

End-of-topic questions

Topic review

- Using your knowledge from the *Structure 2.1* topic, answer the guiding question as fully as possible:
What determines the ionic nature and properties of a compound?
- Explain why ionic substances are always compounds.

Exam-style questions

Multiple-choice questions

- The elements in group 17 generally form ions with which charge?
 - 7+
 - 1+
 - 1-
 - 7-
- The ion of element X has a 2+ charge and contains 20 protons. Give the full electron configuration of this ion.
 - $1s^2 2s^2 2p^6 3s^2 3p^6$
 - $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
 - $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2$
 - $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$
- Which statement about ionic compounds is correct?
 - Ionic bonding results from the electrostatic attraction between cations and anions.
 - Calcium fluoride is made up of CaF_2 molecules.
 - Ionic structures contain delocalized electrons when molten or dissolved, but not when solid.
 - Ions are held together because anions transfer electrons to cations.
- What is the name of CaSO_4 ?
 - carbon sulfite
 - calcium sulfite
 - carbon sulfate
 - calcium sulfate
- What is the formula of sodium nitrate?
 - NaNO_2
 - NaNO_3
 - Na_3N
 - S_3N_2
- Which compound has the largest value of lattice enthalpy?
 - CaS
 - CaO
 - K_2S
 - K_2O
- Which statement is correct?
 - Lattice enthalpy increases when the radii of the component ions increase.
 - Lattice enthalpy represents the energy needed to transfer an electron from a cation to an anion.
 - Lattice enthalpy decreases when the charge of the component ions increases.
 - Lattice enthalpy increases when the charge density of the component ions increases.
- Which equation correctly represents the lattice enthalpy of potassium oxide?
 - $\text{K}_2\text{O}(\text{s}) \rightarrow 2\text{K}^+(\text{g}) + \text{O}^{2-}(\text{g})$
 - $\text{K}_2\text{O}(\text{s}) \rightarrow 2\text{K}(\text{s}) + \frac{1}{2}\text{O}_2(\text{g})$
 - $\text{K}_2\text{O}(\text{s}) \rightarrow \text{K}_2^{2+}(\text{g}) + \text{O}^{2-}(\text{g})$
 - $\text{K}_2\text{O}(\text{s}) \rightarrow 2\text{K}(\text{g}) + \frac{1}{2}\text{O}_2(\text{g})$
- List the lithium halides in order of **increasing** lattice enthalpy.
 - LiF , LiCl , LiBr , LiI
 - LiF , LiBr , LiCl , LiI
 - LiI , LiBr , LiCl , LiF
 - LiI , LiCl , LiBr , LiF

12. Which substance has an ionic structure?

	Melting point / °C	Solubility in water	Electrical conductivity when molten	Electrical conductivity when solid
A	36	high	none	none
B	186	low	none	none
C	1083	high	good	none
D	1710	low	good	good

Extended-response questions

13. Calcium fluoride has applications in the field of optics.

- Deduce the formula for calcium fluoride. [1]
- Describe the structure and bonding in solid calcium fluoride. [3]
- Explain why solid calcium fluoride is a poor electrical conductor, but molten calcium fluoride can conduct electricity. [2]
- The lattice enthalpy of calcium fluoride is 2651 kJ mol^{-1} .
 - Write an equation, including state symbols, that shows the process associated with the lattice enthalpy of calcium fluoride. [2]
 - Explain why the process in part (i) is endothermic. [1]
 - The lattice enthalpy of calcium oxide, CaO , is 3401 kJ mol^{-1} . Explain why the lattice enthalpy of calcium oxide is greater than that of calcium fluoride. [2]

14. Certain types of breathalyser contain the bright orange ionic compound potassium dichromate(VI), $\text{K}_2\text{Cr}_2\text{O}_7$.

- Write the full electron configuration of a potassium ion. [1]
- Explain why the difference in mass between a potassium atom and a potassium ion is negligible. [1]

c. Deduce the charge of the dichromate(VI) ion. [1]

d. Potassium dichromate(VI) contains chromium. Chromium is a transition element that commonly forms Cr^{2+} ions and Cr^{3+} ions among others.

