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91390

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Level 3 Chemistry, 2015

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

2.00 p.m. Wednesday 11 November 2015
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 **23**

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Annotated Exemplar Template

		Excellence exemplar for 901390 2015	Total score	23

Q	Grade score	Annotation
1	**E8**	1b) correct definitions 1c) has clearly linked increased nuclear charge to increase in protons and electrostatic attraction for valence electrons. Links increased attraction to more energy required to remove outer electrons. Links increased electrostatic attraction to being held more tightly by the nucleus hence drawing in the valence electrons. Clearly states that electrons are being added to the same energy level.
2	**E7**	2a) i) correct equation with states. ii) recognises that the equations are the same b) Recognises that energy is required to break the intermolecular bonds in the gas phase and links to the fact that this does not need to happen in the liquid phase. Does not link to bond forming being an exothermic process. c) correct with units
3	**E8**	a) Correct structures and names b) States number of electron density areas, states parent geometry and links to repulsion between bonding electrons. States actual geometry, linked to number of bonding and non-bonding electrons. Gives the reason for bond polarity as being a difference in electronegativity. Gives the polarity of the molecule and links to symmetry and dipoles cancelling/ not cancelling. c) Ii) States that both molecules have the same molar mass. Recognises that difference in boiling point is due to the molecular shape and relates this to packing more tightly together. States that the intermolecular forces are stronger due to increased packing and links to breaking the bonds for boiling point to be reached.

QUESTION ONE

(a) Complete the following table.

Symbol	Electron configuration
Al	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$
Cu^{2+}	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9$
Sc	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^1$

(b) Define the terms electronegativity and first ionisation energy.

Electronegativity: *The measure of attraction between a nucleus and its ~~pair of bon~~ bonding pair of electrons.*

First ionisation energy: *The minimum energy required to remove one electron from each atom in a mole of atoms in gaseous state*

(c) The following table shows the first ionisation energy values for elements in the third period of the periodic table.

Element	First ionisation energy / kJ mol^{-1}
Na	502
Al	584
Si	793
Ar	1 527

Justify the periodic trend of first ionisation energies shown by the data in the table above, and relate this to the expected trend in atomic radii across the third period.

~~As~~ Across the period the number of protons and therefore nuclear charge increases. As there is no further shielding from outer electrons the effective nuclear charge increases. The valence electrons

91390

for elements in the third period are being added to the same valence shell, therefore electrostatic attraction across the period increases. ~~th~~ This means the electrons are held tighter to the nucleus hence ~~Ain~~ the periodic trend is that from group 1 to group 18, the ionisation energy increases since more energy is required to remove the electrons. As electrostatic attraction increases across the period the atomic radii decreases in size because the electrons are held tighter to the nucleus. Na has a much lower first ionisation energy than Ar as it is further across the period.
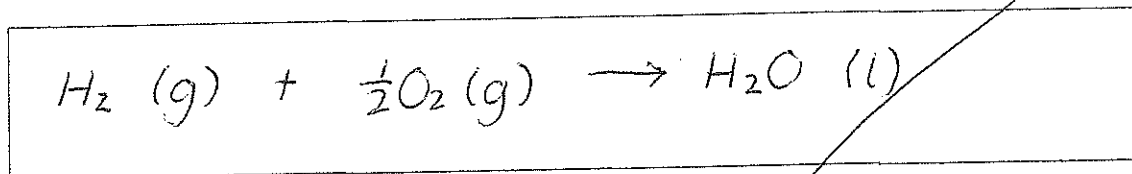
QUESTION TWO

The equation for $\Delta_f H°$ of $H_2O(\ell)$ is:

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(\ell) \qquad -286 \text{ kJ mol}^{-1}$$
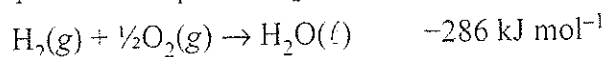
(a) (i) Write the equation for $\Delta_c H° (H_2(g))$.

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$$

(ii) Using the equations above, explain why $\Delta_c H° (H_2)$ and $\Delta_f H° (H_2O)$ have the same value of -286 kJ mol^{-1}.

They are the same equation. The standard enthalpy of combustion involves the same mol of products and reactants and there is no state change therefore the same amount of energy is required to form bonds as it is to completely burn $H_2(g)$ in oxygen.

(b) The enthalpy of formation would change if the water was formed as a gas rather than a liquid.

(i) Circle the correct phrase to complete the sentence below.

$\Delta_f H° (H_2O(g))$ is:

(less negative than) / the same as / more negative than $\Delta_f H° (H_2O(\ell))$.

(ii) Justify your choice.

If H_2O was formed as a gas rather than a liquid more energy is required because energy is needed to completely break the strong hydrogen bonds between water molecules. When H_2O is formed as a liquid only some bonds need to be broken so that the water molecules are less tightly packed. This means less energy is required. Therefore the enthalpy of formation for $H_2O(g)$
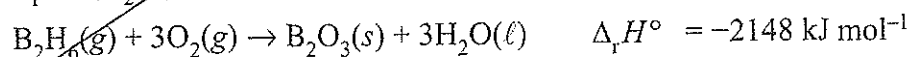
is less negative than $\Delta_f H (H_2O (l))$.

