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NZQA

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 3 Chemistry 2025

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.

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 and other reference material are provided in the Resource Booklet L3–CHEMR.

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

Check that this booklet has pages 2–12 in the correct order and that none of these pages is blank.

Do not write in the margins (⋮⋮⋮). This area will be cut off when the booklet is marked.

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

Achievement TOTAL 11

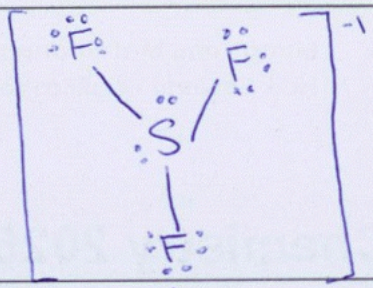
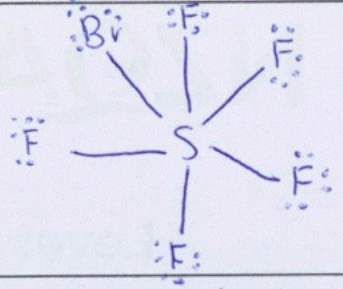
QUESTION ONE

Sulfur forms a range of different fluoride-containing ions and molecules.

(a) Complete the table below:

27 - 6 = 21 - 18 = 2 - 2 = 0

48 - 12 = 36

	SF_3^-	$SBrF_5$
Lewis structure		
Name of shape	T-shaped	Octahedral

(b) The Lewis structure and shape for sulfur tetrafluoride, SF_4, are shown below.

seesaw

(i) Identify and explain the polarity of SF_4.

In ~~there~~ the molecule SF_4 there are 5 reigons of electron density with 4 bonding reigons and 1 non bonding reigon. these reigons of ~~elec~~ electron density repel eachother for maximum seperation. there is a bond dipole due to the difference in electronegativity between the S and F atoms. since this atom is arranged asymmetrically due to the 1 non bonding reigon this means the bond dipoles do not cancel out meaning SF_4 is a polar molecule with a see-saw shape.

(ii) Justify why the F–S–F bond angles in SF_4 are different to the F–S–F bond angles in $SBrF_5$.

SF_4 has 5 reigons of electron density where as $SBrF_5$ has 6 reigons of electron density. these reigons repel eachother for maximum seperation. since there are more atoms surrounding the S atom in $SBrF_5$, therefore atoms have less space to repel giving it a smaller bond angle. since there are less atoms surrounding the S atom in SF_4, there is more space for atoms to repel eachother giving SF_4 a larger bond angle between atoms.

(c) Finely powdered sulfur, S(*s*), readily reacts with fluorine gas, $F_2(g)$, in an exothermic reaction to produce sulfur hexafluoride, $SF_6(g)$. The equation for the reaction is:

$$S(s) + 3F_2(g) \rightarrow SF_6(g)$$

4 1

Justify, in terms of the entropy changes of the system and surroundings, why the reaction is spontaneous.

entropy is the amount of disorder a reaction creates in the system and surroundings. the reaction producing sulfur hexafluride is exothermic meaning heat is let off into the surroundings creating more disorder and therefore the entropy of the surroundings increases. there is a state change in the reaction with 1 mole of solid and 3 moles of gas reactant to produce 1 mole of gaseous product. since there is a solid product in reactants there is more order before the reaction started meaning the entropy of the system also increases. since the entropy of the system and surroundings both increased the reaction is spontanious

QUESTION TWO

(a) (i) Complete the table below.

Symbol	Electron configuration (use *s*, *p*, *d* notation)
Cl	$1s^2, 2s^2, 2p^6, 3s^2, 3p^5$
Cu	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^1, 3d^{10}$
Fe^{3+}	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^3$

(ii) Iron, Fe, can form two different ions, Fe^{2+} and Fe^{3+}. Their ionic radii are given below:

Fe^{2+} 92 pm – gave away 2 electrons

Fe^{3+} 79 pm – gave away 3 electrons.