- Write the abbreviated electron configuration of a chromium atom. [1]
- Copy the diagram below and draw arrows in the boxes to represent the electron configuration in the 3d and 4s orbitals of a Cr^{2+} ion. [1]



- Write the full electron configuration of a Cr^{3+} ion. [1]

15. The equation below shows the formation of lithium fluoride from its elements under standard conditions.



- Balance the equation. [1]
- Identify the charge of the lithium ion. [1]
- Identify the oxidized species and the reduced species in this reaction. [1]
- Sketch a diagram showing the structure of lithium fluoride. [2]

End-of-topic questions

Topic review

1. Using your knowledge from the *Structure 2.2* topic, answer the guiding question as fully as possible:

What determines the covalent nature and properties of a substance?

2. Compare and contrast ionic bonding, covalent bonding and intermolecular forces.
3. Compare and contrast molecular and covalent network substances.

7. The hydronium ion is formed when a water molecule, H_2O , reacts with a hydrogen ion, H^+ . Which type of bond is formed in this reaction?

- A. coordination bond
B. ionic bond
C. hydrogen bond
D. intermolecular force

8. The electronegativities, χ , of four elements are:

Element	H	C	O	Cl
χ	2.2	2.6	3.4	3.2

Which bond is the most polar?

- A. C–H
B. O–H
C. H–Cl
D. C–O

9. Which of the following allotropes of carbon is molecular?

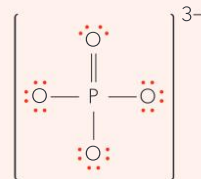
- A. graphite
B. graphene
C. buckminsterfullerene
D. diamond

10. What are the intermolecular forces present between molecules of CH_3F ?

- A. London (dispersion) forces
B. London (dispersion) forces and dipole–dipole forces
C. London (dispersion) forces, dipole–dipole forces and hydrogen bonding
D. hydrogen bonding

11. What are the formal charges on P and O in the Lewis formula of the phosphate oxoanion?

- A. P is -1 and O is 0
B. P is $+5$ and O is -2
C. P is 0 and O is 0 and -1
D. Both are -3



Exam-style questions

Multiple-choice questions

4. Which of the following species is molecular?

- A. Na_2O
B. KBr
C. NH_4NO_3
D. N_2O_4

5. Which molecule has the shortest carbon–oxygen bond?

- A. $\text{CH}_3\text{CH}_2\text{OH}$
B. $(\text{CH}_3)_2\text{O}$
C. $(\text{CH}_3)_2\text{CO}$
D. CO

6. What is the electron domain geometry, the molecular geometry and the Cl–P–Cl bond angle for the molecule of phosphorus trichloride, PCl_3 ?

	Electron domain geometry	Molecular geometry	Cl–P–Cl bond angle / °
A.	tetrahedral	tetrahedral	109.5
B.	tetrahedral	trigonal pyramidal	109.5
C.	tetrahedral	trigonal pyramidal	100.3
D.	trigonal pyramidal	trigonal pyramidal	100.3

12. What is the electron domain geometry of the sulfite oxoanion, $[\text{SO}_3]^{2-}$?

- A. trigonal planar
- B. trigonal pyramidal
- C. tetrahedral
- D. bent (V-shaped)

13. What is the molecular geometry of BrF_5 ?

- A. octahedral
- B. square planar
- C. T-shaped
- D. square pyramidal

14. What is the molecular geometry of $[\text{PF}_6]^-$?

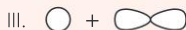
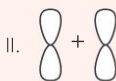
- A. trigonal planar
- B. trigonal bipyramidal
- C. square pyramidal
- D. octahedral

15. Which of the following molecules is non-polar?

- A. SF_4
- B. ClF_3
- C. BrCl_5
- D. SeF_6

16. Which of the combinations of atomic orbitals shown below left results in a sigma bond?

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III



17. What is the hybridization of the oxygen atom in ethanol, $\text{CH}_3\text{CH}_2\text{OH}$?

- A. sp
- B. sp^2
- C. sp^3
- D. It is not hybridized.

