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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.

Merit

TOTAL **16**

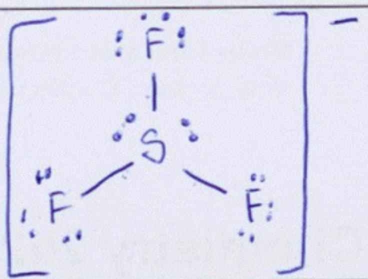
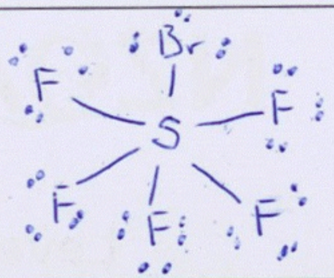
QUESTION ONE

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

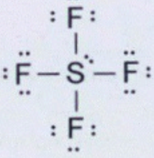
21 ~~29~~ 8.

(a) Complete the table below:

6 7 [ion] 48

	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.

SF_4 has a seesaw shape. SF_4 has ~~8~~ 4 polar S-F bonds, which create bond dipoles due to the E.N difference between S and F. However, even though these bond dipoles are of the same strength, they are ~~anable~~ unable to cancel eachother out due to the asymmetry of the seesaw shape of SF_4, making SF_4 a polar molecule. The SF_4 has bond angles of 90° and 120°/180°

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

thy have diffent bond angles of the F-S-F bond in each molecule due to the number of electron dense areas in each molecule. $SBrF_5$ has 6 areas of electron density meaning for maximum ~~sepa~~ separation there are only bond angles of 90°, whereas SF_4 has both bond angles of 90° and 120° as there are only 5 areas of electron density, causing for more ~~less for~~ space to seperate the bonds.

(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:

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

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

the reaction goes from 1 solid mol and 3 gaseous moles to only 1 gaseous mole, meaning the systems molecules are less able to move around and are Less disordered which decreses the entropy of the system. However the reaction is exothermic, meaning it releases heat energy to the surroundings, this causing the surrounding gas molecules to move with more Kinetic energy, mening the surrounding are more disordered, increasing entropy. Since the reaction is spontaneous the increase in entropy from the surroundings must overcome the decrease in entropy of the ~~sy~~ system.

QUESTION TWO

(a) (i) Complete the table below.

Symbol	Electron configuration (use *s*, *p*, *d* notation)
Cl	$1s^2, 2s^2, 3p^6, 3s^2, 3p^5$
Cu	$[Ar], 4s^2, 3d^9$
Fe^{3+}	$[Ar], 3d^5$

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

Fe^{2+}	92 pm
Fe^{3+}	79 pm

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

both Fe^{2+} and Fe^{3+} have the same nucler charge but Fe^{2+} has an extra 1 e^- then Fe^{3+}. Since the nucler charge is the same and the valence electrons are in the same energy level/shell it is due to electron - electron repulsion that causes Fe^{2+} valence electrons to be pushed further from the nucleus, giving it a larger radius of 92 pm compared to Fe^{3+} 79pm

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

Substance	$\Delta_{vap}H^o$/kJ mol^{-1}	Attractive forces
Hydrogen bromide, $HBr(\ell)$	17.3	tempory, permant.
Hydrogen fluoride, $HF(\ell)$	25.2	, perment, tempory
Bromine, $Br_2(\ell)$	29.6	tempory

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

HF has a higher $\Delta_{vap}H°$ of 29.2 kJmol⁻¹ compare to HBr with 17.3 kJmol⁻¹ this is because HBr only has tempory and permant ~~dipoles~~ dipole intermolecular forces, ~~whereas HF has hydrogen bonding which is the a stronger intermolecular force then permant and tempory.~~ Both HF and HBr have permant & tempory ~~dipoles~~ (intermolecular forces but since F is the most electronegative the permant dipole between H and F is stronger than H-Br, so will require more energy to overcome, so HF has a higher $\Delta_{vap}H°$ of 29.2[illegible] in comparison to HBr with only 17.3 kJmol⁻¹

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

Br_2 has the highest $\Delta_{vap}H°$ of 29.6 kJmol⁻¹ compared to HF and HBr even though it only has tempory dipoles, this is due to it having a much larger molar mass (159.8) meaning it has a larger electron cloud, meaning its temporary dipoles are much stronger then HF and HBr intermolecular forces.

