

ANSWERS



## Level 3 Chemistry

### 91390 Demonstrate understanding of thermochemical principles and the properties of particles and substances

**Credits: Five**

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of thermochemical principles and the properties of particles and substances.	Demonstrate in-depth understanding of thermochemical principles and the properties of particles and substances.	Demonstrate comprehensive understanding of thermochemical principles and the properties of particles and substances

You should attempt ALL the questions in this booklet.

A periodic table is provided in the Resource Sheet.

If you need more room for any answer, use the extra space provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2 – 10 in the correct order and that none of these pages is blank.

**YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.**

TOTAL

ASSESSOR'S USE ONLY

### QUESTION ONE

(a) Complete the following table, using s, p, d notation.

Symbol	Electron configuration
Fe	[Ar] 4s <sup>2</sup> 3d <sup>6</sup> or [Ar] 3d <sup>6</sup> 4s <sup>2</sup>
Cu	[Ar] 4s <sup>1</sup> 3d <sup>10</sup> or [Ar] 3d <sup>10</sup> 4s <sup>1</sup>
Cr <sup>3+</sup>	[Ar] 3d <sup>3</sup>

(b) The following table shows the electronegativity values of the elements from lithium to fluorine.

	Li	Be	B	C	N	O	F
Electronegativity	1.0	1.5	2.0	2.5	3.0	3.5	4.0

(i) Define the term electronegativity.

Electronegativity:

The ability of an atom in a bond to attract electrons towards itself / electronegativity is a measure of how strongly an atom attracts bonding electrons.

(ii) Justify the trend in electronegativity of the elements from lithium to fluorine.

There is an increase in the number of protons and thus the nuclear charge / attractive force of the nucleus. As the electrons are added to the same energy level, there is no increase in repulsion between energy levels. The nuclei with a greater number of protons have a stronger electrostatic attraction for the valence electrons in the third shell, thus the electronegativity increases across a period.

- (c) Ionisation energies provide evidence for the arrangement of electrons in atoms.
- (i) Define the term *first ionisation energy*.

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First ionisation energy is a measure of how easily the first mole of electrons is removed from one mole of gaseous atoms / is the energy required to remove one mole of electrons from one mole of atoms in the gaseous state

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- (ii) The table shows the first ionisation energy of rubidium and some other elements in the same group.

Element	Sodium	Potassium	Rubidium
First ionisation energy / $\text{kJ mol}^{-1}$	494	418	402

Explain the factors influencing the trends in first ionisation energy down a group of the periodic table.

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First ionisation energy decreases down a group. Although the nucleus will become increasingly positive down a group (number of protons increases), the atomic radius increases down a group and the electron being removed is a greater distance from the nucleus, as more energy levels are added and shielding / repulsion from inner shells increases. Therefore, since the electrons in the valence shell are further away from the positive nucleus, resulting in a weaker electrostatic attraction between the nucleus and the valence electrons, it is therefore easier to remove one: first IE decreases.

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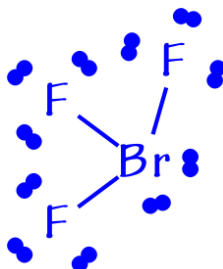
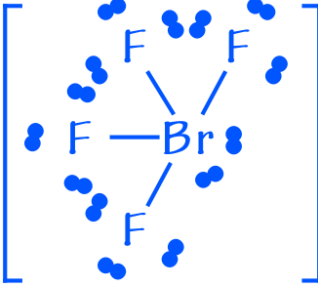
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### Question Two

Two molecules of  $\text{BrF}_3$  react to form ions as shown by the following equation.

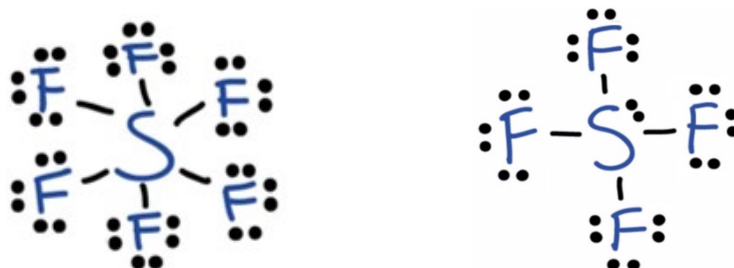


(a) Complete the following table.

	$\text{BrF}_3$	$\text{BrF}_4^-$
Lewis Diagram		
Name of shape	T-shaped	Square planar

Sulfur forms many molecular compounds with the halogens.

(b) The Lewis diagrams of  $\text{SF}_6$  and  $\text{SF}_4$  are shown below.



Compare and contrast the polarities and shapes of these two molecules.

There is an electronegativity difference between S and F, so the S-F bonds are polar covalent (F is more electronegative than S).

The six bond pairs around the central S atom arrange themselves as far apart as possible to minimise repulsion, so  $\text{SF}_6$  has an octahedral shape.

Since this is a symmetrical shape, the bond dipoles cancel out, so  $\text{SF}_6$  is a non-polar molecule.

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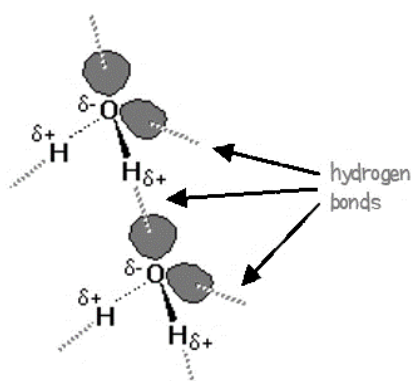
$\text{SF}_4$  is polar. It has 5 areas of electron density around the central S atom, one of which is a lone pair.

