This exemplar for 91390 has been updated on 19 August 2013 in order to better reflect the qualitative requirements of the standard.

3

SAMPLE PAPER

NZQA

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Level 3 Chemistry

3.4: Demonstrate understanding of thermochemical principles and the properties of particles and substances

Credits: Five

Check that you have completed ALL parts of the box at the top of this page.

Check that you have been supplied with the resource sheet for Chemistry 3.4.

You should answer ALL parts of ALL questions in this booklet.

If you need more room for any answer, use the space provided at the back of this booklet.

Check that this booklet has pages 2–11 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO YOUR TEACHER AT THE END OF THE ALLOTTED TIME.

EXEMPLAR FOR LOW EXCELLENCE

NOTE: These exemplars do not fully show Grade Score Marking (GSM) because of the small sample of student scripts involved, and the absence of a cut score meeting to determine grade boundaries. GSM can be seen in the level 1 and level 2 exemplars from the 2012 examinations, which will be published on the NZQA website when the assessment schedules are published.

You are advised to spend 60 minutes answering the questions in this booklet.

Assessor's use only

QUESTION ONE

(a) Write the electron configuration using *s*, *p*, *d* notation for:

Symbol	Electron configuration
Mg^{2+}	$1s^2, 2s^2, 2p^6$
As	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}, 4p^3$
V^{3+}	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6,$ ~~4s~~ $3d^3$ $4s^2$

Two correct electron configurations.

(b) Give a justification for each of the following:

(i) A chloride ion, Cl^-, is larger than a chlorine atom, Cl, whereas a sodium ion, Na^+, is smaller than a sodium atom, Na.

There is one extra electron than protons in Cl^- ~~than the Cl atom~~. The same enc (effective nuclear charge) ~~attracting on each electron~~ is acting over more same energy level electrons, so a lesser force of attraction is experienced by the electrons. As they are not held as tightly by the protons, the Cl^- ion is larger. (In Cl atoms same number of electrons as protons) A ||

Na^+ has one less electron than protons. The same enc acts over less same energy level electrons, so a higher enc acts on each ~~inner~~ electron. There is a greater attraction between the electrons and protons so the Na^+ ion is smaller than Na. (In Na atoms same number of electrons as protons) A ||

Candidate does not describe the increased electron–electron repulsion occurring when an electron is added.

Candidate does not describe the effect on size of the loss of an entire energy level.

Candidate has not fully explained the effect of increasing number of protons.

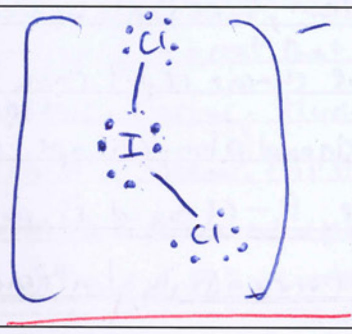
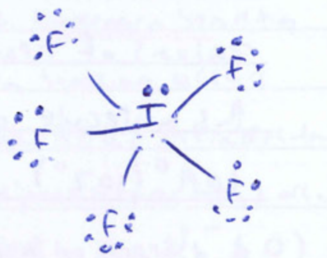
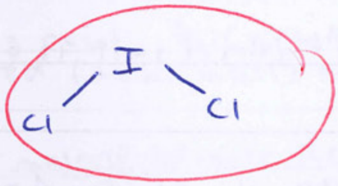
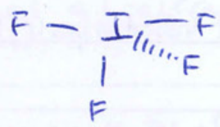
Use of shorthand (abbreviations) does not give clarity in a written explanation.

Assessor's use only

(ii) A chlorine atom has a greater first ionisation energy than a sodium atom.

