Cambridge Assessment International Education

Cambridge International AS & A Level

2: Bonding and structure – Topic questions

The questions in this document have been compiled from a number of past papers, as indicated in the table below.

Use these questions to formatively assess your learners' understanding of this topic.

Question	Year	Series	Paper number
2	2017	March	22
2	2017	June	21
2	2017	June	22

The mark scheme for each question is provided at the end of the document.

2 Hydrogen halides are compounds formed when halogens (Group 17 elements) react with hydrogen. The bond polarity of the hydrogen halides decreases from HF to HI.

Some relevant data are shown in the table.

hydrogen halide	HF	HC*l*	HBr	HI
boiling point / °C	19	–85	–67	–35
H–X bond energy / KJ mol^{-1}	562	431	366	299

(a) (i) Explain the meaning of the term *bond polarity*.

.....

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..... [1]

(ii) Suggest why the boiling point of HF is **much** higher than the boiling points of the other hydrogen halides.

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..... [2]

(iii) Describe and explain the relative thermal stabilities of the hydrogen halides.

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..... [3]

(b) The equation for the preparation of hydrogen chloride using concentrated sulfuric acid is shown.

$$H_2SO_4 \quad NaCl \rightarrow NaHSO_4 + HCl$$

(i) Use the Brønsted-Lowry theory of acids and bases to identify the base and its conjugate acid in this reaction. Explain your answer.

Brønsted-Lowry base (base-I) = ...

conjugate acid (acid-II) = ...

.....

.....

.....

[2]

(ii) Explain why the reaction of concentrated sulfuric acid and sodium iodide is **not** suitable for the preparation of hydrogen iodide.

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..... [2]

(c) Hydrogen chloride undergoes a reversible reaction with oxygen.

$$4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$$

The reaction is carried out at 400 °C in the presence of a copper(II) chloride catalyst.

(i) Use the data in the table to calculate the overall enthalpy change of reaction.

compound	enthalpy change of formation / mol ^{1}
$HCl(g)$	–92
$H_2O(g)$	–242

enthalpy change of reaction = ... mol^{-1} [2]

(ii) State the **type** of catalyst used in this reaction. Explain how a catalyst is able to increase the rate of a chemical reaction.

.....

.....

.....

..... [2]

(iii) The reaction exists in dynamic equilibrium.

The reaction was repeated at 1000 °C and the same pressure.

State and explain the effect on the composition of the equilibrium mixture of the change in temperature.

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.....

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..... [2]

(iv) When 1.60 mol of HCl are mixed in a sealed container with 0.500 mol of O_2 at 400 °C, 0.600 mol of Cl_2 and 0.600 mol of H_2O are formed. The

total pressure inside the container is 1.50×10^5 Pa.

- Calculate the amounts, in mol, of HCl and O_2 in the equilibrium mixture.

HCl = ... mol

O_2 = ... mol

- Calculate the mole fraction of Cl_2 and hence the partial pressure of Cl_2 in the equilibrium mixture.

mole fraction of Cl_2 = ...

p_{Cl_2} = ... Pa

[3]

(v) In a separate experiment, an equilibrium reaction mixture was found to contain the four gases at the partial pressures shown in the table.

gas	HCl	O_2	Cl_2	H_2O
partial pressure / Pa	4.8×10^4	3.0×10^4	3.6×10^4	3.6×10^4

$$K_p = \frac{(p_{Cl_2})^2 \times (p_{H_2O})^2}{(p_{HCl})^4 \times p_{O_2}}$$

Use this information and the expression given for K_p to calculate a value for K_p. State the units of K_p.

K_p = ...

units = ...
[2]

(vi) The reaction is repeated without a catalyst.

State the effect of this on K_p.

..... [1]

[Total: 22]

2 Nitrogen gas, N_2, is very unreactive.

(a) Explain why nitrogen gas is so unreactive.

.....

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..... [2]

(b) Despite the low reactivity of N_2, oxides of nitrogen occur in the atmosphere through both natural and man made processes.

(i) Explain why oxides of nitrogen can be produced by internal combustion engines.

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.....

..... [2]

(ii) State and explain, using a suitable equation, how oxides of nitrogen produced by internal combustion engines can be prevented from reaching the atmosphere.

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..... [2]

(iii) State the role of nitrogen dioxide, NO_2, in the formation of acid rain by oxides of sulfur. Write suitable equations to explain this role.

role .....

equation 1 .....

equation 2 .....
[3]

(iv) Suggest an equation to show how NO_2 can contribute **directly** to acid rain.