Maximum separation for minimum repulsion means that the shape is based on a trigonal bipyramid arrangement, but the molecule itself has a see-saw shape.

The S-F bonds are polar, due to the greater electronegativity of F.

The molecule is not symmetrical, and so the dipole moments cannot cancel, making the molecule polar.

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- (c) (i) Draw a diagram to show how two molecules of water are attracted to each other by intermolecular forces. Your diagram should include
- partial charges
  - all lone pairs of electrons.



- (ii) The table below shows the boiling points of some hydrogen compounds formed by Group 16 elements.

	H <sub>2</sub> O	H <sub>2</sub> S	H <sub>2</sub> Se	H <sub>2</sub> Te
Boiling point / K	373	212	232	271

Use the information above to explain the difference in the boiling points of water and hydrogen sulfide by comparing and contrasting the relative strengths of all the attractive forces between the molecules involved.

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FORCES

- hydrogen bonding
- permanent dipoles
- instantaneous / temporary dipoles.

H<sub>2</sub>O and H<sub>2</sub>S both have temporary and permanent dipoles, as they are polar molecules. However, H<sub>2</sub>O has hydrogen bonding between the molecules which means the boiling point is higher due to these stronger forces of attraction. This is despite H<sub>2</sub>S having more/stronger instantaneous dipole-instantaneous dipole attractions as it has a greater mass and therefore more electrons.

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### Question Three

- (a) Define the term standard enthalpy of combustion.

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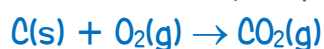
The standard enthalpy change of combustion of a compound is the enthalpy change which occurs when one mole of the compound is burned completely in oxygen under standard conditions, and with everything in its standard state.

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- (b) Explain why the value for the standard enthalpy of formation of carbon dioxide,  $\text{CO}_2(\text{g})$ , which is  $-394 \text{ kJ mol}^{-1}$ , has the same as the value for the standard enthalpy of combustion of carbon.

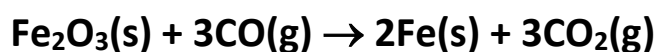
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The equation for the combustion of carbon is the same as the equation for the heat of formation of carbon dioxide.



- (c) (i) Use the standard enthalpies of formation in the table below and the equation to calculate a value for the standard enthalpy change,  $\Delta_r H^\circ$  for the extraction of iron using carbon monoxide.

	$\text{Fe}_2\text{O}_3(\text{s})$	$\text{CO}(\text{g})$	$\text{CO}_2(\text{s})$
$\Delta_f H^\circ / \text{kJ mol}^{-1}$	-822	-111	-394



$$\begin{aligned} \Delta_r H^\circ &= \sum \Delta_f H^\circ(\text{products}) - \sum \Delta_f H^\circ(\text{reactants}) \\ &= (3 \times -394) + 0 - (-822) + (3 \times -111) \\ &= -27.0 \text{ kJ mol}^{-1}. \end{aligned}$$

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- (ii) The  $\Delta_{\text{fus}}H$  for iron, Fe is  $13.8 \text{ kJ mol}^{-1}$ . How would the enthalpy change you calculated in (c)(i) be different if the iron was formed as a liquid, rather than as a solid.

Circle the correct phrase and justify your answer. There is no need to do a calculation but you may wish to include one to justify your answer.

**less negative** / the same / more negative

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The enthalpy change would be less negative.

Heat energy is released when converting a liquid to a solid. Therefore if the iron formed were in the liquid state rather than as a solid, then less energy would be released in its formation / products would have a higher enthalpy.



$$\begin{aligned}\Delta_r H^\circ &= \Sigma \Delta_f H^\circ(\text{products}) - \Sigma \Delta_f H^\circ(\text{reactants}) \\ &= (3 \times -394) + (2 \times +13.8) - (-822 + (3 \times -111)) \\ &= +0.600 \text{ kJ mol}^{-1}.\end{aligned}$$

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- (d) When sodium chloride, NaCl, dissolves in excess water,  $\Delta H$  is  $+3.90 \text{ kJ mol}^{-1}$ .



- (i) Explain the entropy changes of the system and surroundings for the dissolution of sodium chloride.

System:  $\Delta S$  for the system is  $+305 \text{ J K}^{-1} \text{ mol}^{-1}$ .

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The system has increased in entropy as shown by the  $+\Delta S$  value. Ions in solution have higher entropy than solids as there is an increase in the dispersal of matter / degree of disorder.

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Surroundings:  $\Delta S$  for the surroundings is  $-13.1 \text{ J K}^{-1} \text{ mol}^{-1}$ .

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When  $\text{NaCl(s)}$  dissolves in water, the process is endothermic ( $\Delta H$  is  $+3.90 \text{ kJ mol}^{-1}$ ). The entropy of the surroundings decreases because heat is transferred from the surroundings. This results in less random motion of the particles in the surroundings.

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- (ii) Discuss why the  $\text{NaCl}$  dissolves readily in water despite  $\Delta H = +3.90 \text{ kJ mol}^{-1}$ .
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When solid  $\text{NaCl}$  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.

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