

91390



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## Level 3 Chemistry, 2017

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

2.00 p.m. Wednesday 15 November 2017

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.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

**You should attempt ALL the questions in this booklet.**

A periodic table is provided on the Resource Sheet L3-CHEMR.

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 2–11 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.**

**Excellence**

**TOTAL**

**21**

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## QUESTION ONE

(a) Complete the following table.

Symbol of particle	Electron configuration (use <i>s</i> , <i>p</i> , <i>d</i> notation)	Charge	Atomic number
Cl	$1s^2 2s^2 2p^6 3s^2 3p^5$	0	17
18. $Ca^{2+}$	$1s^2 2s^2 2p^6 3s^2 3p^6$	+2	20
23 $Mn^{2+}$	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$	2+	25

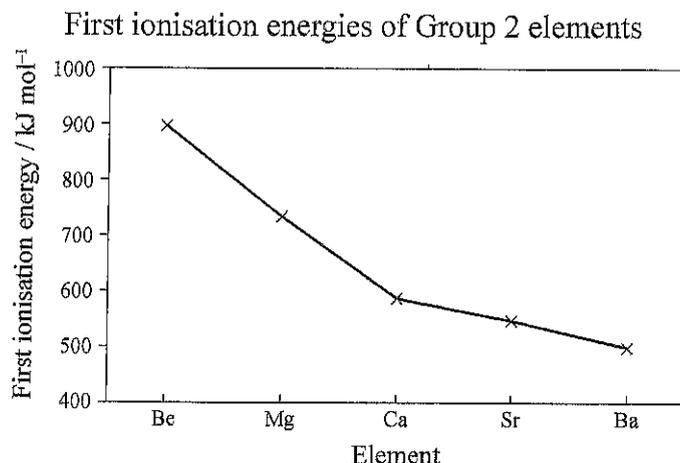
(b) (i) Define the term electronegativity.

Electronegativity is the level of attraction of a given atom for bonding electrons.

(ii) Explain why the electronegativity of chlorine is greater than that of phosphorus.

The electronegativity of chlorine is greater than that of phosphorus, this is because, even though both chlorine and phosphorus have the same energy level, thus the same amount of shielding. However chlorine has more protons and electrons (greater nuclear charge) and electrons as compared to phosphorus. This means that there is stronger electrostatic attraction between the nucleus and valence electrons of chlorine than phosphorus, thus making chlorine more electronegative than phosphorus.

- (c) The following graph shows the first ionisation energies of the Group 2 elements from Be to Ba.



- (i) Write an equation to show the first ionisation energy for the element calcium.



- (ii) Explain the trend shown of first ionisation energies of the Group 2 elements.

Ionisation energy is the energy required to remove one mole of electrons from one mole of ions or atoms in gaseous state. The ionisation energies in group 2 decreases down the group from Be to Ba. Be (around 900 kJ mol<sup>-1</sup>) to Ba (around 500 kJ mol<sup>-1</sup>). This is because the outer energy levels increase down the group so the distance between the nucleus and valence electrons increase, thus the amount of shielding also increase. This means there is weaker attraction between nucleus and valence electrons (as further away and more shielded) making Ca, Sr, Ba less tightly held together down a group so less energy is required to remove an electron. This means it is harder to remove an electron from Be (more tightly held together due to less shielding and less number of outer energy levels, a stronger attraction between nucleus and valence electrons) than it is for Ba. Despite nuclear charge increasing (more protons) down a group (which increases attraction between nucleus and valence electrons) this is outweighed by the increased distance outer energy level and shielding which is more significant compared to nuclear charge increasing.

## QUESTION TWO

Molecule	Boiling Point / °C	M / g mol <sup>-1</sup>
Hydrazine, N <sub>2</sub> H <sub>4</sub>	114	32
Iodomethane, CH <sub>3</sub> I	42.4	142
Decane, C <sub>10</sub> H <sub>22</sub>	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.

In hydrazine, there is the ~~intermolecular~~ <sup>intermolecular or</sup> forces of temporary dipole-dipole, permanent dipoles and hydrogen bonding as compared to iodomethane which has only temporary dipole-dipole and permanent dipole-dipole. ~~Despite~~ Hydrazine having hydrogen bonding which is the strong intermolecular forces of attraction, it has a lower boiling point due to N-H bond makes Hydrazines have a higher boiling point than Iodomethane. As Iodomethane only has temporary ~~temporary~~ <sup>dipole-dipole</sup> and permanent dipole which are weaker intermolecular forces of attraction so are held less tightly together as compared to N<sub>2</sub>H<sub>4</sub> resulting in lower boiling point of 114. ~~Despite~~ having a larger molar mass for CH<sub>3</sub>I, the hydrogen bonding in N<sub>2</sub>H<sub>4</sub> is more significant than large molar mass so higher boiling point for N<sub>2</sub>H<sub>4</sub>. ~~MM~~

(ii) Iodomethane and decane.