..... [1]

(c) Explain how the uncontrolled use of nitrate fertilisers on land can lead to a severe reduction in water quality in rivers.

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..... [3]

[Total: 13]

2 Structure and bonding can be used to explain many of the properties of substances.

(a) Copper, ice, silicon(IV) oxide, iodine and sodium chloride are all crystalline solids.

Complete the table with:

- the name of a type of bonding found in each crystalline solid,
- the type of lattice structure for each crystalline solid.

crystalline solid	type of bonding	type of lattice structure
copper		
ice		
silicon(IV) oxide		
iodine		
sodium chloride		

[5]

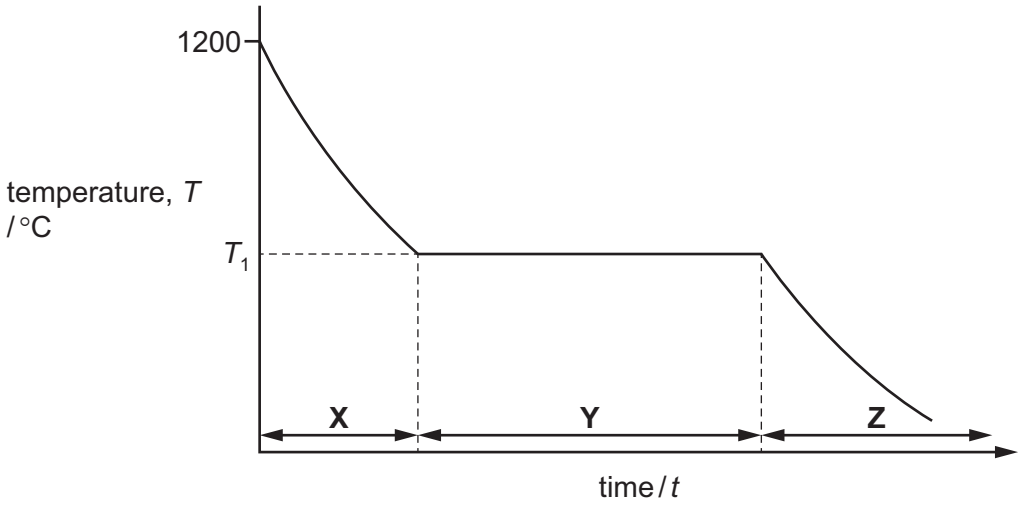
(b) **(i)** Name the strongest type of intermolecular force in ice.

..... [1]

(ii) Draw a fully labelled diagram of two water molecules in ice, showing the force in **(i)** and how it forms.

[3]

(c) The graph represents how the temperature of a sample of copper (melting point 1085 °C) changes as it is gradually cooled from 1200 °C.



(i) Identify the state(s) of matter present during each stage of the process shown in the graph.

X .....

Y .....

Z .....

[2]

(ii) State what is happening to the energy and movement of the particles in the copper during stage **X**.

.....

.....

..... [2]

(iii) Explain why the temperature stays constant at T_1 during stage **Y**.

.....

.....

.....

..... [2]

[Total: 15]

Question	Answer	Marks
2 (a) (i)	bond in which the centres of positive and negative charges do not coincide **OR** electron distribution is asymmetric / unequal **OR** two (bonded) atoms are partially charged	**1**
2 (a) (ii)	HF has the strongest (permanent) dipole–dipole / van der Waals' (forces) / HF has hydrogen bonding	**1**
	requires more energy to overcome (than weaker (permanent) dipole–dipole / van der Waals' forces between other hydrogen halides)	**1**
2 (a) (iii)	thermal stability of the hydrogen halides decreases down group (17)	**1**
	larger (halogen) atoms / atomic radius (down group) / increased shielding	**1**
	bond energies decrease / less energy required to break H–X	**1**
2 (b) (i)	**M1** Base is Cl^- AND conjugate acid is HCl OR Base is HSO_4^- AND conjugate acid is H_2SO_4	**1**
	M2 Cl^- / HSO_4^- / base is a proton acceptor OR HCl / H_2SO_4 / (conjugate) acid has more H^+	**1**
2 (b) (ii)	H_2SO_4 is (too strong) an oxidising agent	**1**
	I_2 would be formed instead	**1**
2 (c) (i)	$\Delta_r H$ = $\Delta_r H$ {products} – $\Delta_r H$ {reactants} = 2 × (−242) − 4 × (−92)	**1**
	= −116 (sign **AND** answer)	**1**
2 (c) (ii)	heterogeneous (catalyst)	**1**
	provides an alternative pathway or lower activation energy	**1**
2 (c) (iii)	reaction is exothermic	**1**
	(increased temperature) shifts equilibrium to the left AND decreases yield of products (Cl_2 and / or H_2O) / less product formed	**1**