(c) Calculate the $\Delta_f H°$ for $B_2H_6(g)$, given the following data:

$\Delta_f H° (B_2O_3(s))$ $= -1255 \text{ kJ mol}^{-1}$

$\Delta_f H° (H_2O(l))$ $= -286 \text{ kJ mol}^{-1}$

$B_2H_6(g) + 3O_2(g) \rightarrow B_2O_3(s) + 3H_2O(l)$ $\Delta_r H° = -2148 \text{ kJ mol}^{-1}$

The melting point of boron is 2300°C.

~~$2B(g) + 3H_2(g) \rightarrow B_2H_6(g)$~~ ~~$\Delta_f H° = ?$~~

~~$2B(g) +$~~
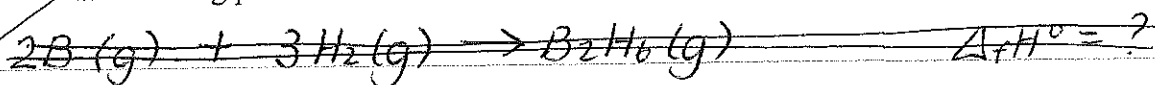
$\Delta_r H° = \Sigma \Delta_r H° \text{products} - \Sigma \Delta_r H° \text{reactants}$

~~$B_2H_6(g)$ $((-1255) + (3(-286))$~~

~~$(-1255 + (3(-286))) - (B_2H_6(g)) =$~~

$(-1255 + 3(-286)) - (B_2H_6 + O)$ $= -2148 \text{ kJmol}^{+1}$

$-2113 + 2148 = B_2H_6$

$B_2H_6 = 35$

$\Delta_f H° (B_2H_6) = {}^+35 \text{kJmol}^{-1}$

$\Delta_f H° (B_2H_6) = +35.0 \text{ kJmol}^{-1}$ $(3sf)$
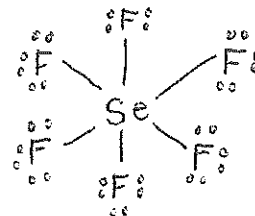
QUESTION THREE

(a) Complete the following table.

	AsF_5	SeF_6
Lewis diagram		
Name of shape	trigonal bipyramid	octahedral

(b) The Lewis diagrams and shapes for XeO_2F_2 and GeH_4 are shown below.
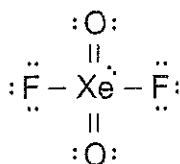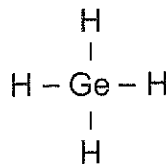
see-saw   tetrahedral

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

For XeO_2F_2, there are five regions of electron density around the central Xe atom. According to the VSEPR theory, electron pair geometry which minimises the electron-electron repulsion for 5 regions is trigonal bipyramid. However, due to the presence of one lone pair ~~around~~, the shape is distorted and XeO_2F_2 has the ~~geometrical~~ molecular shape geometry see-saw. There is a difference in electronegativity between Xe and O with δ^+ on Xe and δ^- on O, and there is a difference in electronegativity between Xe and F with δ^- on F and δ^+ on Xe. This creates a permanent dipole moment so the Xe-O and the Xe-F bonds are polar. Furthermore,

due to the asymmetrical see-saw shape of XeO_2F_2 the bond dipoles do not cancel, so XeO_2F_2 is ~~as~~ polar.

For GeH_4, there are 4 regions of electron density around the central Ge atom. According to the VSEPR theory, ~~molecular shape~~ electron pair geometry which minimises the electron-electron repulsion for four regions is tetrahedral. As there are no lone pairs the molecular shape tetrahedral. There is a difference in electronegativity between Ge and H, with δ^+ on H and δ^- on Ge. This creates a permanent dipole moment so the Ge-H bonds are polar. However, GeH_4 has the symmetrical tetrahedral shape. This means that the bond dipoles cancel and so GeH_4 ~~has the~~ is non-polar.

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

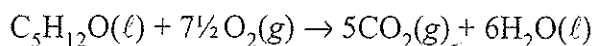| Name	Pentan-1-ol	Dimethylpropan-1-ol
Structure	$CH_3-CH_2-CH_2-CH_2-CH_2-OH$	$CH_3-\overset{\overset{\displaystyle CH_3}{\mid}}{\underset{\underset{\displaystyle CH_3}{\mid}}{C}}-CH_2-OH$
Boiling point	138°C	113°C

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

→ permanent dipole-dipole attraction, temporary dipole-dipole attraction and hydrogen bonding

Pentan-1-ol ~~and~~ and dimethylpropan-1-ol are both polar molecules therefore they have permanent and temporary dipole-dipole forces of attraction. They also contain a hydroxyl group so are capable of hydrogen bonding. ~~with adjacent OH groups~~

(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.