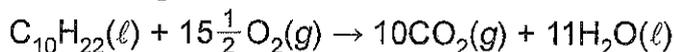
Decane has a higher boiling point of 174°C than Iodomethane of 42.4°C. Decane has temporary dipole-dipole which Iodomethane also has, but Iodomethane not has only same temporary ~~temp~~ dipole-dipole, but also permanent dipole-dipole (stronger intermolecular force than temporary dipole-dipole). ~~Both~~ Both have the same molar mass. Despite Iodomethane having stronger intermolecular forces of attraction, decane has a higher boiling point. This is due to decane being a very large molecule as compared to Iodomethane. There are 10 decane's decane's has more electrons which means stronger temporary-dipole/dipole so more energy is required to break the forces of decane than it is for Iodomethane. ~~MM~~

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

Solubility of hydrazine in water is greater than decane in water. This is because hydrazine is a polar molecule and water is a polar molecule so the attractive forces between hydrazine and water can be overcome resulting in hydrazine dissolving in water.

However for decane, it is a nonpolar molecule so it does not dissolve in water because the attractive forces between water and decane cannot be overcome, thus the intermolecular forces of decane so it does not dissolve.

- (c) Carbon dioxide and water are formed when decane burns completely in oxygen. The reaction is shown in the equation below.

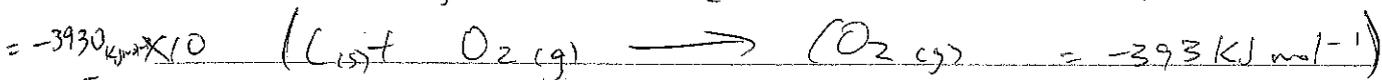
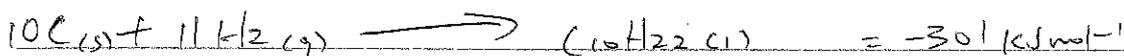
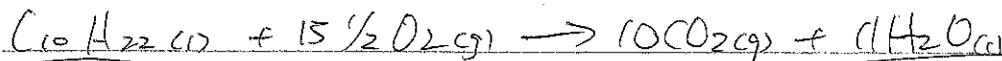


Calculate the enthalpy of combustion for decane, given the following data:

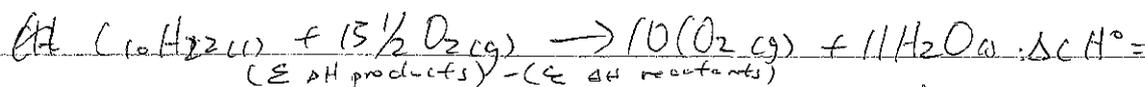
$$\Delta_f H^\circ (\text{C}_{10}\text{H}_{22}(\ell)) = -301 \text{ kJ mol}^{-1}$$

$$\Delta_c H^\circ (\text{C}) = -393 \text{ kJ mol}^{-1}$$

$$\Delta_c H^\circ (\text{H}_2) = -286 \text{ kJ mol}^{-1}$$



$$\Delta_c H^\circ = \Delta_c H^\circ =$$

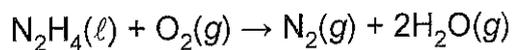


$$\Delta_c H^\circ = \sum \Delta_f H^\circ (\text{products}) - \sum \Delta_f H^\circ (\text{reactants})$$

$$\Delta_c H^\circ = (-3930 + -3146) - (-301)$$

$$= -6775 \text{ kJ mol}^{-1}$$

- (d) The reaction for the complete combustion of hydrazine is shown in the equation below.



This is an exothermic reaction.

Explain the entropy changes associated with this reaction.

This is an exothermic reaction so entropy of surrounding increase, so energy is released to produce  $\text{N}_2(\text{g})$  and  $\text{H}_2\text{O}(\text{g})$ . The entropy of the system also increase because of the amount of gaseous particles that have increased, from 1 to 3 mol. This means particles are more spread out and random and less ordered so an entropy of system increases. Overall this means the complete combustion of hydrazine is a spontaneous reaction.

### QUESTION THREE

Chlorine,  $\text{Cl}_2$ , bromine,  $\text{Br}_2$ , and iodine,  $\text{I}_2$ , 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.

*[Handwritten scribble]*

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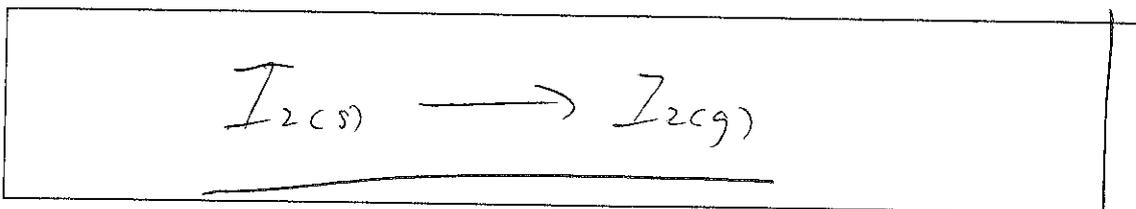


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- (b) (i) Write an equation for the sublimation of iodine in the box below.