~~Na atoms have 3 energy levels, whereas a chlorine atom has four. Because of the extra energy level, the outer electrons in the chlorine atom~~ Cl and Na are in the same period. There are a greater number of protons as we go left to right across a period, so Cl has a greater ~~number of~~ enc due to protons for the number of extra electrons. The greater enc acting on the outermost electron in the chlorine atom results in a greater first ionisation energy. //

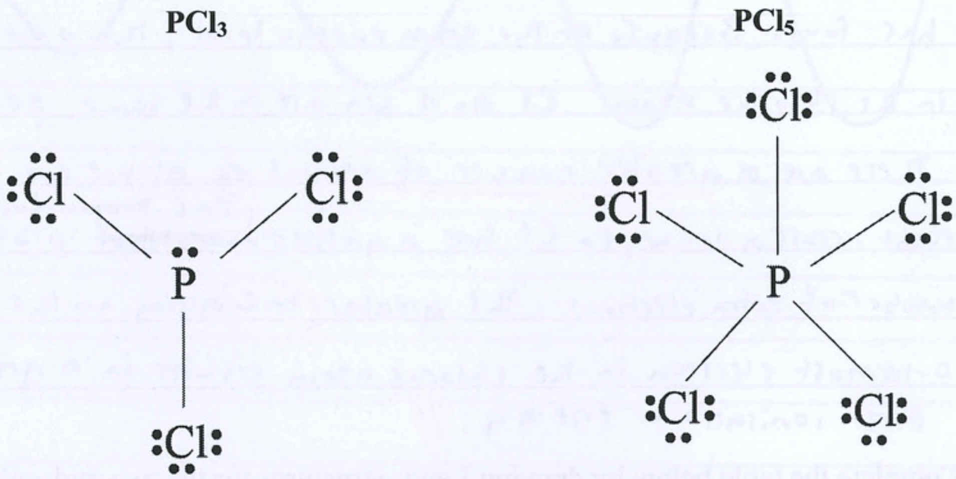
(c) (i) Complete the table below by drawing Lewis structures for the two molecules, drawing the shape of each molecule, and naming the shape of each molecule.

Molecule	ICl_2^-	IF_5
Lewis structures		
Diagram of shape		
Name of shape	T-shaped.	square pyramidal

Correct Lewis structure and shape for IF_5.

Assessor's use only

(ii) The Lewis structures for the two molecules PCl_3 and PCl_5 are shown below. Compare and contrast the shapes and the polarities of these two molecules.



PCl_3 has four regions of negative charge around the central P atom. (One lone pair of electrons, three single bonds)). These four regions of negative charge repel each other in 3D to give the molecule a trigonal planar shape in 3D, with approx bond angles of 109° (107°). The P–Cl bond is polar, this is caused by a difference in electronegativity (attraction of the electron cloud) between the two atoms. The overall molecule is unsymmetrical, so the bond dipole's don't cancel so it is overall polar.

Greater electronegativity of Cl compared to P not identified.

PCl_5 has five electron clouds around the central P atom, all single P–Cl bonds. These repel each other in 3D to give the molecule a trigonal bypyramidal shape in 3D (bond angles 120°/90°) The P–Cl bond is polar, due to the difference in electronegativities of the P/Cl atoms. However, the bond dipoles cancel each other out as the overall molecule is symmetrical in 3D, so the overall molecule is non-polar.

Incorrect shape for PCl_3. Three correct statements for A_3.

A3

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Assessor's use only

QUESTION TWO

(a) (i) Write an equation for the reaction that represents the heat of combustion of sulfur $\Delta_c H$ (S, *s*).

$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$

(ii) Explain why $\Delta_c H$ (S, *s*) and $\Delta_f H$ (SO_2, *g*) have the same value.

ΔcH is the ~~formation~~ complete combustion of ~~~~ one mole of S. ~~~~
The equation is $S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$.
ΔfH is the formation of one mole of SO_2 from its constituent elements in their elemental states. Its equation is also
$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$. The reactions are the same, hence the same value.

(b) Ammonia can be oxidised to produce nitrogen, N_2, and steam as shown in the equation below:

$4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(g) \quad \Delta_r H = -1267 \text{ kJ mol}^{-1}$

Calculate the energy produced when 50.0 g of ammonia reacts as shown in the equation above.

~~n(NH3) = m/M = 50.0~~ M(NH3) = 14.0 + 3 × 1.0 = 17.0 g mol⁻¹
n(NH3) = m/M = 50.0/17.0 = 2.94 mol

4 mol of NH3 produces 1267 kJ of energy.
2.94 mol of NH3 produces ? of energy.

4/2.94 = 1267/x ⇒ x = ~~4/2.94 × 1267~~ 1267/(4 ÷ 2.94)
= 932 kJ (3sf).

Correctly identifies $\Delta_c H$ $\Delta_f H$ as referring to the same equation.

Correct calculation.

