MEGA LECTURE

IB DP CHEMISTRY

Structure 2 · Models of Bonding and Structure

TOPICAL WORKSHEET

S2.1 The Ionic Model · S2.2 The Covalent Model

S2.3 The Metallic Model · S2.4 From Models to Materials

Standard and Higher Level · Syllabus 2025

Fahad H. Ahmad

+92 323 509 4443 | Megalecture.com

Original exam-style questions written for the IB Diploma Programme Chemistry course (first assessment 2025)

Section A — Multiple Choice (15 marks)

Circle the letter of the best answer to each question. Each question is worth 1 mark.

1. An ionic bond is best described as **[1]**

A the sharing of a pair of electrons between two atoms

B the electrostatic attraction between a sea of delocalized electrons and a lattice of cations

C the electrostatic attraction between oppositely charged ions formed by electron transfer

D a weak intermolecular force between polar molecules

2. In the ionic lattice of sodium chloride, the coordination number of each ion (the number of oppositely charged nearest neighbours) is **[1]**

A 4

B 6

C 8

D 12

3. Which property is characteristic of ionic compounds? **[1]**

A Low melting point and good electrical conductivity as a solid

B High melting point and electrical conductivity only when molten or in aqueous solution

C Low melting point and no electrical conductivity in any state

D High melting point and electrical conductivity as a solid

4. Lattice enthalpy generally increases as ionic radius decreases and ionic charge increases. Which pair of ions would be expected to form a compound with the greatest lattice enthalpy? **[1]**

A Na^{+} and Cl^{-}

B Na^{+} and F^{-}

C Mg^{2+} and O^{2-}

D K^{+} and Br^{-}

5. A covalent bond is best described as **[1]**

A the electrostatic attraction between oppositely charged ions

B a shared pair of electrons that provides an attractive force between two atomic nuclei

C the transfer of electrons from one atom to another

D the attraction between a delocalized electron sea and cations

6. Using VSEPR theory, the molecular shape of methane, CH_4, (4 bonding pairs, 0 lone pairs on the central atom) is **[1]**

A trigonal planar

B trigonal pyramidal

C tetrahedral

D linear

7. Which of the following statements about a polar covalent bond is correct? **[1]**

A The bonded atoms have identical electronegativities

B There is an unequal sharing of the bonding electron pair, creating partial charges on each atom

C The bonding electron pair is completely transferred to one atom

D Polar bonds only occur between two atoms of the same element

8. A central atom has 2 bonding electron domains and 2 lone pairs. What is the resulting molecular shape (e.g. as in H_2O)? **[1]**

A Linear

B Bent (V-shaped)

C Trigonal pyramidal

D Tetrahedral

9. Metallic bonding can be described as **[1]**

A a lattice of anions in a sea of delocalized electrons

B the electrostatic attraction between a lattice of cations and a sea of delocalized electrons

C covalent bonds between adjacent metal atoms

D hydrogen bonds between metal atoms

10. Metals are good conductors of electricity mainly because **[1]**

A their ions are free to move through the lattice

B they contain delocalized electrons that are free to move throughout the structure

C they have low melting points

D their atoms are covalently bonded in a rigid lattice

11. Metals are malleable (can be hammered into shape) because **[1]**

A the layers of cations can slide over each other without breaking the non-directional metallic bond

B the covalent bonds between atoms are very strong

C the ionic bonds break and reform easily

D metals have very low densities

12. An alloy is best defined as **[1]**

A a pure metallic element in its natural state

B a mixture of a metal with one or more other elements (often metals), designed to enhance its properties

C an ionic compound formed between two metals

D a compound formed by covalent bonding between metal atoms

13. Silicon dioxide, SiO_2, is an example of a **[1]**

A simple molecular covalent structure

B giant covalent (macromolecular) structure

C giant ionic lattice

D metallic lattice

14. Graphite is able to conduct electricity, unlike diamond, because **[1]**

A graphite contains free-moving ions

B each carbon atom in graphite is bonded to only 3 others, leaving one delocalized electron per atom free to move within the layers