18. What is the hybridization of the carbon atom in hydrogen cyanide, HCN ?

- A. sp
- B. sp^2
- C. sp^3
- D. It is not hybridized.

19. How many sigma and pi bonds are present in a molecule of hydrogen cyanide, HCN ?

	sigma	pi
A.	1	3
B.	2	1
C.	2	2
D.	3	1

Extended-response questions

20. Describe the meaning of the term **covalent bond**. [2]

21. The phosphonium ion, PH_4^+ , is formed when a hydrogen ion, H^+ , reacts with a molecule of phosphine, PH_3 . For each species, phosphine and phosphonium:

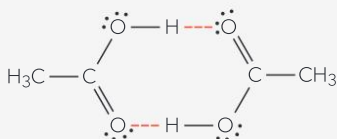
- a. Draw the Lewis formula. Identify any coordination bonds [3]
- b. Deduce the electron domain geometry and molecular geometry. [2]
- c. Suggest the bond angle. [2]
- d. Deduce whether it is polar or non-polar. Explain your reasoning. [2]

22. Methane, CH_4 , ammonia, NH_3 , and water, H_2O , all have tetrahedral electron domain geometry with bond angles of 109.5° , 107° and 104.5° , respectively. Explain these differences in bond angle values. [2]

23. Diamond and graphite are allotropes of carbon. Describe and explain the electrical conductivity of these two materials. [3]

24. Household vinegar is made from aqueous ethanoic acid, CH_3COOH .

- Draw the Lewis formula of ethanoic acid. [2]
- Draw a diagram to represent the intermolecular interaction between a molecule of ethanoic acid and a water molecule. [2]
- Ethanoic acid molecules can form dimers, particularly when gaseous or dissolved in a non-polar solvent. Dimerization means that two ethanoic acid molecules can associate as shown below.



- Calculate the molar mass of an ethanoic acid dimer. [1]
 - Suggest why ethanoic acid is more likely to form dimers when dissolved in non-polar solvents (such as hexane) than in polar solvents (such as water). [2]
 - Ethanoic acid, CH_3COOH , dissolves readily in water. The aqueous solubility of hexanoic acid, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH}$, is very low. Explain this difference in solubility. [2]
- AHL**
- State the number of pi and sigma bonds in a molecule of ethanoic acid. [1]
 - Deduce the hybridization of the carbon and oxygen atoms in ethanoic acid. [2]

25. The following substances all have similar molar masses.

- ethanoic acid, CH_3COOH
 - propan-1-ol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
 - methoxyethane, $\text{CH}_3\text{CH}_2\text{OCH}_3$
 - butane, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$
- Use your knowledge of intermolecular forces and structure to list these four substances in order of increasing boiling point. Explain your reasoning. [4]
 - Explain why, when comparing the strength of different intermolecular forces, it is helpful to compare substances that have similar molar masses. [1]

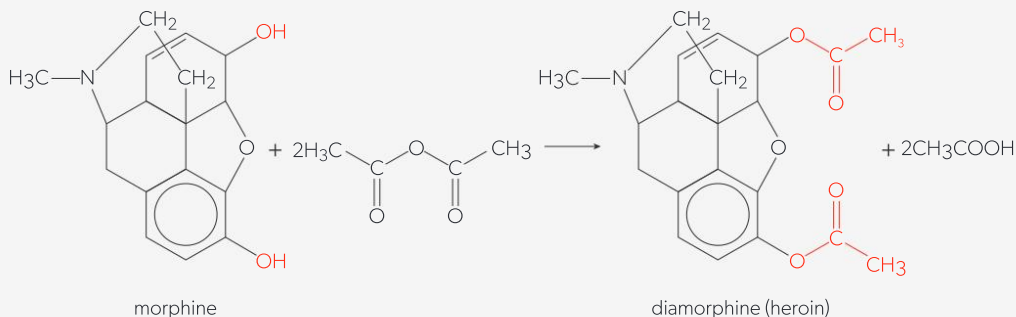
26. Explain why the boiling point of the group 17 elements increases down the group. [2]