Assessor's use only

(c) Ammonia gas can be oxidised to produce nitrogen monoxide, NO, and water as shown in the equation below:

$$4NH_3(g) + 5O_2(g) \rightarrow 6H_2O(l) + 4NO(g)$$

Calculate the enthalpy change, $\Delta_r H$, for this reaction using the information given below.

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ $\Delta_r H = -92$ kJ mol^{-1} x -2

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ $\Delta_r H = -484$ kJ mol^{-1} x 3

$N_2(g) + O_2(g) \rightarrow 2NO(g)$ $\Delta_r H = +180$ kJ mol^{-1} x 2

$H_2O(l) \rightarrow H_2O(g)$ $\Delta_{vap} H = +41$ kJ mol^{-1} x -6

$4NH_3(g) \rightarrow 6H_2(g) + 2N_2(g)$ $\Delta_r H = +184$ kJ mol^{-1}

$6H_2(g) + 3O_2(g) \rightarrow 6H_2O(g)$ $\Delta_r H = -1452$ kJ mol^{-1}

$2N_2(g) + 2O_2(g) \rightarrow 4NO(g)$ $\Delta_r H = 360$ kJ mol^{-1}

$6H_2O(g) \rightarrow 6(H_2O)(l)$ $\Delta_r H = -246$ kJ mol^{-1}

$\Delta_r H = +184 - 1452 + 360 - 246 = -1154$ kJ mol^{-1}

Correct calculation.

E8

Assessor's use only

QUESTION THREE

(a) Predict the entropy change for each of the following reactions by stating whether the entropy will increase OR decrease. Give a reason for each answer.

(i) Ammonium chloride solid $NH_4Cl(s)$ dissolves in water to form $NH_4^+(aq)$ and $Cl^-(aq)$.

increases

The free energy of the NH_4^+ and Cl^- ions increases.

(ii) $3O_2(g) \rightarrow 2O_3(g)$

decreases

The level of disorder has decreased. (3 mol → 2 mol of gas particles).

(iii) $N_2O_4(g) \rightarrow 2NO_2(g)$

increases.

The level of disorder has increased. (1 mol → 2 mol of gas particles)

Correct change in entropy with reason.

(b) At room temperature, 25ºC, steam condenses to water as shown in the equation below. This reaction occurs spontaneously.

$$H_2O(g) \rightarrow H_2O(l)$$

Explain why this reaction is spontaneous by considering the entropy changes when steam condenses.

Clearly explains the intermolecular forces involved in the three molecules. Good comparison.

Assessor's use only

(c) Use the information in the table to answer the following question.

Molecule	Boiling point °C	Molar mass / g mol^{-1}
Water, H_2O	100	18.0
Oxygen, O_2	–183	32.0
Hydrogen sulfide, H_2S	–62	34

Compare and contrast the boiling points of water, oxygen, and hydrogen sulfide in terms of the similarities and differences in the relative strengths of the attractive forces present between particles.

water, oxygen and hydrogen sulfide are all discrete molecules. Then hence all have temporary induced dipoles ~~and~~ van der waals intermolecular forces. (under the heading) This is due to the random movement of electrons in their orbitals.

H_2O is a polar molecule, due to the difference in electronegativities between the O and H atoms and that it is unsymmetrical. This difference is so great that both hydrogen bonding and permanent dipole-dipole attractions occur. Hydrogen bonding occurs when a H is covalently bonded to a O, N or F atom. This strengthens the intermolecular forces to 1/10 of a covalent bond. The permanent dipole-dipole attractions occur because water is polar, so the δ+ end (H) is attracted to the δ− (O) end of nearby molecules. These intermolecular forces are relatively strong and require more energy to break so water has a high boiling point. This means it has a much higher mp/bp compared to similarly sized (molar mass) molecules.

Oxygen, O_2, is a non-polar molecule because the electronegativities of each O atom is the same (and it is symmetrical). There is ~~no~~ hence no hydrogen bonds or permanent dipole-dipole attractions, just dispersion forces between O_2 molecules. The boiling point observed is very low as relatively little energy is required to break these bonds.

