AS91390 Demonstrate understanding of thermochemical principles and the properties of particles and substances

COLLATED QUESTIONS

Attractive forces between atoms, ions, and molecules. These will include ionic bonds, covalent bonds, and intermolecular attractions due to temporary dipoles and permanent dipoles (including hydrogen bonding).

2017:2

Molecule	Boiling Point / °C	M / g mol^{-1}
Hydrazine, N_2H_4	114	32
Iodomethane, CH_3I	42.4	142
Decane, $C_{10}H_{22}$	174	142

Use the information in the table above to compare and contrast the boiling points of the substances below. In your answers, you should:

• list the types of intermolecular forces present for each substance

• explain the relative strength between the particles involved.

(a) (i) Hydrazine and iodomethane.

(ii) Iodomethane and decane.

(b) Explain why the solubility of hydrazine in water is greater than that of decane in water.

2017: 3

Chlorine, Cl_2, bromine, Br_2, and iodine, I_2, are all halogens. Bromine is a liquid at room temperature.

(a) (i) In the box below, tick the type(s) of intermolecular attractions in liquid bromine.

Intermolecular attraction	Tick (✓)
Temporary dipole-dipole attractions	
Permanent dipole-dipole attractions	
Hydrogen bonding	

(ii) Explain why bromine is a liquid at room temperature, whereas chlorine is a gas.

(b) (i) Write an equation for the sublimation of iodine in the box below.

(ii) Define the enthalpy of sublimation for iodine.

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2016:2

The standard enthalpy of vaporisation, $\Delta_{vap}H°$, of sodium chloride, NaCl, hydrogen chloride, HCl, and chloromethane, CH_3Cl, are given in the table below.

(a) Identify all the attractive forces between particles of the following compounds in their liquid state.

Compound	$\Delta_{vap}H°$ / kJ mol^{-1}	Attractive forces
NaCl	194	
HCl	16.0	
CH_3Cl	22.0	

(b) (i) Explain why Δ_{vap} H°(NaCl) is significantly higher than both Δ_{vap} H°(HCl) and Δ_{vap} H°(CH_3Cl).

(ii) Explain why Δ_{vap} H°(CH_3Cl) is greater than Δ_{vap} H°(HCl).

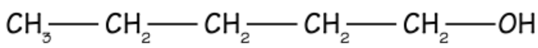
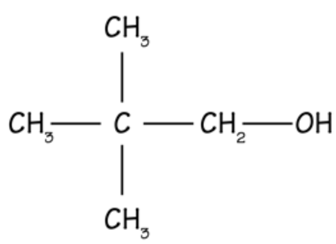
(c) (i) Define Δ_{fus}H°(NaCl).

(ii) Why is Δ_{vap} H°(NaCl) greater than Δ_{fus}H°(NaCl)?

(iii) Why does NaCl readily dissolve in water, even though the process is slightly endothermic? $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$ $\Delta_r H° = +3.90$ kJ mol^{-1}

2015: 3

(c) The two molecules below have the same molecular formula ($C_5H_{12}O$) but have different boiling points.

Name	Pentan-1-ol	Dimethylpropan-1-ol
Structure		
Boiling point	138°C	113°C

(i) List all the forces of attraction between these molecules in each of their liquid states.

(ii) Use the information above to explain the difference in the boiling points of pentan-1-ol and dimethylpropan-1-ol by comparing and contrasting the relative strengths of the attractive forces between the molecules involved.

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2014: 2

(a) The boiling points of ammonia, NH_3, fluorine, F_2, and hydrogen chloride, HCl, are given in the table below. Complete the table to identify (all) the attractive forces between the molecules in their liquid state.

Molecule	Boiling point / °C	Attractive forces
Ammonia, NH_3	-33	
Fluorine, F_2	-188	
Hydrogen chloride, HCl	-85	

(b) Discuss the differences between the boiling points of NH_3 and HCl, in terms of the strength of the attractive forces between the particles involved. Then describe why F_2 has the lowest boiling point.

2013: 3

Molecule	Boiling point / °C
Hydrazine, N_2H_4	114
Fluoromethane, CH_3F	78.4
Decane, $C_{10}H_{22}$	174

Use the information in the table above to compare and contrast the boiling points of hydrazine, fluoromethane, and decane in terms of the relative strengths of the attractive forces between the particles involved.

