91390

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NZQA

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MANA TOHU MĀTAURANGA O AOTEAROA

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# Level 3 Chemistry, 2014

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

2.00 pm Tuesday 11 November 2014
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 space for any answer, use the page(s) 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.**

EXCELLENCE.

TOTAL 22

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## QUESTION ONE

U = understanding (Achievement)
i = in-depth understanding (Merit)
C = comprehensive understanding (Excellence)

(a) Complete the following table.

| Symbol | Electron configuration |
|---|---|
| K | $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$ |
| $Cr_{24}$ | $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$ |
| $As_{33}$ | $1s^2 2s^2 3p^6 3s^2 3p^6 4s^2 3d^{10} 4p^3$ |

All correct = i

(b) Explain the difference between the radii of the K atom and the $K^+$ ion.

K and $K^+$ both have the same nuclear charge of 19 as they both have 19 protons. However $K^+$ has a larger effective nuclear charge as its 19 protons are attracting one less electron (18) than K (19) as it has lost one. This means that $K^+$'s electrons are held on more tightly to the nucleus hence $K^+$ is smaller than K. Also because K is in group one the loss of one electron means it has lost an entire energy shell ($4s^1$) and hence $K^+$ is physically smaller than K.

Both have the same number of protons. Has lost one energy level, but mistakenly states that one less electron results in greater attraction = i

(c) The following table shows the electron configurations of four atoms, He, B, N, and Ne.

Arrange these atoms in order of increasing first ionisation energy by writing the symbol of the appropriate atom in the boxes below.

| Atom | He | B | N | Ne |
|---|---|---|---|---|
| Electron configuration | $1s^2$ | $1s^2 2s^2 2p^1$ | $1s^2 2s^2 2p^3$ | $1s^2 2s^2 2p^6$ |

B → N → Ne → He

lowest ionisation energy — highest ionisation energy

Correct order.

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(d) The halogens make up Group 17 of the periodic table.

(i) The polarity of the HBr molecule is shown below.

$$\overset{\delta+}{H}—\overset{\delta-}{Br}$$

(c) + (d)(i) all correct = i

Using this as an example, indicate the polarity of the following bonds by indicating any dipoles present.

1. $\overset{\delta-}{F}—\overset{\delta+}{Cl}$ ←

2. $\overset{\delta+}{At}—\overset{\delta-}{Cl}$ →

(ii) Using your knowledge of trends in the periodic table, circle the atom below that has the greater electronegativity value.

(Br) I

Does not mention that the greater number of shells outweighs the increase in nuclear charge.

Justify your answer.

Electronegativity refers to the ability of an ~~molecule~~ atom or ion to attract other pairs of electrons from other ~~molecules~~ atoms or ions. The amount of electronegative value depends on the size of ~~atom~~ ion/~~molecule~~ and also the effective nuclear charge of the ~~molecule~~ atom or ion. The more nuclear charge an atom contains the more it can attract other electrons due to a great amount of protons in the nucleus ~~and~~ electrons. The more protons in the nucleus increases attraction of electrons. Br and I ~~have the same~~ are found in the same group of halogen atoms. It is the size of the atom that effects its electronegativity. I has more contains more electron shells with 5s, 4d and 5p shells. Therefore the distance between nucleus and electrons decreases the attraction from nucleus. Also the screening effect of closer electron shells that reduces attraction from nucleus. Because I has more shells than Br therefore it is less electronegative and less likely to attract other electrons as ~~well~~ efficient as Br.

i = i

M6

4 × i = M

## QUESTION TWO

(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 the attractive forces between the molecules in their liquid state.

| Molecule | Boiling point/°C | Attractive forces |
|---|---|---|
| Ammonia, $NH_3$ | −33 | induced dipole, dipole, and hydrogen bonding |
| Fluorine, $F_2$ | −188 | induced dipole |
| Hydrogen chloride, HCl | −85 | induced dipole, dipole |

Correctly listed. = 4

(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.

Full discussion linking forces to the boiling points of all 3 compounds. = C.

ammonia has a higher boiling point than hydrogen chloride.