H_2S is of comparative size to O_2, but it is polar due to the difference in electronegativities of the H and S atoms. It is also unsymmetrical, so the bond dipoles do not cancel. Hence permanent dipole-dipole attractions occur between molecules, in addition to dispersion forces. The δ+ end (H) is attracted to the ~~nearby~~ (δ−) S end of ~~to~~ nearby molecules. The increased attraction requires more energy to break hence a higher bp than O_2. Lack of hydrogen bonding means it has a lower bp than H_2O (as less energy is required to break these bonds).

E8

3

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3.4: Demonstrate understanding of thermochemical principles and the properties of particles and substances

Credits: Five

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EXEMPLAR FOR HIGH EXCELLENCE

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Assessor's use only

You are advised to spend 60 minutes answering the questions in this booklet.

QUESTION ONE

(a) Write the electron configuration using *s*, *p*, *d* notation for:

Symbol	Electron configuration
$_{10}Mg^{2+}$	$1s^2 2s^2 2p^6$
$_{33}As$	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^3$
$_{20}V^{3+}$	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^2$

Correct electron configuration.

(b) Give a justification for each of the following:

(i) A chloride ion, Cl^-, is larger than a chlorine atom, Cl, whereas a sodium ion, Na^+, is smaller than a sodium atom, Na.

When chlorine forms a Cl^- ion an extra electron is added ~~which~~ to the outer shell which increases electron-electron repulsion, therefore causing the outer electrons to spread out. ~~and~~ There are still the same number of protons but more electrons so the attractive force between outer electrons and nucleus is not as strong, the outer electrons are situated further from the nucleus and so Cl^- is larger than Cl. When Na forms an Na^+ ion, the outer energy level of electrons is removed so the new outer electrons are situated closer to the nucleus, there is a stronger attractive force between the outer electrons and the nucleus so the Na^+ ion is smaller than Na.

Correctly identifies electron–electron repulsion as the cause of Cl^- being larger than Cl^- and the removal of the outer energy level in Na for the reduction in size of Na^+.

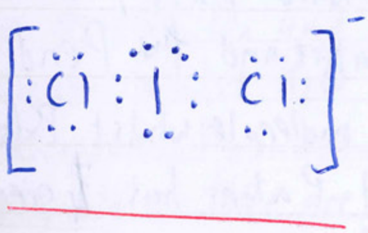
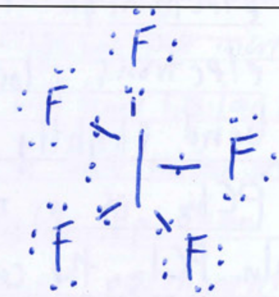
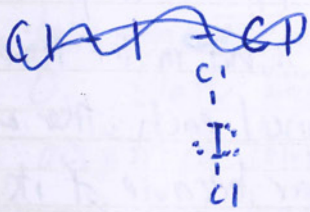
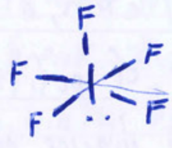
Correctly identifies addition of protons across the period, causing an increase in IE.

Assessor's use only

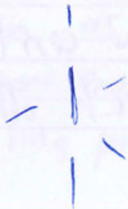
(ii) A chlorine atom has a greater first ionisation energy than a sodium atom.

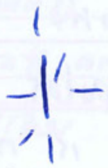
This is because 1st IE increases across a period. Across a period, the number of protons in the nucleus is increasing while electrons are being added to the same energy level so the effective nuclear charge on the outer electrons is increasing. This means that there is a stronger attractive force holding the outer electrons in chlorine than there is in sodium, so it takes more energy to remove the outermost electron from Cl than from Na so Cl has a higher 1st IE (energy required to remove outermost electron).

(c) (i) Complete the table below by drawing Lewis structures for the two molecules, drawing the shape of each molecule, and naming the shape of each molecule.

Molecule	ICl_2^-	IF_5
Lewis structures	22 	42 
Diagram of shape		
Name of shape	linear	square based pyramid