C graphite has a lower density than diamond

D diamond is an ionic compound

15. Compared with a giant covalent structure, a simple molecular covalent substance (e.g. I_2 or CO_2) typically has a **[1]**

A much higher melting point, due to strong covalent bonds between molecules

B much lower melting point, because only weak intermolecular forces need to be overcome, not covalent bonds

C similar melting point, since both contain covalent bonds

D higher electrical conductivity in the solid state

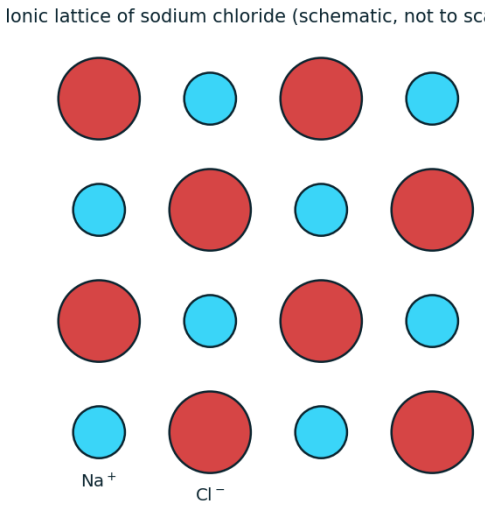
Section B — Structured Questions (66 marks)

Answer all questions in the space provided. Working must be shown for full marks.

S2.1 The Ionic Model

Question 1 [7 marks]

The diagram shows part of the ionic lattice structure of sodium chloride, NaCl.



Ionic lattice of sodium chloride (schematic, not to scale).

(a) Using the diagram, state the coordination number of the Na^+ ion in this lattice (in the full three-dimensional structure). **[2]**

(b) Explain, in terms of electron transfer, how the ionic bond between sodium and chlorine forms. **[3]**

(c) Deduce the empirical formula of sodium chloride from the ratio of ions shown in the lattice. **[2]**

Question 2 [6 marks]

Ionic compounds such as sodium chloride share several characteristic physical properties.

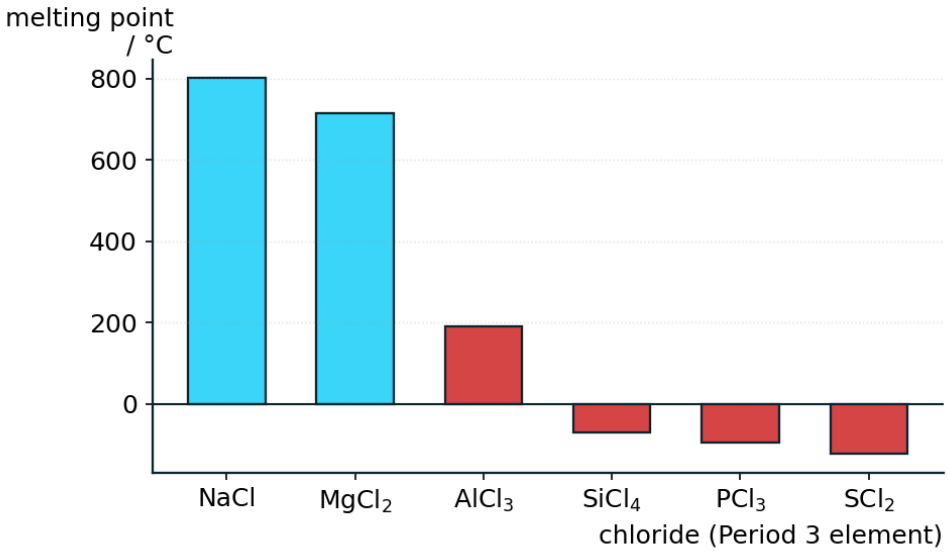
(a) State and explain why ionic compounds typically have high melting points. **[2]**

(b) Explain why solid sodium chloride does not conduct electricity, but molten or aqueous sodium chloride does. **[2]**

(c) Explain why ionic crystals are brittle and tend to shatter when struck, rather than bending. **[2]**

Question 3 [7 marks]

The graph shows the melting points of the chlorides of the Period 3 elements, from sodium to sulfur.



