iBLaurel

Premium IB tuition — Physics, Chemistry, Maths

IB DIPLOMA CHEMISTRY · FIRST ASSESSMENT 2025

Structure 2 Models of Bonding and Structure

Paper 2 Style Practice · Short-answer and extended-response questions

Medium to hard exam-style questions on Structure 2.1 – 2.4, with a full markscheme

Standard Level & Higher Level

Timing and marks

Higher Level: answer all five questions. Total **57 marks**. Suggested time **about 95 minutes**.

Standard Level: answer Questions 1–4 and omit Question 5 HL . Total **46 marks**. Suggested time **about 85 minutes**.

These timings use the same rate as the real examination (SL Paper 2: 50 marks in 1 h 30; HL Paper 2: 90 marks in 2 h 30).

Inside this booklet

1. Question 1 — The ionic model (8 marks)
2. Question 2 — Covalent bonding, shapes and polarity (13 marks)
3. Question 3 — Structures and intermolecular forces (12 marks)
4. Question 4 — Metals, the bonding triangle and materials (13 marks)
5. Question 5 — HL: expanded octets, formal charge, benzene, condensation polymers (11 marks)
6. Markscheme and worked solutions

Instructions

- Work under examination conditions: set a timer, and do not look at the markscheme until you have finished.
- You need a **calculator** and a copy of the **IB Chemistry data booklet** (first assessment 2025).
- Write your answers in the spaces provided. Show all working in calculations. Draw Lewis formulas and structures clearly, showing all lone pairs where they are relevant.
- The number of marks for each part is shown in brackets. As a guide, one mark usually requires one distinct, correct point.

Question 1 The ionic model (8 marks)

Magnesium reacts with nitrogen when it burns in air.

(a) (i) State the formula of magnesium nitride. **[1]**

(ii) State the full electron configuration of the nitride ion. **[1]**

The lattice enthalpies of four compounds are given below.

Compound	NaCl	NaF	CaO	MgO
Lattice enthalpy / kJ mol^{-1}	+790	+930	+3401	+3791

(b) Explain, in terms of the ions present, why the lattice enthalpy of MgO is greater than that of NaF and greater than that of CaO. **[3]**

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

(d) Calcium phosphate is a major component of bone. State its formula and describe the bonding in the compound. **[2]**

Question 2 Covalent bonding, shapes and polarity (13 marks)

Carbonyl chloride, $COCl_2$, is a toxic gas used in the manufacture of polymers. Carbon is the central atom.

(a) (i) Draw the Lewis formula of $COCl_2$. **[1]**

(ii) Deduce the molecular geometry of $COCl_2$ and predict the Cl–C–Cl bond angle, explaining whether it is larger or smaller than the ideal value. **[2]**

(b) The hydronium ion, H_3O^+, forms when water reacts with a hydrogen ion. Draw the Lewis formula of H_3O^+, identify the type of bond that forms between water and H^+, and deduce the shape and H–O–H bond angle of the ion. **[3]**

(c) Carbon dioxide, CO_2, is non-polar, but carbonyl sulfide, OCS, which has the same linear shape, is polar. Explain this difference. Use Section 9 of the data booklet. **[3]**

(d) The carbon–oxygen bond in CO_2 is shorter and stronger than the carbon–oxygen bond in methanol, CH_3OH. Explain why. **[2]**

(e) Explain why the H–N–H bond angle in ammonia, NH_3, is smaller than the H–C–H bond angle in methane, CH_4. **[2]**

Question 3 Structures and intermolecular forces (12 marks)

The boiling points of the hydrides of group 16 are shown.