Although both molecules have the same molecular formula and therefore the same molar mass, Pentan-1-ol has a higher boiling point than dimethylpropan-1-ol. This is because pentan-1-ol is a straightchain molecule and can therefore pack more tightly with other pentan-1-ol molecules. This means more temporary dipole-dipole forces of attraction exist between the pentan-1-ol molecules and so more energy is required to overcome the attractive force. In contrast, dimethylpropan-1-ol is a branched molecule and cannot pack as closely. This means the molecule has fewer temporary dipole-dipole attractive forces and so less energy is required to overcome the bonds between dimethylpropan-1-ol molecules. ~~Both molecules at~~ Therefore dimethylpropan-1-ol has a lower boiling point.

Chemistry 91390, 2015

See over
page over

(d)   The equation for the combustion of pentan-1-ol is:

$$C_5H_{12}O(\ell) + 7\frac{1}{2}O_2(g) \rightarrow 5CO_2(g) + 6H_2O(\ell)$$
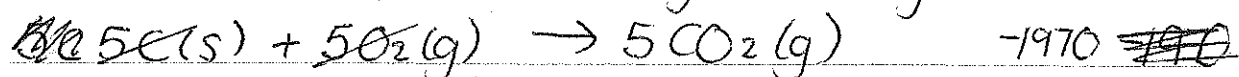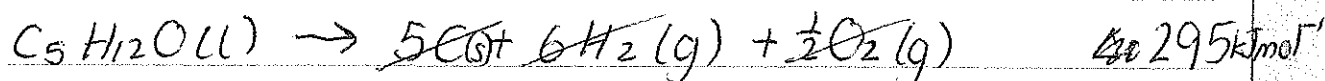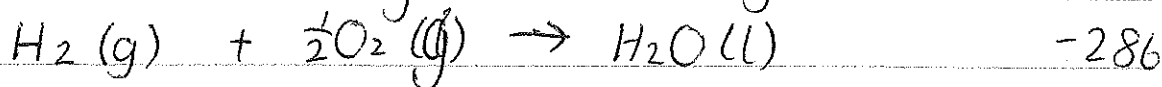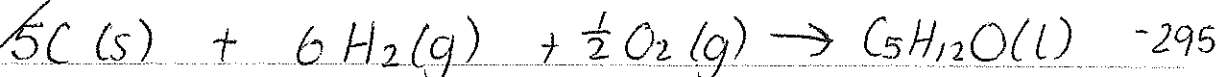
Calculate $\Delta_c H^\circ$ for pentan-1-ol, given the following data:

$\Delta_f H^\circ (C_5H_{12}O(\ell))$ $= -295$ kJ mol^{-1}

$\Delta_f H^\circ (CO_2(g))$ $= -394$ kJ mol^{-1}

$\Delta_f H^\circ (H_2O(\ell))$ $= -286$ kJ mol^{-1}

$5C(s) + 6H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_5H_{12}O(l)$ -295

$C(s) + O_2(g) \rightarrow CO_2(g)$ -394

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ -286

$C_5H_{12}O(l) \rightarrow 5C(s) + 6H_2(g) + \frac{1}{2}O_2(g)$ ~~Δ~~ 295 kJmol^{-1}

~~$5/2$~~ $5C(s) + 5O_2(g) \rightarrow 5CO_2(g)$ -1970 ~~-788~~

~~$6H_2(g)$~~ $+ 3O_2(g) \rightarrow 6H_2O(l)$ ~~-1717~~ -1716

$C_5H_{12}O(l) + 7\frac{1}{2}O_2(g) \rightarrow 5CO_2(g) + 6H_2O(l)$
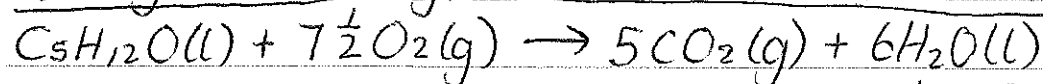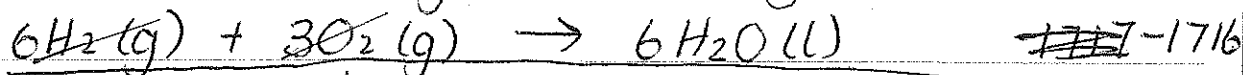
$\Delta_c H^\circ = -3391$ kJmol^{-1}

	Extra paper if required.
QUESTION NUMBER	Write the question number(s) if applicable.

Q3 cii Both ~~pe~~ pentan-1-ol and dimethylpropan-1-ol also contain permanent dipole-dipole forces of attraction as they ~~are pe~~ contain polar bonds and are polar molecules. They also contain hydrogen bonds due to the hydroxyl group which enables them to hydrogen bond with the OH groups of adjacent molecules. ~~This~~ These forces of attraction increase their boiling point as more energy is required to overcome these attractive forces.