2012: 4 (From expired AS 90780)

(a) (ii) Explain why $\Delta_{vap}H°(H_2O) = 40.7 \text{ kJ mol}^{-1}$ is greater than $\Delta_{fus}H°(H_2O) = 6.01 \text{ kJ mol}^{-1}$. In your answer you should include:

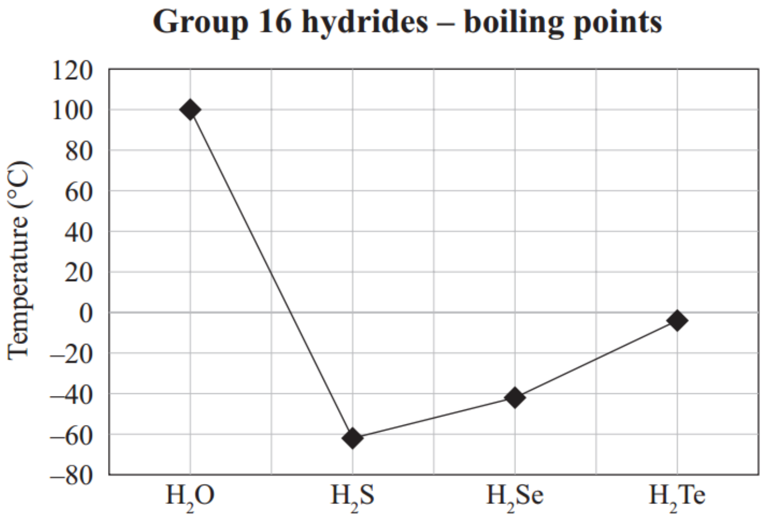
- a description of the attractive forces between the molecules in the different phases (states) of water
- a discussion of how these forces relate to the given enthalpy values.

(b) Chloroethanol ($HOCH_2CH_2Cl$) and chloropropane ($CH_3CH_2CH_2Cl$) have similar molar masses, but significantly different boiling points. Identify the substance with the higher boiling point, and justify your choice.

2011:3 (From expired AS 90780)

(b) Discuss the trend in boiling points shown in the graph below for the Group 16 hydrides. In your discussion:

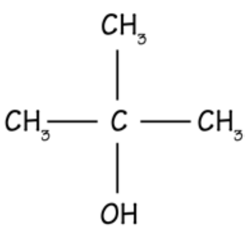
- explain why H_2O has a much higher boiling point than the other hydrides
- account for the rise in boiling points from H_2S to H_2Te
- compare the boiling points of H_2S, H_2Se and H_2Te, and explain the observed trend in terms of bonding AND mass



2010:4 (From expired AS 90780)

(b) Ethanol (CH_3CH_2OH) and propane ($CH_3CH_2CH_3$) have similar molar masses but ethanol is a liquid at room temperature, while propane is a gas. Identify the types of intermolecular forces for each of these substances and explain why ethanol has a higher boiling point than propane.

(c) Account for the difference in the boiling points of the two substances in the table below by comparing all the intermolecular forces.

Name	Structure	Boiling Point / °C
butan-1-ol	$CH_3-CH_2-CH_2-CH_2-OH$	117.7 2
methylpropan-2-ol		82.6

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Answers

2016: 2

(a) NaCl: Ionic bonds.
HCl: Permanent dipole-dipole attractions, temporary dipole-dipole attractions.
CH_3Cl: Permanent dipole-dipole attractions, temporary dipole-dipole attractions.

(b) (i) Much more heat energy is required to overcome the attraction between its particles and convert NaCl from a liquid to a gas than HCl and CH_3Cl, because NaCl has strong ionic bonding between its ions compared to weak intermolecular bonding between the HCl and CH_3Cl molecules.

(ii) Both HCl and CH_3Cl are polar molecules and therefore have permanent dipole-dipole attractions and temporary dipole-dipole attractions between their molecules. However, CH_3Cl has a larger molar mass and therefore more electrons, so its temporary dipole-dipole attractions are stronger than between the HCl molecules. This means more heat energy is required to overcome the attractions between liquid CH_3Cl molecules, so it has a higher $\Delta_{vap}H^\circ$.

(c) (i) Enthalpy of fusion is the energy required to change 1 mol of a substance (NaCl) from a solid to a liquid

(ii) Fusion of NaCl only requires sufficient heat energy to break / overcome some of the ionic bonds, whereas vaporisation requires much more heat energy to overcome all the ionic bonds, therefore the $\Delta_{vap}H^\circ$ of NaCl is much greater than its $\Delta_{fus}H^\circ$.

(iii) When solid NaCl dissolves in water, there is an increase in the entropy of the system since the ions in solution have greater entropy than in the solid lattice, i.e. more random / disordered arrangement. Although the ions in solution have more energy / energetically less stable than in the solid lattice (since the process is endothermic), the increase in entropy makes the process spontaneous.

2015: 3

(i) FORCES

- hydrogen bonding
- permanent dipoles
- instantaneous dipoles.

(ii) The attractive forces due to the hydrogen bonding and permanent dipoles are similar between the molecules in both liquids, as they both have one OH group, which causes the molecule to be polar and take part in hydrogen bonding.

The two molecules have the same mass, and so the same number of electrons involved in the weak instantaneous dipoles.