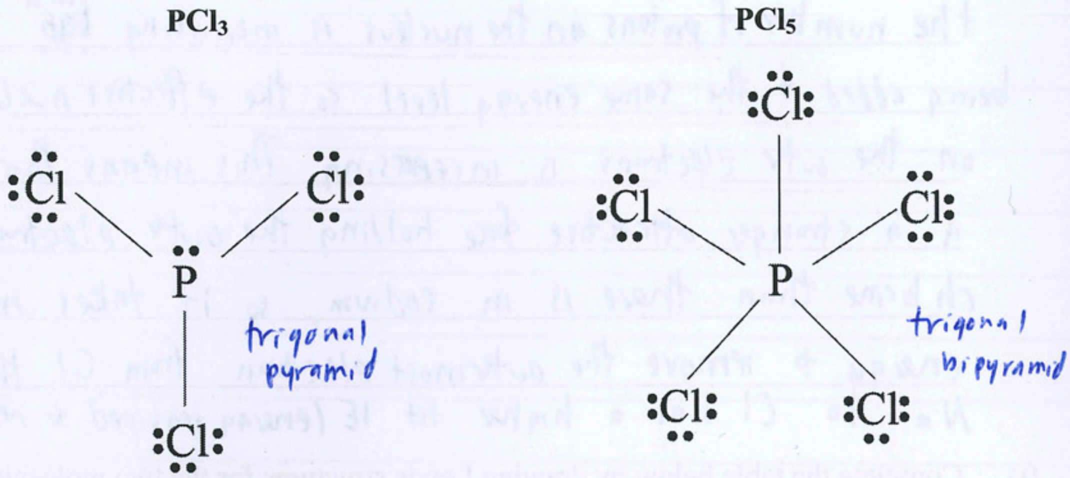
All structures and shapes correct.





(ii) The Lewis structures for the two molecules PCl_3 and PCl_5 are shown below. Compare and contrast the shapes and the polarities of these two molecules.

Assessor's use only



Both PCl_3 and PCl_5 contain polar bonds, because Cl is more electronegative than P therefore Cl attracts the bonding electrons closer toward itself, leaving the Cl end of the bond slightly negative and the P end slightly positive. However, PCl_3 is a polar molecule whilst PCl_5 is a non polar molecule. In PCl_3, the central P atom has 4 areas of electron density around it which repel each other as far apart as possible due to VSEPR but as only 3 are bonded to Cl atoms, a trigonal pyramid shape is observed. This shape is asymmetrical so the centre of positive charge is not in the same place as the centre of negative charge, the dipoles do not cancel each other out and the PCl_3 molecule is polar. PCl_5 is non-polar because of its different shape. In PCl_5, the central P atom has 5 areas of electron density around it which repel each as far apart as possible and as all 5 are bonded to Cl atoms, a trigonal bipyramid shape is observed. This is a symmetrical shape so the centre of positive charge is in the same place as the centre of negative charge, the dipoles cancel each other out and the overall PCl_5 molecule is non-polar //

Complete answer.

E8

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Assessor's use only

QUESTION TWO

(a) (i) Write an equation for the reaction that represents the heat of combustion of sulfur $\Delta_c H$ (S, *s*).

$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$ $\Delta_r H = \Delta_c H (S_{(s)})$

(ii) Explain why $\Delta_c H$ (S, *s*) and $\Delta_f H$ (SO_2, *g*) have the same value.

Because the equation for the enthalpy of formation of SO_2 is $S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$, as this is the same equation as the enthalpy of combustion equation shown above both ~~will~~ will have the same enthalpy change.

(b) Ammonia can be oxidised to produce nitrogen, N_2, and steam as shown in the equation below:

$4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(g)$ $\Delta_r H = -1267 \text{ kJ mol}^{-1}$

Calculate the energy produced when 50.0 g of ammonia reacts as shown in the equation above.

~~$n(NH_3) = \frac{m}{M}$~~ $M(NH_3) = 1 \times 3 + 14 = 17 \text{ g mol}^{-1}$

$n(NH_3) = \frac{m}{M} = \frac{50}{17} = 2.94 \text{ mol}$

~~$\Delta E = 1267 \times 2.94$~~

~~$= 3725.5 = 3730 \text{ kJ}$ of energy produced. (3sf)~~

When 4 mol of NH_3 react, 1267 kJ released.

So when 2.94 mol react, $\frac{1267}{4} \times 2.94 = 931.6$

$= 932 \text{ kJ}$ (3sf) released.

Both excellence answers correct.

Assessor's use only

(c) Ammonia gas can be oxidised to produce nitrogen monoxide, NO, and water as shown in the equation below:

$$4NH_3(g) + 5O_2(g) \rightarrow 6H_2O(l) + 4NO(g)$$

Calculate the enthalpy change, $\Delta_r H$, for this reaction using the information given below.