Hydride	H_2O	H_2S	H_2Se	H_2Te
Boiling point / °C	100	−60	−41	−2

(a) Explain the trend in boiling point from H_2S to H_2Te, and why the boiling point of H_2O does not fit this trend. **[3]**

(b) Draw a diagram to show a hydrogen bond between two molecules of ammonia, NH_3. Include all relevant lone pairs and partial charges. **[2]**

(c) Ethanol, C_2H_5OH, mixes with water in all proportions, but hexan-1-ol, $C_6H_{13}OH$, is only slightly soluble. Explain this difference. **[2]**

(d) Graphite and diamond are both allotropes of carbon. Explain why graphite conducts electricity but diamond does not, and why graphite is soft. **[3]**

(e) Carbon and silicon are both in group 14. Explain why carbon dioxide is a gas at room temperature, whereas silicon dioxide is a solid with a very high melting point. **[2]**

Question 4 Metals, the bonding triangle and materials (13 marks)

(a) Describe metallic bonding, and explain how it accounts for the electrical conductivity of metals. **[2]**

(b) The melting point of sodium is 98 °C and that of magnesium is 650 °C. Explain this difference. **[2]**

(c) Beryllium chloride, $BeCl_2$, melts at 399 °C, whereas magnesium chloride, $MgCl_2$, melts at 714 °C. Use Sections 9 and 17 of the data booklet to determine the position of each compound in the bonding triangle, and use your answer to explain the difference in melting points. **[3]**

(d) Brass is an alloy of copper and zinc. Explain why brass is harder than pure copper. **[2]**

Poly(chloroethene), PVC, is made by the addition polymerization of chloroethene, $CH_2{=}CHCl$.

(e) (i) Draw the repeating unit of PVC. **[1]**

(ii) Explain why PVC and similar plastics persist in the environment for a very long time. **[2]**

(iii) State why the atom economy of the polymerization is 100%. **[1]**

HL Question 5 Expanded octets, formal charge, benzene and condensation polymers (11 marks)

(a) Sulfur tetrafluoride, SF_4, is used to make fluorinated organic compounds. Draw its Lewis formula, deduce its electron-domain geometry and molecular geometry, and state, with a reason, whether the molecule is polar. **[3]**

(b) Two Lewis formulas can be drawn for phosphoryl chloride, $POCl_3$, in which phosphorus is the central atom: one with a P–O single bond and one with a P=O double bond. In both, each chlorine has three lone pairs. Calculate the formal charges on P and O in each structure, and deduce which structure is preferred. **[2]**

(c) Describe two pieces of evidence that the bonding in benzene, C_6H_6, is not three alternating single and double bonds, and explain, in terms of hybridization, how the π electrons in benzene are arranged. **[3]**

(d) Draw the repeating unit of the polymer formed from 1,4-diaminobutane, $H_2N(CH_2)_4NH_2$, and hexanedioic acid, $HOOC(CH_2)_4COOH$, and state the other product of the reaction. **[2]**

(e) Deduce the number of σ and π bonds in but-2-ynoic acid, $CH_3C{\equiv}CCOOH$. **[1]**

End of questions

Markscheme and worked solutions

Bold [1] shows where each mark is awarded. Accept equivalent wording that conveys the same chemistry. Text in italics gives examiner-style guidance.

Question 1 (8 marks)

(a) (i) Mg_3N_2 **[1]** (ii) $1s^2\ 2s^2\ 2p^6$ **[1]** *(not [He] $2s^2\ 2p^6$, since the question asks for the full configuration)*

(b) MgO contains ions with charges of 2+ and 2−, whereas NaF contains 1+ and 1− ions; higher charges give a much stronger electrostatic attraction **[1]**. Mg^{2+} is smaller than Ca^{2+} (one fewer occupied shell), so the distance between ion centres in MgO is shorter **[1]**. The stronger attraction between oppositely charged ions means more energy is needed to separate the lattice into gaseous ions **[1]**.

(c) In the solid, the ions are held in fixed positions in the lattice and cannot move **[1]**. When molten, the ions are free to move and carry charge **[1]**. *Do not award a mark for "electrons" moving.*

(d) $Ca_3(PO_4)_2$ **[1]**. Ionic bonding (electrostatic attraction) between Ca^{2+} and PO_4^{3-} ions, and covalent bonding between P and O within each phosphate ion **[1]**.