Melting points of Period 3 chlorides (given data).

(a) Using the graph, identify which chlorides are ionic and which are simple molecular covalent, giving a reason based on melting point. **[2]**

(b) Explain the sharp fall in melting point between $MgCl_2$ and $AlCl_3$ in terms of bonding type. **[3]**

(c) Explain why $SiCl_4$ has a very low melting point. **[2]**

S2.2 The Covalent Model

Question 4 [7 marks]

Ammonia, NH_3, is a simple covalent molecule with the nitrogen atom as the central atom.

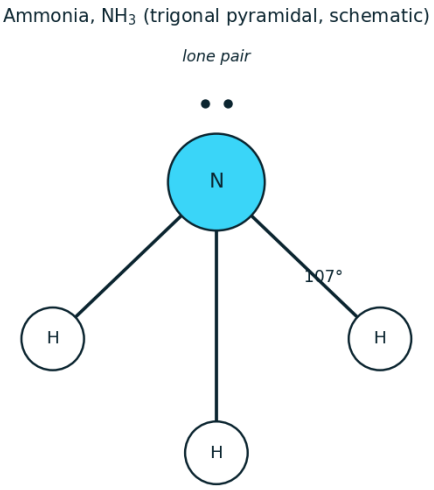
(a) State the number of bonding electron pairs and the number of lone pairs on the central nitrogen atom in NH_3. **[2]**

(b) Using VSEPR theory, deduce the molecular shape and approximate bond angle of NH_3. **[3]**

(c) Explain why the H_3N bond angle (107°) is smaller than the ideal tetrahedral angle of 109.5°. **[2]**

Question 5 [6 marks]

The diagram shows the shape of an ammonia molecule, NH_3, determined using VSEPR theory.



Ammonia, NH_3 (trigonal pyramidal, schematic).

(a) Identify the molecular shape and bond angle shown in the diagram. **[2]**

(b) Explain the difference between 'electron domain geometry' and 'molecular geometry' for a molecule such as NH_3. **[2]**

(c) Predict the molecular shape of a water molecule, H_2O, which has 2 bonding pairs and 2 lone pairs on the central oxygen atom. **[2]**

Question 6 [7 marks]

Consider the carbon-chlorine bond in tetrachloromethane, CCl_4. (Pauling electronegativities: C = 2.55, Cl = 3.16.)

(a) Calculate the electronegativity difference between carbon and chlorine, and use it to explain the polarity of a single C−Cl bond. **[2]**

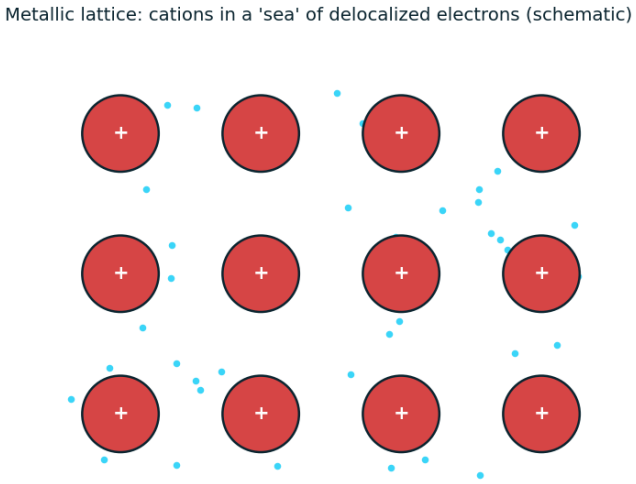
(b) CCl_4 is a tetrahedral molecule with four identical, symmetrically arranged C−Cl bonds. Deduce whether the CCl_4 molecule as a whole is polar, explaining your reasoning. **[3]**

(c) Compare the boiling points expected for CH_4 and CCl_4, explaining your answer in terms of intermolecular forces. **[2]**

S2.3 The Metallic Model

Question 7 [6 marks]

The diagram shows a simplified model of the structure of a typical metal.