Ammonia and hydrogen chloride both experience temporary/induced dipole-induced dipole forces. These are caused by the electrons in one molecule being attracted to the nuclear charge within another molecule, resulting in an induced and temporary dipole across the molecule. All molecules experience this type of bond and it is very weak. The strength of this bonding is affected by molar mass. Larger molecules attract the electrons more strongly, creating a stronger dipole and a stronger bond. Hydrogen chloride has a larger molar mass than ammonia, so the temporary dipole forces will be stronger, but other forces still lead ammonia to have a higher boiling point. Both ammonia and hydrogen chloride have a molecular dipole as some will form bonds between the slightly positive end of one molecule and the slightly negative end of another. These bonds are stronger than temporary dipole, but still weak. Ammonia has a higher boiling point primarily because it experiences hydrogen bonding, and hydrogen chloride does not. Hydrogen bonding is the bond between the $\delta^+$ hydrogen and, in this case, $\delta^-$ nitrogen from another molecule. The electronegativity difference is such that H–N bonds are polar and form bonds between molecules stronger than other intermolecular forces. see extra paper back pages.

Not included here.

(c) An equation for the reaction of ammonia gas with hydrogen chloride gas is:

$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$

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Calculate the standard enthalpy change, $\Delta_r H°$, for this reaction, using the following data.

$\Delta_f H°\ (NH_3(g)) = -46$ kJ mol$^{-1}$
$\Delta_f H°\ (HCl(g)) = -92$ kJ mol$^{-1}$
$\Delta_f H°\ (NH_4Cl(s)) = -314$ kJ mol$^{-1}$

$\Delta_r H° = \Sigma \Delta_f H°$ products $- \Sigma \Delta_f H°$ reactants

$= (-314) - (-46 + -92)$

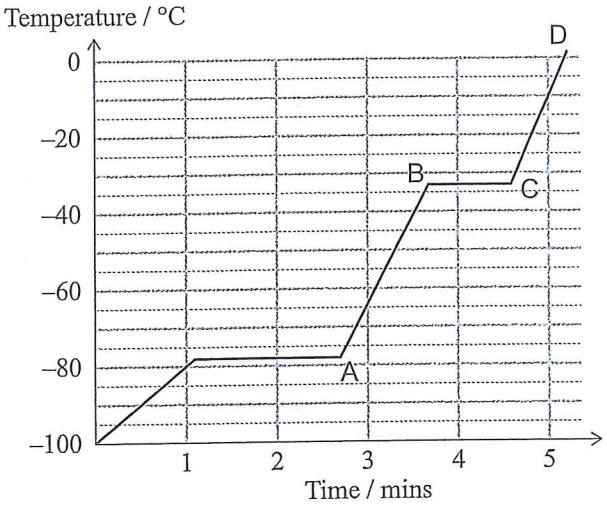
$= -314 - -138$

$= -176$ kJ mol$^{-1}$

Correct process leading to the correct answer with units = 1

(d) The following graph shows the change in temperature over a five-minute period for a sample of ammonia, where a constant amount of heat was applied per minute.

**Heating curve for ammonia**




Using the graph above, justify the physical changes occurring to ammonia between points A and D, in terms of the energy of the particles and the intermolecular forces of attraction.

At point A ammonia has just become a liquid. From A to B the energy of heating is going into increasing the temperature of the ammonia. The non-directional kinetic (thermal) energy is increasing but it is not enough to break all the intermolecular bonds between ammonia molecules, so it remains a liquid. From B to C the energy of heating is going into breaking the intermolecular bonds that are keeping ammonia in the liquid state. The temperature does not increase at this point because at the boiling point the bonds between ammonia molecules need to be broken to allow more movement and see an increase in temperature. From C to D the temperature increases again as the gas molecules of $NH_3$ gain increasing thermal energy and move more and more. The energy of heating has no intermolecular bonds to break so can continue to increase the temperature = C

Understands that kinetic energy is gained during A→B and C→D.
Also understands that intermolecular bonds are broken in B→C.

E8

## QUESTION THREE

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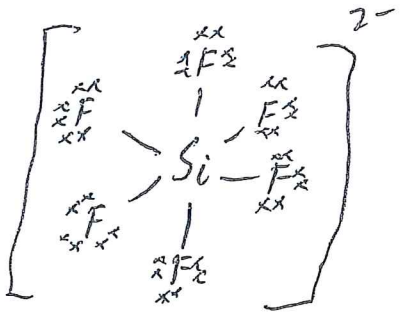
(a) In New Zealand, fluoride for water treatment is supplied as sodium fluorosilicate, $Na_2SiF_6$.
One of the ions formed in the solution from sodium fluorosilicate is $SiF_6^{2-}$.