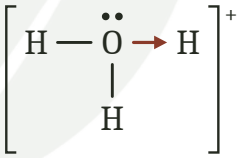
Question 2 (13 marks)

(a) (i) Lewis formula with C=O, two C–Cl bonds, two lone pairs on O and three on each Cl **[1]**. *All 24 valence electrons must be shown.*



(ii) Triangular planar (also called trigonal planar) **[1]**. Cl–C–Cl slightly less than 120° (about 111–112°), because the C=O double bond has greater electron density and repels the C–Cl bonds more strongly **[1]**.

(b) Lewis formula: three O–H bonds, one lone pair on O, in square brackets with a + charge **[1]**. A coordination (dative covalent) bond, in which O donates a lone pair to H^+ **[1]**. Trigonal pyramidal, ≈ 107° (accept 104–108°) **[1]**.



(c) In CO_2 both C=O bonds are polar (O 3.4, C 2.6) but the two dipoles are equal and point in opposite directions, so they cancel **[1]**. In OCS the C=O bond is polar but the C=S bond is non-polar (or much less polar), since C and S both have $\chi = 2.6$ **[1]**. The bond dipoles therefore do not cancel, so OCS has a net dipole moment **[1]**.

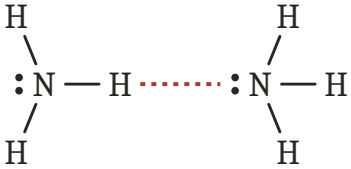
(d) The bonds in CO_2 are double bonds (two shared pairs), whereas methanol has a C–O single bond **[1]**. Greater electron density between the nuclei gives a stronger electrostatic attraction for both nuclei, pulling them closer and requiring more energy to break the bond **[1]**. *Data booklet: C=O 122 pm, 804 kJ mol^{-1}; C–O 143 pm, 358 kJ mol^{-1}.*

(e) Both have four electron domains; NH_3 has one lone pair and three bonding pairs, whereas CH_4 has four bonding pairs **[1]**. Lone pair–bonding pair repulsion is greater than bonding pair–bonding pair repulsion, so the N–H bonds are pushed closer together: 107° compared with 109.5° **[1]**.

Question 3 (12 marks)

(a) From H_2S to H_2Te the number of electrons increases, so London forces become stronger **[1]**. H_2O has a much higher boiling point because its molecules form hydrogen bonds **[1]**, as O is small and highly electronegative and has lone pairs; hydrogen bonds are much stronger than the intermolecular forces between the other hydrides **[1]**.

(b) A dashed line from the H of one NH_3 to the lone pair on the N of another, with N–H-N drawn in a straight line and the lone pair shown **[1]**; partial charges δ+ on that H and δ− on both N atoms **[1]**.



(c) Ethanol's –OH group forms hydrogen bonds with water molecules, and its non-polar chain is short **[1]**. In hexan-1-ol the long non-polar hydrocarbon chain can form only London forces with water; it disrupts the hydrogen bonding between water molecules and outweighs the effect of the single –OH group **[1]**.

(d) In graphite each carbon forms three covalent bonds, so one electron per atom is delocalized and free to move through the layer, carrying charge **[1]**. In diamond each carbon forms four covalent bonds, so all valence electrons are localized and none are free to move **[1]**. Graphite's layers are held together only by weak London forces, so they slide over one another **[1]**.

(e) CO_2 exists as small discrete molecules held together by weak London forces, which need little energy to overcome **[1]**. SiO_2 is a giant covalent network in which each Si is bonded to four O atoms; melting requires breaking many strong Si–O covalent bonds **[1]**.

Question 4 (13 marks)

(a) Electrostatic attraction between a lattice of cations and delocalized electrons **[1]**. The delocalized electrons are mobile and move through the lattice when a potential difference is applied, carrying charge **[1]**.

(b) Mg forms Mg^{2+} ions and contributes two delocalized electrons per atom, compared with Na^+ and one; Mg^{2+} is also smaller **[1]**. The attraction between the cations and the delocalized electrons is therefore stronger, and more energy is needed to overcome it **[1]**.