However, the pentan-1-ol molecule has no side chains and so the main chains can get closer to each other (less steric hindrance, greater surface area), thus the instantaneous dipoles are stronger / greater in pentan-1-ol, and therefore the boiling point is higher.

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2014:2

NH_3 = Hydrogen bonds AND instantaneous dipoles
F_2 = Instantaneous dipoles
HCl = Permanent dipoles AND instantaneous dipoles
NH_3 and HCl both have temporary and permanent dipoles, as they are polar molecules. However, NH_3 has H-bonding, which means the boiling point is higher due to these stronger forces of attraction. HCl has a permanent dipole, but not H-bonding.
F_2 has the lowest boiling point, due to having only temporary dipoles.

2013:3

N_2H_4 is a polar molecule. (Due the presence of the highly polar N-H bonds), there is hydrogen bonding between N_2H_4 molecules.

CH_3F is also a polar molecule. (Due to the presence of the C-F bond), there are permanent dipole attractions between the CH_3F molecules.

The attractive forces due to permanent dipoles in CH_3F must be weaker than the attractive forces due to hydrogen bonding in N_2H_4, because CH_3F boils at a lower temperature and they are similar masses so temporary dipole attractions are similar.

$C_{10}H_{22}$ is a non-polar molecule. The only attractive forces between the $C_{10}H_{22}$ molecules are due to temporary dipoles. However, since $C_{10}H_{22}$ is a significantly larger molecule than N_2H_4, and CH_3F, it is more polarisable / has more electrons / greater molar mass, so (the sum of) its temporary dipole attractions are even stronger than the hydrogen bonds in N_2H_4. As a result, $C_{10}H_{22}$ requires the most heat energy to break its intermolecular forces and therefore has the highest boiling point.

2012:4

(a) (ii) Less energy is required to overcome the attractive forces/ hydrogen bonds between the solid molecules to turn them into a liquid, as only some of these forces need to be broken. However, more energy is required to fully break all forces / hydrogen bonds between molecules in the liquid phase to vapourise the substance to turn them into a gas. Hence the $\Delta_{vap}H^o$ is always greater than the $\Delta_{fus}H^o$.

(b) The instantaneous-induced dipoles (temporary dipoles/ dispersion forces/ London forces) in each substance are the same as the molar mass and hence the size of the electron cloud is the same. $CH_3CH_2CH_2Cl$ is a polar molecule so also has permanent dipole force between the molecules. $HOCH_2CH_2Cl$ is a polar molecule, so also has permanent dipole forces between the molecules. $HOCH_2CH_2Cl$ has an H atom bonded to an atom of high electronegativity (oxygen), so can form hydrogen bonds (H bond) between the molecules. These are strongest of the intermolecular forces. So the forces of attraction between $HOCH_2CH_2Cl$ molecules are stronger thus this substance has a higher boiling point.

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2011:3

H_2O

- has hydrogen bonding because it has H joined to atom of high electronegativity, causing attraction of H to O on another molecule
- strongest of the intermolecular forces
- more energy needed to break these bonds than other intermolecular forces, therefore higher boiling point.

H_2S to H_2Te

- going down a group molecules have greater molar mass/ more electrons
- stronger temporary dipoles / instantaneous dipoles / London's forces
- more energy required to break bonds, therefore higher boiling point.
- As the electronegativities of S > Se > Te decrease down the group, the permanent dipole-dipole interactions will decrease, so boiling points would be expected to decrease. However, as the mass increases, the temporary dipole interactions play a greater role and thus the boiling points increase.

2010:4

(b) The instantaneous-induced dipoles (temporary dipoles/ dispersion forces/ London forces) in each substance are the same as the molar mass and hence the size of the electron cloud is the same. $CH_3CH_2CH_3$ is a non-polar molecule so has temporary dipole intermolecular forces only. CH_3CH_2OH is the same size, so same temporary dipole forces. CH_3CH_2OH is a polar molecule so also has permanent dipole forces between molecules – these are stronger than the temporary dipoles. And CH_3CH_2OH also has an H atom bonded to an atom of high electronegativity, so can also form hydrogen bonds (H bond) between the molecules – these are strongest intermolecular force. So the forces of attraction between CH_3CH_2OH molecules are stronger thus this substance has a higher boiling point.

(c) Both molecules are polar, so same permanent dipole forces. Able to form same hydrogen bonds to other molecules (because the –O–H group is attracted to the O–H of adjacent molecules) so H bonding force the same. The difference in the boiling points is related to the shape of the molecule – one molecule having a straight chain, the other, a branched chain. The straight chain butan-1-ol molecules can pack together more closely / less stearic hindrance / more surface area for formation of temporary dipoles than the 2-methylpropan-2-ol molecules, so even though the molecules have the same molar mass (and so normally same temporary dipole forces) there will be stronger instantaneous / temporary dipole attraction in the straight chain molecule, thus increasing the boiling point.