Metallic lattice: cations in a 'sea' of delocalized electrons (schematic).

(a) Describe the type of bonding shown in the diagram. **[2]**

(b) Explain why metals are good conductors of electricity, using the diagram to support your answer. **[2]**

(c) Explain why metals are malleable (can be bent or hammered into shape without breaking). **[2]**

Question 8 [7 marks]

Sodium (Na) and magnesium (Mg) are both Period 3 metals with the giant metallic structure.

(a) Magnesium has a considerably higher melting point than sodium. Explain this difference in terms of metallic bonding. **[3]**

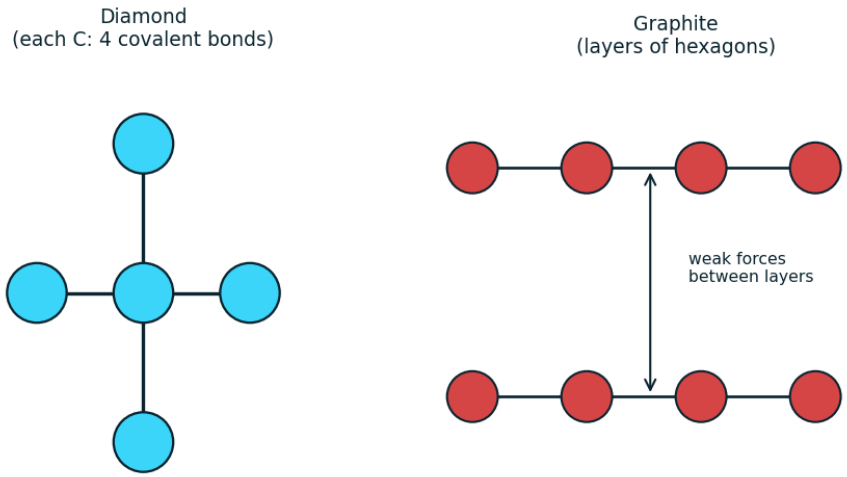
(b) Explain why alloys, such as bronze (copper and tin), are generally harder than the pure metals from which they are made. **[2]**

(c) Suggest one practical advantage of using an alloy such as steel (iron and carbon) rather than pure iron in construction. **[2]**

S2.4 From Models to Materials

Question 9 [6 marks]

The diagrams show simplified models of the structures of diamond and graphite, both giant covalent forms of carbon.



Diamond (tetrahedral network) and graphite (layered hexagonal sheets), schematic.

(a) Describe the key structural difference between diamond and graphite shown in the diagrams. **[2]**

(b) Explain why graphite conducts electricity but diamond does not. **[2]**

(c) Explain why graphite is soft and slippery, making it useful as a lubricant, while diamond is extremely hard. **[2]**

Question 10 [7 marks]

Silicon dioxide (SiO_2, found in sand and quartz) and carbon dioxide (CO_2) are both oxides of Group 14 elements, but have very different structures and properties.

(a) Classify the structure of SiO_2 and explain why it has a very high melting point (1710°C) and does not conduct electricity. **[3]**

(b) CO_2 is a simple molecular covalent substance with a melting point of −78°C. Explain this very large difference in melting point compared with SiO_2. **[2]**

(c) Graphene (a single layer of graphite) is an example of a nanostructured material. Suggest one property of graphene and a related application based on this property. **[2]**