Summary

Unit 4/14 Chemical Bonding

Subject	Year	Start date	Duration
Chemistry	IB1	Week 2, November	5 weeks 12 hours

Course Part

Core and Higher level

Description

The universe may be in chaos overall, but the pockets of order within the whole can be a source of great beauty. One area that demonstrates the impressive beauty of self-assembly and order is the field of ionic crystals. Ionic compounds consist of ions held together in a lattice structure by ionic bonds. Larger structures and more in-depth explanations of bonding systems often require more sophisticated concepts and theories of bonding.

Inquiry & Purpose

Inquiry / Higher Order Questions

Type	Inquiry Questions
Concept-based	Science has been described as a self-correcting and communal public endeavour. To what extent do these characteristics apply to the other areas of knowledge?

Curriculum

Aims

Develop an ability to analyse, evaluate and synthesize scientific information

Develop a critical awareness of the need for, and the value of, effective collaboration and communication during scientific activities

Develop experimental and investigative scientific skills including the use of current technologies

Develop and apply 21st century communication skills in the study of science

Objectives

Demonstrate knowledge and understanding of

communicating scientific information

Apply

methodologies and techniques

Formulate, analyse and evaluate

hypotheses, research questions and predictions

scientific explanations

Syllabus Content

Core

4. Chemical bonding and structure

4.1 Ionic bonding and structure

Nature of science:

Use theories to explain natural phenomena - molten ionic compounds conduct electricity but solid ionic compounds do not. The solubility and melting points of ionic compounds can be used to explain observations.

Understandings:

Positive ions (cations) form by metals losing valence electrons.

Negative ions (anions) form by non-metals gaining electrons.

The number of electrons lost or gained is determined by the electron configuration of the atom.

The ionic bond is due to electrostatic attraction between oppositely charged ions.

Under normal conditions, ionic compounds are usually solids with lattice structures.

Applications and skills:

Deduction of the formula and name of an ionic compound from its component ions, including polyatomic ions.

Explanation of the physical properties of ionic compounds (volatility, electrical conductivity and solubility) in terms of their structure.

4.2. Covalent bonding

Nature of science:

Looking for trends and discrepancies - compounds containing non-metals have different properties than compounds that contain non-metals and metals.

Use theories to explain natural phenomena - Lewis introduced a class of compounds which share electrons. Pauling used the idea of electronegativity to explain unequal sharing of electrons.

Understandings:

A covalent bond is formed by the electrostatic attraction between a shared pair of electrons and the positively charged nuclei.

Single, double and triple covalent bonds involve one, two and three shared pairs of electrons respectively.

Bond length decreases and bond strength increases as the number of shared electrons increases.

Bond polarity results from the difference in electronegativities of the bonded atoms.

Applications and skills:

Deduction of the polar nature of a covalent bond from electronegativity values.

4.3 Covalent structures

Nature of science:

Scientists use models as representations of the real world - the development of the model of molecular shape (VSEPR) to explain observable properties.

Understandings:

Lewis (electron dot) structures show all the valence electrons in a covalently bonded species.

The “octet rule” refers to the tendency of atoms to gain a valence shell with a total of 8 electrons.

Some atoms, like Be and B, might form stable compounds with incomplete octets of electrons.

Resonance structures occur when there is more than one possible position for a double bond in a molecule.

Shapes of species are determined by the repulsion of electron pairs according to VSEPR theory.

Carbon and silicon form giant covalent/network covalent structures.

Applications and skills:

Deduction of Lewis (electron dot) structure of molecules and ions showing all valence electrons for up to four electron pairs on each atom.

The use of VSEPR theory to predict the electron domain geometry and the molecular geometry for species with two, three and four electron domains.

Prediction of bond angles from molecular geometry and presence of non-bonding pairs of electrons.

Prediction of molecular polarity from bond polarity and molecular geometry.

Deduction of resonance structures, examples include but are not limited to C_6H_6, CO_3^{2-} and O_3.

Explanation of the properties of giant covalent compounds in terms of their structures.

4.4 Intermolecular forces

Nature of science:

Obtain evidence for scientific theories by making and testing predictions based on them - London (dispersion) forces and hydrogen bonding can be used to explain special interactions. For example, molecular covalent compounds can exist in the liquid and solid states. To explain this, there must be attractive forces between their particles which are significantly greater than those that could be attributed to gravity.

Understandings:

Intermolecular forces include London (dispersion) forces, dipole-dipole forces and hydrogen bonding.

The relative strengths of these interactions are London (dispersion) forces < dipole-dipole forces < hydrogen bonds.

Applications and skills:

Deduction of the types of intermolecular force present in substances, based on their structure and chemical formula.

Explanation of the physical properties of covalent compounds (volatility, electrical conductivity and solubility) in terms of their structure and intermolecular forces.

4.5 Metallic bonding

Nature of science:

Use theories to explain natural phenomena - the properties of metals are different from covalent and ionic substances and this is due to the formation of non-directional bonds with a “sea” of delocalized electrons.

Understandings:

A metallic bond is the electrostatic attraction between a lattice of positive ions and delocalized electrons.

The strength of a metallic bond depends on the charge of the ions and the radius of the metal ion.

Alloys usually contain more than one metal and have enhanced properties.

Applications and skills:

Explanation of electrical conductivity and malleability in metals.

Explanation of trends in melting points of metals.

Explanation of the properties of alloys in terms of non-directional bonding.

Additional higher level

14. Chemical bonding and structure

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.

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 = (Number of valence electrons)-½(Number of bonding electrons)-(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.

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 NOx.

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.

Understandings:

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

Applications:

Explanation of the formation of sp3, sp2 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.

ATL Skills

Approaches to Learning

Thinking

- In this unit, we will

ask students to formulate a reasoned argument to support their opinion or conclusion

give students time to think through their answers before asking them for a response

reward a new personal understanding, solution or approach to an issue

ask open questions

set students a task which required higher-order thinking skills (such as analysis or evaluation)

build on a specific prior task

help students to make their thinking more visible (for example, by using a strategy such as a thinking routine)

require students to take an unfamiliar viewpoint into account when formulating arguments

ask questions that required the use of knowledge from a different subject from the one you are teaching

include a reflection activity

make a link to TOK

Communication

- In this unit, we will

ask students to explain their understanding of a text or idea to each other

construct a task around the use of different vocabulary and examples when speaking to different audiences

have students give an oral presentation without reading from their notes

ask students to monitor and check the quality of their writing

encourage all students to contribute to discussions

Developing IB Learners

Learner Profile

Knowledgeable

Thinkers