- (ii) Define the enthalpy of sublimation for iodine.

*Enthalpy of sublimation means energy required to break the forces in to convert one mole of solid iodine to gas*

Question Three continues  
on the following page.

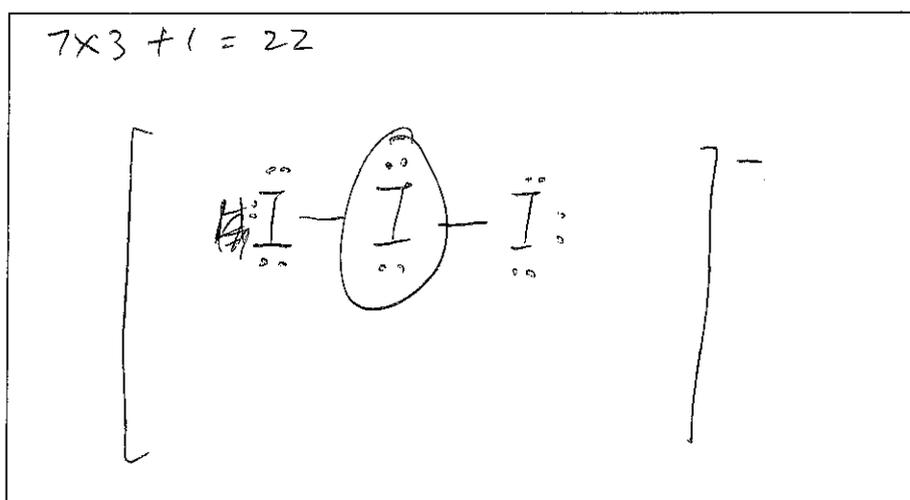
- (iii) Explain why the sublimation of iodine is spontaneous, even though the enthalpy of sublimation is a positive value.

Sublimation of iodine is spontaneous because ~~sublimation~~ this converts the solid to a gas which means there is ~~more random~~ gaseous particles spread out which increases the entropy of the system. This is more significant than the unpositive value indicating it is an endothermic reaction, thus is a spontaneous reaction.

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- (c) Iodine forms a linear  $I_3^-$  ion.

- (i) Draw the Lewis structure for the  $I_3^-$  ion in the box below.



- (ii) Explain why the  $I_3^-$  ion has a linear shape.

$I_3^-$  has a linear shape because there are 4 electron density regions around the central atom I which are arranged with maximum separation to minimise  $e^-e^-$  repulsion give a base shape of tetrahedral. As there are 2 bonding and 2 non bonding regions, the actual shape is linear.

(iii)  $\text{IF}_5$  has a square pyramidal shape.

Indicate whether the molecule  $\text{IF}_5$  is polar or non-polar.

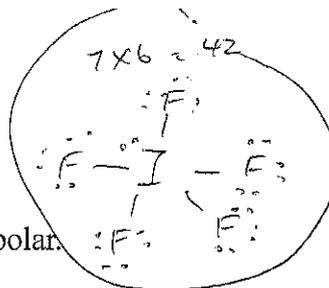
Circle your choice.

**polar**

**non-polar**

Justify your choice.

~~It is~~ The bonds in  $\text{IF}_5$ ,  $\text{I}-\text{F}$  are polar due to a difference in electronegativity between ~~the~~ I and F (F more electronegative) which results in dipoles for each bond. These dipoles are arranged in a nonsymmetrical square pyramidal shape (due to 5 bonding and one non bonding regions of  $\text{IF}_5$ ) the dipoles do not cancel out, resulting in an overall dipole. This means  $\text{IF}_5$  is polar.  $\text{IF}_5$  has 6 regions of electron density ~~with~~ around central atom I which are arranged with maximum separation to minimise  $e^-$  repulsion giving octahedral base shape but because 5 are bonding and 1 non bonding shape is square pyramidal, a non symmetrical shape as explained before.



**Excellence exemplar 2017**

<b>Q</b>	<b>Grade score</b>	<b>Annotation</b>
1	E8	The candidate clearly understands the factors that affect electronegativity and ionisation energy. They are also able to distinguish which factors are most important to determine trends.
2	E8	The candidate has a thorough understanding of intermolecular forces and can evaluate each molecule to compare their strengths. They can also calculate enthalpy accurately using correct units. Their entropy answer was not at excellence level as they did not link the increase in entropy of the surroundings to an increase kinetic energy of particles.
3	M5	This candidate was unable to compare intermolecular attraction differences for bromine and chlorine. Their answer for the sublimation of iodine's spontaneity was not specific enough to demonstrate understanding of the opposing nature of the enthalpy and entropy of this reaction. Their answer for the polarity of IF <sub>5</sub> was at excellence level.