Complete the table below.

| | $SiF_6^{2-}$ |
|---|---|
| **Lewis diagram** |  |
| **Name of shape** | octahedral |

7 16 of 2

Both correct, including the charge. = i

(b) Ammonium nitrate is used in 'cold packs' to relieve symptoms of a sports injury. The dissolving of the solid crystals of ammonium nitrate (shown in the equation below) is spontaneous, despite being endothermic.

$$NH_4NO_3(s) \rightarrow NH_4^+(aq) + NO_3^-(aq)$$

Explain why this is so, in terms of the entropy change for the reaction system.

For a reaction to be spontaneous the product of temperature and entropy change must exceed ~~the~~ enthalpy change

$\Delta G = \Delta H - T\Delta S$ negative number = spontaneous.

The dissolving of ammonium nitrate increases entropy because one mole of solid leads to 2 moles of aqueous ions. In the aqueous ~~phase~~ state there is more randomised movement than in the rigid solid lattice structure. When the temperature is high enough the increasing entropy has greater effect ~~on spontaneous~~ in making this reaction spontaneous than the endothermic enthalpy change.

= i

Clearly understands the topic.

(c) Ammonium nitrate dissociates in an endothermic reaction, as shown in the equation below.

$$NH_4NO_3(s) \rightarrow NH_3(g) + HNO_3(g)$$

Below is a table outlining four statements about changes in entropy that may occur during any reaction.

Tick (✓) to the left of any statement that is correct for the above reaction.

| Tick (✓) | Entropy statement |
|---|---|
| ✓ | The entropy of the system increases. |
| | The entropy of the surroundings increases. |
| | The entropy of the system decreases. |
| ✓ | The entropy of the surroundings decreases. |

Correct.

Justify your choice(s).

The system has solid converted to 2 moles of gas. There is alot of randomised movement in the gas phase, so entropy is increasing from the less random rigid ionic lattice structure of the solid.

The reaction is endothermic, which means the surroundings lose thermal energy, reducing there will be less randomised movement in the colder surroundings, so the entropy of the surroundings decreases.

Has a clear understanding of entropy and has explained why entropy is affected by an increase or decrease of energy. = C

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(d) (i)

| Compound | kJ mol$^{-1}$ |
|---|---|
| $\Delta_c H^\circ$ ($C(s)$) | –394 |
| $\Delta_f H^\circ$ ($H_2O(\ell)$) | –286 |
| $\Delta_c H^\circ$ ($C_2H_5OH(\ell)$) | –1367 |

Calculate the standard enthalpy of formation of liquid ethanol using the information given above.

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -394\ kJ\ mol^{-1}$

$H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(g)}$ $\Delta H = -286\ kJ\ mol^{-1}$

$C_2H_5OH_{(l)} + O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(g)}$ $\Delta H = -1367\ kJ\ mol^{-1}$

$2C_{(s)} + 2H_{2(g)} \rightarrow C_2H_{2(g)}$ $\Delta H = -788\ kJ\ mol^{-1}$

$2CO_{2(g)} + 3H_2O_{(g)} \rightarrow C_2H_5OH_{(l)} + O_{2(g)}$ $\Delta H = 1367\ kJ\ mol^{-1}$

$3H_{2(g)} + \frac{3}{2}O_{2(g)} \rightarrow 3H_2O_{(l)}$ $\Delta H = -858$

$2C_{(s)} + 3H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow C_2H_5OH_{(l)}$ $\Delta H = -279\ kJ\ mol^{-1}$

Correct process leading to an accurate answer with units. = C

(ii) Discuss how the value of the enthalpy change would differ if the ethanol product formed was a gas rather than a liquid.

*No calculation is necessary.*

To convert from liquid to gas bonds must be broken
This requires energy to break bonds.
It would take more energy to form in a gas state.
$\Delta H$ would be greater than $-279\ kJ\ mol^{-1}$
either less exothermic or endothermic.

= U

E8