$N_2(g)$	+	$3H_2(g)$	→	$2NH_3(g)$	$\Delta_r H = -92$ kJ mol^{-1} x-2
$2H_2(g)$	+	$O_2(g)$	→	$2H_2O(g)$	$\Delta_r H = -484$ kJ mol^{-1} ×3
$N_2(g)$	+	$O_2(g)$	→	$2NO(g)$	$\Delta_r H = +180$ kJ mol^{-1} x2
		$H_2O(l)$	→	$H_2O(g)$	$\Delta_{vap} H = +41$ kJ mol^{-1} x-6

$4NH_{3(g)} \rightarrow 2N_{2(g)} + 6H_{2(g)}$ $\Delta_r H = +184$ kJ

$2N_{2(g)} + 2O_{2(g)} \rightarrow 4NO_{(g)}$ $\Delta_r H = +360$ kJ

$6H_{2(g)} + 3O_{2(g)} \rightarrow 6H_2O_{(g)}$ $\Delta_r H = -1452$ kJ

$6H_2O_{(g)} \rightarrow 6H_2O_{(l)}$ $\Delta_r H = -246$ kJ

$4NH_{3(g)} + 5O_{2(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(l)}$ $\Delta_r H = -1154$ kJmol^{-1}

$= -1150$ kJmol^{-1} (3sf)

All parts correct.

E8

Assessor's use only

QUESTION THREE

(a) Predict the entropy change for each of the following reactions by stating whether the entropy will increase OR decrease. Give a reason for each answer.

(i) Ammonium chloride solid $NH_4Cl(s)$ dissolves in water to form $NH_4^+(aq)$ and $Cl^-(aq)$.

(ii) $3O_2(g) \rightarrow 2O_3(g)$

(iii) $N_2O_4(g) \rightarrow 2NO_2(g)$

(b) At room temperature, 25ºC, steam condenses to water as shown in the equation below. This reaction occurs spontaneously.

$$H_2O(g) \rightarrow H_2O(l)$$

Explain why this reaction is spontaneous by considering the entropy changes when steam condenses.

Gases generally have higher entropy than liquids. For spontaneous change, the total entropy must increase overall. However, when steam condenses into liquid water at 25°C, the entropy decreases. Need to take into account that energy ~~4~~ is important in working out the 'total' entropy change. Energy is released into the surroundings as water condenses, so the entropy of the surroundings increases. The total entropy (water condensing and of the surroundings) is positive, so the reaction is spontaneous.

Assessor's use only

(c) Use the information in the table to answer the following question.

Molecule	Boiling point °C	Molar mass / g mol^{-1}
Water, H_2O H bonds	100	18.0
Oxygen, O_2 non polar	–183	32.0
Hydrogen sulfide, H_2S polar	–62	34

Compare and contrast the boiling points of water, oxygen, and hydrogen sulfide in terms of the similarities and differences in the relative strengths of the attractive forces present between particles.

Water and hydrogen sulfide are both polar molecules, while O_2 is a non polar molecule. All 3 molecules will contain weak intermolecular forces called dispersion forces due to the temporary and induced dipoles that occur between molecules. The strength of dispersion forces depends on the number of electrons creating the temporary dipole, so the strength of the dispersion force increases with increasing molar mass. Therefore O_2 and H_2S will have similar strength dispersion forces between molecules, whilst H_2O with its lower molar mass has weaker dispersion forces. However, H_2S has a higher bp than O_2 because H_2S is a polar molecule so there are stronger permanent dipole-dipole attractions also occuring between molecules. These forces are stronger than the dispersion forces that are the only intermolecular attractive forces holding O_2 molecules together so take more energy to break, therefore H_2S has a higher bp than O_2. Water has a much higher bp. than either of these substances despite its lower molar mass so weaker dispersion forces. This is because H is bonded to O, one of the most electronegative element, so strong intermolecular bonding occurs between the δ+ H and the lone pairs on O atoms of adjacent molecule. This is known as hydrogen bonding, and is much stronger than dispersion forces or permanent dipole-dipole attractions (these 2 types of forces are also known as van der Waals' forces), so the H bonds take a lot more energy to separate and therefore H_2O has a much higher boiling point than either H_2S or O_2.

Clear comparison of intermolecular forces in all three molecules.

E7