27. Water is an excellent solvent.

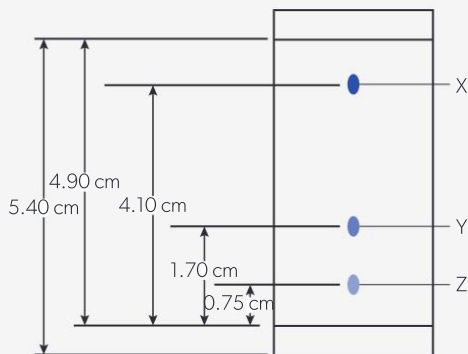
- Oxygen dissolved in water bodies supports the presence of aquatic organisms. Describe the type of intermolecular forces that occur between oxygen molecules, O_2 , and water molecules, H_2O . [1]
- Ionic compounds often dissolve in water but not in organic solvents. Explain why ionic compounds do not readily dissolve in hydrocarbon solvents. [2]

28. Morphine and diamorphine are strong painkillers belonging to a group of substances known as opiates. The esterification of morphine produces diamorphine (heroin), as shown below:

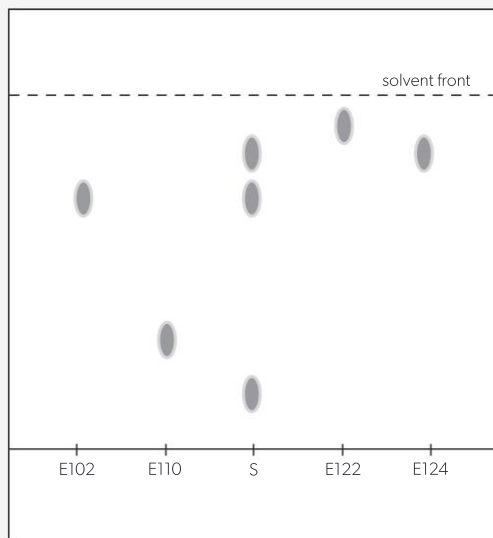
- Identify and explain which of these two opiates has a higher aqueous solubility. [3]
- The potency of opiates depends on their ability to cross from the blood into the brain. The blood-brain barrier is composed of lipids which are non-polar. Identify and explain which of these two opiates dissolves more readily in non-polar environments. [1]



29. A paper chromatogram for a mixture of amino acids is obtained using a non-polar solvent.
- Calculate the retardation factor, R_F , for the spot labelled X in the chromatogram. [2]
 - Deduce which of the three components is likely to have the lowest polarity. [1]



30. The diagram below is a chromatogram of an extract from a supermarket curry sauce (labelled S). Four reference samples of food colourings have also been run on the chromatogram. Outline three conclusions that can be derived from the information in the chromatogram. [3]



31. The carbonate ion contains delocalized electrons.
- Draw the three resonance structures of the carbonate ion, CO_3^{2-} . [2]
 - State the bond order of the carbon–oxygen bond in the carbonate ion. [1]
32. Benzene, C_6H_6 , contains delocalized electrons and is often represented as follows.



- Explain, with reference to hybridization, why the delocalized electrons in benzene form a ring above and below the plane of the molecule. [2]
 - Outline how bond length data confirms the structure of benzene. [1]
 - Describe one piece of chemical evidence that further supports the structure of benzene shown above. [2]
33. Sulfur trioxide, SO_3 , is an acidic gas. If present in the atmosphere, sulfur trioxide can dissolve in rainwater leading to acid rain.
- Draw two Lewis formulas for SO_3 , one that follows the octet rule, and one where the sulfur atom has an expanded octet. [3]
 - Determine the formal charges of each of the atoms in the Lewis formulas you drew in (a). [2]
 - Deduce, using the concept of formal charge, which of the two Lewis formulas is preferred. Explain your reasoning. [1]