Explain why the radius of the Fe^{2+} ion is larger than the radius of the Fe^{3+} ion.

the ion Fe^{2+} has donated 2 electrons to another atom where as the ion Fe^{3+} has donated 3 electrons to another atom. Fe^{2+} has more electrons in its outer shell then Fe^{3+}. these electrons reped eachother for maximum seperation, exanding the radius of the ion resulting in Fe^{2+} having a larger radius then Fe^{3+}.

(b) (i) Identify all the types of attractive forces between particles of the following substances in their liquid state.

Substance	$\Delta_{vap}H^{\circ}$/kJ mol^{-1}	Attractive forces
Hydrogen bromide, $HBr(\ell)$	17.3	Hydrogen bonding permanent dipole attractions temporary dipole attractions
Hydrogen fluoride, $HF(\ell)$	25.2	hydrogen bonding permanent dipole attractions temporary dipole attractions
Bromine, $Br_2(\ell)$	29.6	~~ionic bonding~~ temporary dipole attractions

MM −20

MM −81

MM −1860

20 81

(ii) Explain why the $\Delta_{vap}H^\circ$ of HF is higher than that of HBr.

even though the molecule HBr has a larger molar mass. since they have the same intermolecular forces of attraction, fluvine is a more electronegative atom creating a large bond dipole between the H and F atom resulting in more sheilding for the molecule and making it easier to break apart. in HBr. Br is less electronegative then fluvine so the bond dipole between the H and Br atom is smaller and easier to break apart. therefore since the bond between H-F is harder to break apart, it has a higher evaporation/boiling point.

(iii) Justify why Br_2 has the highest $\Delta_{vap}H^\circ$ of the three substances.

even though Br_2 is held together by only temporary dipole attractions, which are weaker then both hydrogen bonding and permanent dipole attractions, Br_2 the molecules molar mass is significantly higher then that of both HF and HBr, meaning it is much harder to Break the bond between these two atoms and also gives the atom a lot of sheilding meaning the bond is harde to break apart and giving it a high evaperation/Boiling point.

(c) Dinitrogen tetroxide, N_2O_4, was reacted with methylhydrazine, CH_3NHNH_2. The equation for the reaction is: ✓

$$4CH_3NHNH_2(\ell) + 5N_2O_4(\ell) \rightarrow 4CO_2(g) + 12H_2O(g) + 9N_2(g)$$ ✓

(i) Calculate the standard enthalpy change of this reaction, using the following data.

$C(s) + 3H_2(g) + N_2(g) \rightarrow CH_3NHNH_2(\ell)$	$\Delta_rH^\circ = +54.1$ kJ mol^{-1} = −324.6
$C(s) + O_2(g) \rightarrow CO_2(g)$	$\Delta_rH^\circ = -394$ kJ mol^{-1} = −1576
$N_2(g) + 2O_2(g) \rightarrow N_2O_4(\ell)$	$\Delta_rH^\circ = -20.0$ kJ mol^{-1} = +180
$H_2(g) + ½\ O_2(g) \rightarrow H_2O(\ell)$	$\Delta_rH^\circ = -286$ kJ mol^{-1} = −3432
$H_2O(\ell) \rightarrow H_2O(g)$	$\Delta_rH^\circ = +40.7$ kJ mol^{-1} = +480

$4CH_3NHNH_2(l) \rightarrow 4C(s) + 12H_2(g) + 4N_2(g)$

$4C(s) + 4O_2(g) \rightarrow 4CO_2(g)$

$5N_2O_4(l) \rightarrow 5N_2(g) + 10O_2(g)$

$12H_2(g) + 6O_2(g) \rightarrow 12H_2O(l)$

$12H_2O(l) \rightarrow 12H_2O(g)$

$4CH_3NHNH_2(l) + 5N_2O_4(l) \rightarrow 4CO_2(g) + 12H_2O(g) + 9N_2(g)$ $\Delta_rH = -4673$ kJ mol^{-1}

$\Delta_rH = -324.6 + -1576 + 180 + -3432 + 480 = -4672.6$ kJ

(ii) Explain the effect on the standard enthalpy change calculated in part (c)(i) if the water was produced as a liquid.

if water was produced as a liquid the reaction $H_2O(l) \rightarrow H_2O(g)$ would have to be flipped creating a change in the Δ_rH° for that reaction and therefore resulting in a more negative/ more exothermic reaction/ Δ_rH°

QUESTION THREE

(a) Nitric acid, HNO_3, is manufactured from ammonia, NH_3. The equation for one of the reactions in the process is:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(\ell) \qquad \Delta_r H^\circ = -1172 \text{ kJ mol}^{-1}$$

(i) Write the balanced equation to represent the standard enthalpy of formation of ammonia in the table below.

