron dot) structure alone.

International-mindedness:

- How has ozone depletion changed over time? What have we done as a global community to reduce ozone depletion?
- To what extent is ozone depletion an example of both a success and a failure for solving an international environmental concern?

Theory of knowledge:

- Covalent bonding can be described using valence bond or molecular orbital theory. To what extent is having alternative ways of describing the same phenomena a strength or a weakness?

Utilization:

- Drug action and links to a molecule's structure.
- Vision science and links to a molecule's structure.

Syllabus and cross-curricular links:

Topics 4.2 and 4.3—Lewis (electron dot) structures, VSEPR theory, resonance and bond and molecular polarity
 Topic 10.1—shapes of organic molecules
 Topic 13.1—transition metal chemistry

14.1 Further aspects of covalent bonding and structure**Applications and skills:**

- Prediction whether sigma (σ) or pi (π) bonds are formed from the linear combination of atomic orbitals.
- Deduction of the Lewis (electron dot) structures of molecules and ions showing all valence electrons for up to six electron pairs on each atom.
- Application of FC to ascertain which Lewis (electron dot) structure is preferred from different Lewis (electron dot) structures.
- Deduction using VSEPR theory of the electron domain geometry and molecular geometry with five and six electron domains and associated bond angles.
- Explanation of the wavelength of light required to dissociate oxygen and ozone.
- Description of the mechanism of the catalysis of ozone depletion when catalysed by CFCs and NO_x .

Guidance:

- The linear combination of atomic orbitals to form molecular orbitals should be covered in the context of the formation of sigma (σ) and pi (π) bonds.
- Molecular polarities of geometries corresponding to five and six electron domains should also be covered.

Aims:

- **Aim 1:** Global impact of ozone depletion.
- **Aim 7:** Computer simulations can be used to model structures predicted by VSEPR theory.
- **Aim 8:** Moral, ethical, social, economic and environmental implications of ozone depletion and its solution.

Essential idea: Hybridization results from the mixing of atomic orbitals to form the same number of new equivalent hybrid orbitals that can have the same mean energy as the contributing atomic orbitals.

14.2 Hybridization

Nature of science:

The need to regard theories as uncertain—hybridization in valence bond theory can help explain molecular geometries, but is limited. Quantum mechanics involves several theories explaining the same phenomena, depending on specific requirements. (2.2)

Understandings:

- A hybrid orbital results from the mixing of different types of atomic orbitals on the same atom.

Applications:

- Explanation of the formation of sp^3 , sp^2 and sp hybrid orbitals in methane, ethene and ethyne.
- Identification and explanation of the relationships between Lewis (electron dot) structures, electron domains, molecular geometries and types of hybridization.

Guidance:

- Students need only consider species with sp^3 , sp^2 and sp hybridization.

Theory of knowledge:

- Hybridization is a mathematical device which allows us to relate the bonding in a molecule to its symmetry. What is the relationship between the natural sciences, mathematics and the natural world? Which role does symmetry play in the different areas of knowledge?

Utilization:

Syllabus and cross-curricular links:

Topic 4.3—Lewis (electron dot) structures, VSEPR theory, resonance and bond and molecular polarity

Topic 10.1—shapes of organic molecules

Topic 13.1—transition metal chemistry

Aims:

- **Aim 7:** Computer simulations could be used to model hybrid orbitals.