(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}

×4 $C(s) + O_2(g) \rightarrow CO_2(g)$ — $\Delta_rH^\circ = -394$ kJ mol^{-1}

×5 $N_2(g) + 2O_2(g) \rightarrow N_2O_4(\ell)$ 10 — $\Delta_rH^\circ = -20.0$ kJ mol^{-1}

$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(\ell)$ ×12 6 — $\Delta_rH^\circ = -286$ kJ mol^{-1}

$H_2O(\ell) \rightarrow H_2O(g)$ ×12 — $\Delta_rH^\circ = +40.7$ kJ mol^{-1}

$4CH_3NHNH_2 \rightarrow 4C + 12H_2 + 4N_2 = -216.4.$

$4C + 4O_2 \rightarrow 4CO_2$ ✓ ✓ $= -1576.$

$5N_2O_4$ ✓ $\rightarrow 10O_2 + 5N_2 = 100$

~~$12H_2O_{(l)} \rightarrow 12H_2 + 6O_2 = 3432.$~~

$12H_2 + 6O_2 \rightarrow 12\ H_2O_{(l)} = -3432.$

$12\ H_2O_{(l)} \rightarrow 12H_2O_{(g)}$ ✓ $= 488.4$

$4CH_3NHNH_{2(l)} + 5N_2O_{4(l)} \rightarrow 4CO_{2(g)} + 12H_2O_{(g)} + 9N_{2(g)}$
$= \Delta_rH^\circ = -4636\text{ kJ mol}^{-1}$

2×0

endo

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

if water were produced as a liquid as opposed to a gas ~~the~~, ~~[illegible]~~ the reaction would be more endothermic as less bonds would be broken, making Δ_rH° of the reaction less negative / more positive.

QUESTION THREE

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

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

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

Substance	Equation	$\Delta_fH°$ kJ mol^{-1}
$NH_3(g)$	$\frac{1}{2}N_{2(g)} + \frac{3}{2}H_{2(g)} \rightarrow NH_{3(g)}$	+45.7
$NO(g)$	$\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \rightarrow NO(g)$	+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, $\Delta_fH°(NH_3(g))$, using the data given in part (i).

prodects - reactnts. $= \Delta_r H°$

$(4(90.3) + 6(-286)) - (4(NH_3) = -1172$

$(-1354.8) - (4NH_3) = -1172$

$-4NH_3 = 182.8$

$4NH_3 = -182.8$

$NH_3 = 45.7$ kJmol^{-1}

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

Mg and Sr are ~~and~~ in the same group. ionisation energy decreases when going down a group. Sr, while having a higher nuclear charge also has it's valence electrons in shells/energy levels, further from its nucleus, meaning the valence electrons experience sheilding from the inner shell's causing it to be less strongley held/attracted by the nucleus and since the first ionisation energy is the energy required to remove an e^- from the valence shell in its gaseous state Sr will require less energy to do so. Mg has it's valence electrons more strongly ~~closely~~ attracted due to less sheilding, meaning more energy is required, giving Mg a higher I.E than Sr.

(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.

The atomic radius decreses when moving across the period. this is due to the valence electrons being held in the same energy levels/shells but as you move down the period the nuclear charge increases. This increase in nuclear charge attracts the valence electrons more strongly, pulling them closer to the nucleus and therefore decreasing the atomic radius, which is why Na has the largest atomic radius of 0.191nm in period 3 and P has the smallest with 0.110 nm.

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

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

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}.

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

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

$\Delta T = 2.8°C$ $\qquad$ 4.18×10^{-3} kJ g^{-1} °C^{-1}

$m(CaCl) = 68.0g.$ $\qquad$ $\Delta H = -81.3.$

$q = 68 \times 4.18 \times 10^{-3} \times 2.8$

$q = 0.795872$

$n = \frac{-q}{\Delta_r H}$ $\qquad$ $m = n \times M$

$n = \frac{-0.795872}{-81.3}$ $\qquad$ $m = 9.789 \times 10^{-3} \times 111$

$n = 9.789 \times 10^{-3}$ mol $\qquad$ ~~me~~ $m(CaCl_{2(s)}) = 1.09$ g.

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

QUESTION NUMBER

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QUESTION NUMBER

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Merit

Subject: L3 Chemistry

Standard: 91390

Total score: 16

Q	Grade score	Marker commentary
One	M6	Correctly drew both Lewis diagrams and named the resulting shapes, explained the polarity of the molecule by recognising the arrangement of bond dipoles, and explained the spontaneity of the process by referring to the change in the surroundings' entropy.
Two	M5	Explained the difference in the ionic radius of the ions (Fe^{2+} and Fe^{3+}), correctly applied Hess' Law to calculate the enthalpy change for a reaction, and explained the differences in $\Delta_{vap}H^{\circ}$ by linking the strength of temporary dipole attractions to a larger electron cloud.
Three	M5	Explained the difference in first ionisation energy and atomic radii in terms of the number of energy levels, nuclear charge, and the attraction between the nucleus and valence electrons. Calculated the mass of a solid dissolved correctly.