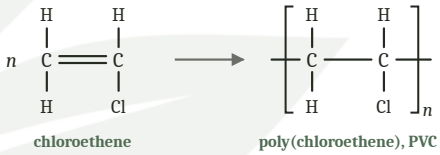
(c) $BeCl_2$: $\Sigma\chi = (1.6 + 3.2)/2 = 2.4$, $\Delta\chi = 1.6$, which lies in the polar covalent region **[1]**. $MgCl_2$: $\Sigma\chi = (1.3 + 3.2)/2 = 2.25$, $\Delta\chi = 1.9$, which lies in the ionic region **[1]**. $BeCl_2$ has considerable covalent character, so less energy is needed to melt it than to break down the ionic lattice of $MgCl_2$, which has strong electrostatic attraction between ions throughout **[1]**.

(d) Zinc atoms are a different size from copper atoms and disrupt the regular layers of cations **[1]**, so the layers cannot slide over each other as easily **[1]**.

(e) (i) Repeating unit $–CH_2–CHCl–$ in square brackets, with open bonds through the brackets and a subscript *n* **[1]**.

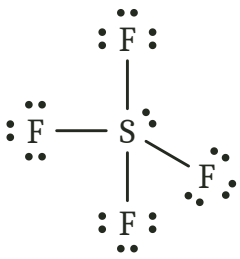
(ii) The chain consists of strong C–C and C–H bonds and has no functional groups that microorganisms or water can attack, so PVC is unreactive **[1]**. It is non-biodegradable, so it is not broken down by natural processes **[1]**.

(iii) All the atoms of the reactant (monomer) end up in the polymer; there is no by-product **[1]**.



HL Question 5 (11 marks)

(a) Lewis formula: S with four S–F bonds and one lone pair, and three lone pairs on each F (34 valence electrons) **[1]**. Electron-domain geometry triangular (trigonal) bipyramidal; molecular geometry see-saw, with the lone pair in an equatorial position **[1]**. Polar: the shape is not symmetrical, so the S–F bond dipoles do not cancel **[1]**.



(b) P–O structure: P = 5 − (4 + 0) = +1; O = 6 − (1 + 6) = −1. P=O structure: P = 5 − (5 + 0) = 0; O = 6 − (2 + 4) = 0 **[1]**. The P=O structure is preferred because its formal charges are closest to zero **[1]**. *Chlorine is 0 in both.*

(c) Any two pieces of evidence, each with a comparison **[2]**: all six C–C bonds are the same length (139 pm), intermediate between C–C (154 pm) and C=C (134 pm); the enthalpy change of hydrogenation (−208 kJ mol^{-1}) is much less exothermic than predicted for three C=C bonds (3 × −120 = −360 kJ mol^{-1}); benzene undergoes substitution rather than the addition typical of alkenes; only three isomers of dibromobenzene exist. Each carbon is sp^2 hybridized; the unhybridized p orbitals on all six carbons overlap sideways to form a delocalized π system above and below the plane of the ring **[1]**.

(d) $-[NH-(CH_2)_4-NH-CO-(CH_2)_4-CO]_n-$, with the amide C=O and N–H shown, brackets, open bonds and *n* **[1]**. Water, H_2O **[1]**.

(e) 9 σ and 3 π **[1]**. *σ: three C–H, C–C, the σ bond of C≡C, C–C, the σ bond of C=O, C–O and O–H. π: two in C≡C and one in C=O.*

These practice papers are a free resource, shared for any IB student who finds them useful.

If a particular idea here still isn't clicking, specialist one-to-one support in Physics, Chemistry and Maths from a past A Level examiner is available at iBLaurel — call or message **+44 7404 710097**, or use the contact form at **www.iBLaurel.com**.

Written and produced independently by iBLaurel. Not affiliated with, endorsed by, or published in association with the International Baccalaureate Organization. These are original practice questions in the style of the IB Chemistry examinations (first assessment 2025); they are not past IB papers.