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Question	Answer					Marks
2 (c) (iv)		HC*l*	O_2	Cl_2	H_2O	**3**
	Initial number of moles	1.60	0.500	0	0	
	M1 eqm number of moles	1.60 – 2 × 0.600 = 0.400	0.500 – ½ × 0.600 = 0.200	0.600	0.600	
	M2 mole fraction			0.600 / 1.80		
	M3 partial pressure			0.600 / 1.80 × p_{tot} = 5.00 × 10^4		
2 (c) (v)	$Kp = \frac{(3.6 \times 10^4)^2 \times (3.6 \times 10^4)^2}{(4.8 \times 10^4)^4 \times 3.0 \times 10^4} = 1.05 \times 10^{-5}$					**1**
	units = Pa^{-1}					**1**
2 (c) (vi)	*K*p would not change					**1**
						Total: 22

Question	Answer			Marks
2 (a)	substance	type of bonding	type of lattice structure	
	copper	metallic	giant / metallic	**1**
	ice	covalent OR hydrogen(-bonding) / H(-bonding)	hydrogen-bonded / simple / molecular	**1** **1** **1**
	silicon(IV) oxide	covalent	giant (molecular) / macromolecular	**1**
	iodine	covalent	simple / molecular	
	sodium chloride	ionic	giant / ionic	
2 (b) (i)	hydrogen bonding			**1**
2 (b) (ii)	H-bond between O and H of different molecules			**1**
	minimum three partial charges (in a row) over two H_2O molecules, i.e.: either $^{\delta-}O—H^{\delta+}$ - - - - $^{\delta-}O$ or $H^{\delta+}$ - - - - $^{\delta-}O—H^{\delta+}$			**1**
	lone pair of electrons on O of H-bond, in line with H-bond			**1**

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Question	Answer	Marks
2 (c) (i)	X = liquid AND Z = solid	**1**
	Y = liquid and solid OR 'liquid / solid' OR 'liquid or solid'	**1**
2 (c) (ii)	(kinetic) energy reducing	**1**
	motion slowing *owtte*	**1**
2 (c) (iii)	energy given out / released forming bonds / forming bonds exothermic	**1**
	compensates for / counteracts heat loss / cooling *owtte*	**1**
		Total: 15

Question	Answer	Marks
2 (a)	strong triple bond	**1**
	non-polar / no dipole	**1**
2 (b) (i)	any 2 points covered correctly scores 2 marks; any 1 point covered correctly scores 1 mark • nitrogen (and oxygen) from the air / atmosphere (react): • high temperature (of internal combustion engine) / (engine) produces enough OR a lot of heat (energy); • (so) breaks (strong) bond(s) in nitrogen (and oxygen)	**2**
2 (b) (ii)	reduction / decomposition of NO_x using a catalyst / catalytic converter	**1**
	$2NO_2 + 4CO \rightarrow 4CO_2 + N_2$ OR $2NO + 2CO \rightarrow 2CO_2 + N_2$	**1**
2 (b) (iii)	(acts as a homogenous) catalyst OR oxidising agent	**1**
	$SO_2 + NO_2 \rightarrow SO_3 + NO$	**1**
	$NO + ½O_2 \rightarrow NO_2$ OR $SO_3 + H_2O \rightarrow H_2SO_4$	**1**
2 (b) (iv)	$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$ OR $4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$	**1**

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Question	Answer	Marks
2 (c)	fertiliser / nitrates dissolve in (river water) OR fertiliser / nitrates are washed / leached out / flows into (river water)	**1**
	algal bloom / promote algal growth / explosion of plant growth AND EITHER sunlight is blocked out (preventing photosynthesis) / plants can no longer carry out photosynthesis (and die) OR bacteria break down or decay dead organisms / plants / algae	**1**
	drop in oxygen (concentration)	**1**
		Total: 13

Notes about the mark scheme are available separately.