Substance	Equation	$\Delta_f H^\circ$ kJ mol^{-1}
$NH_3(g)$	$N_{2(g)} + H_{2(g)} \rightarrow NH_{3(g)}$	+180
$NO(g)$	$\frac{1}{2} N_2(g) + \frac{1}{2} O_2(g) \rightarrow NO(g)$	+90.3
$H_2O(\ell)$	$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(\ell)$	–286

(ii) Calculate the standard enthalpy of formation for ammonia, $\Delta_f H^\circ(NH_3(g))$, using the data given in part (i).

$\Delta_r H^\circ = \Sigma \Delta_f H^\circ$ (products) $- \Delta_f H^\circ$ (reactants)

$\Delta_r H^\circ = \Sigma \Delta_f H^\circ (90.3 \times 4 + -286 \times 6) - \Delta_f H^\circ (+180)$

$\Delta_r H^\circ = -1539.8 \text{ kJ mol}^{-1}$

$\Delta_r H^\circ = -1535 \text{ kJ mol}^{-1}$

(b) (i) Justify, using your knowledge of periodic trends, why magnesium, Mg, has a greater first ionisation energy than strontium, Sr.

first ionisation energy is the amount of energy required to remove one electron from an atoms outer shell. magnesium has ~~more~~ less energy levels then Sr. Sr has 5 energy levels where as magnesium has 3. Since magnesium has less energy levels, protons have a stronger attraction to the electrons creating a greater strength and making it harder to remove an electron from its outer shell. Sr has more energy levels meaning electrons are further away from the positive nucleus and creating less strength making it easier to remove an electron from its outer shell. Therefore mg has a greater first ionisation energy.

(ii) The atomic radii of five elements from Period 3 are shown in the table below.

Period 3 element	Na	Mg	Al	Si	P
Atomic radius / nm	0.191	0.160	0.130	0.118	0.110

Explain the trend in atomic radius shown in the table.

looking across the period, atomic radius of period 3 elements decreases. this is because of the increase in protons which attract electrons from the outer shell, pulling them in closer to the nucleus and making the atom more compact decreasing its radius.

(c) When solid calcium chloride, $CaCl_2(s)$, dissolves in water, the temperature increases from 20.4 °C to 23.2 °C. ΔT

$$CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2Cl^-(aq) \qquad \Delta H = -81.3 \text{ kJ mol}^{-1}$$

Calculate the mass of $CaCl_2(s)$ that must dissolve to cause this temperature increase.

Assume the specific heat capacity of the calcium chloride solution is 4.18 J g^{-1} °C^{-1}. C

Assume the mass of the calcium chloride solution is 68.0 g. m

$M(CaCl_2) = 111$ g mol^{-1} M

$q = mc\Delta T$

$q = 68.0 \times 4.18 \times (23.2 - 20.4)$

$q = 795.87$

$n = -q \div \Delta_r H$

$n = -795.87 \div -81.3 \quad n = 9.79$

$m = n \times M$

$m = 9.79 \times 111$

$m = 1086.69 \text{ g mol}^{-1}$

$m = 1087 \text{ g mol}^{-1}$

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

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Achievement

Subject: L3 Chemistry

Standard: 91390

Total score: 11

Q	Grade score	Marker commentary
One	A4	Drew the Lewis structure and named the shape correctly, recognised the different number of electron densities in both molecules, described entropy as an increase in disorder, and recognised that the reaction was exothermic and released heat into the surroundings.
Two	A4	Wrote the correct order and electron configuration notation, identified the different number of valence electrons, correctly identified attractive forces in two substances, and correctly manipulated two values to find the enthalpy change.
Three	A3	Recognised the difference in energy levels down the group and knew that across the period, atomic radii decreased due to an increase in protons, and calculated heat energy released correctly in Joules.