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Draw a cross through the box (☒) if you have NOT written in this booklet

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NZQA

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

# Level 3 Chemistry 2024

## 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 any cross-hatched area (▨). This area will be cut off when the booklet is marked.

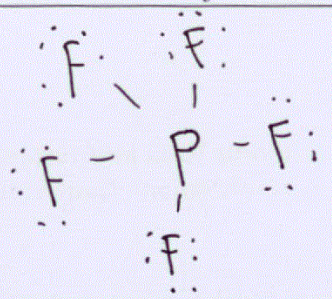
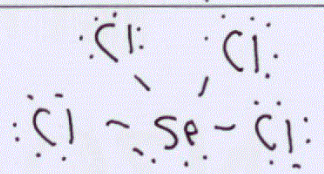
**YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.**

Merit

TOTAL 16

## QUESTION ONE

(a) Complete the table below.

| | $PF_5$ | $SeCl_4^{2-}$ |
|---|---|---|
| $5+5\times7$ $=40$ **Lewis structure** $6+4\times7+2$ $=36$ |  |  |
| **Shape** | Trigonal bipyramidal | See-Saw |

(b) (i) The reaction between chlorine trifluoride, $ClF_3(g)$, and hydrazine, $N_2H_4(\ell)$, is explosive. It was investigated as a potential rocket fuel. The reaction is shown below.

$$4ClF_3(g) + 3N_2H_4(\ell) \rightarrow 12HF(g) + 3N_2(g) + 2Cl_2(g)$$

Calculate $\Delta_r H^\circ$ for the reaction, given the following data.

(1) $N_2H_4(\ell) + O_2(g) \rightarrow N_2(g) + 2H_2O(\ell)$ $\quad \Delta_r H^\circ = -623$ kJ mol$^{-1}$

(2) $2ClF_3(g) + 2NH_3(g) \rightarrow 6HF(g) + N_2(g) + Cl_2(g)$ $\quad \Delta_r H^\circ = -1200$ kJ mol$^{-1}$

(3) $4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(g)$ $\quad \Delta_r H^\circ = -1270$ kJ mol$^{-1}$

(4) $H_2O(\ell) \rightarrow H_2O(g)$ $\quad \Delta_{vap} H^\circ = 40.7$ kJ mol$^{-1}$

3(1) + 2(2) + (3) + 6(4)

$3N_2H_4(\ell) + 3O_2(g) + 4ClF_3(g) + 4NH_3(g) + 4NH_3 + 3O_2(g) + 6H_2O(\ell)$

$\rightarrow 3N_2(g) + 6H_2O(\ell) + 12HF(g) + 2N_2(g) + 2Cl_2(g) + 2N_2(g) + 6H_2O(g)$

$3(1) + 2(2) - (3) + 6(4) = -2754.8$

$3(-623) + 2(-1200) + -(-1270) + 6(40.7)$

$= -2754.8$ kJ mol$^{-1}$

$\Delta_r H^\circ = -2754.8$

(ii) Justify, in terms of the entropy changes of the system and the surroundings, why the reaction between chlorine trifluoride and hydrazine is spontaneous.

$$4ClF_3(g) + 3N_2H_4(\ell) \rightarrow 12HF(g) + 3N_2(g) + 2Cl_2(g)$$

initialy there are 4(g) particles and 3(l) particles after there are ~~12(g) particles an~~ 17(g) particles. So there is an increase in particle number and increased energy state. This means there is a large increase is disorder so large increase in entropy. Also system gives heat of / heats up so particles gain kinetic energy and hence also contributes to entropy increase. (+ΔrH shows this)

Since the system releases heat, The surroundings gain heat hence, kinetic energy and The particles of surroundings increase in disorder as they move more. this means entropy in the surroundings increases.

## QUESTION TWO

(a) (i) The table below gives the electron configurations of three elements.

| Argon, Ar | Neon, Ne | Phosphorus, P |
|---|---|---|
| $1s^2 2s^2 2p^6 3s^2 \mathbf{3p^6}$ | $1s^2 2s^2 2p^6$ | $1s^2 2s^2 2p^6 3s^2 3p^3$ |

When considering the $3p^6$ part of the electron configuration of argon, what is represented by the following?

3 number of energy levels.

p energy orbital / way the electron orbits the nucleus

6 number of electrons in this orbital.

(ii) Arrange the three elements Ar, Ne, and P, in order of decreasing first ionisation energy.

Use your knowledge of periodic trends to justify your order.

Ne > Ar > P

Ne and Ar are both in the 18 the group of the periodic table. This means both have ~~8~~ 8 electrons in the outer energy level / valence shell. P is in the same Period as Ar So P and Ar have ~~same number~~ 3 energy levels while Ne only has 2 energy levels. This means P and ~~Ar~~ have the same amount of shielding (repulsion) from inner electrons. Ne has less shielding due to having less energy levels. (less repulsion from inner electrons).

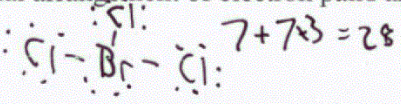
P has 5 valence electrons while Ne and Ar have 8 valence electrons. Due to energy levels ~~Ar and P has the smaller~~ and valence electrons Ne has the smallest atomic radii with Ar then P after.

first Ionisation energy is the amount of energy required to remove 1 mol of electrons from 1 mol of ~~valence~~ gaseous particles. ~~This means Ar has the largest ionisation energy~~

~~due to least shielding and so looses electrons easier.~~ most
~~going down a period to [illegible] increases ionisation~~
~~moving across~~
See Q1. a in extra paper

(b) The two possible shapes of bromine trichloride, $BrCl_3$, are T-shaped and trigonal planar. Both of these shapes are based on the trigonal bipyramidal arrangement of electron pairs around the central atom.

Research shows that the $BrCl_3$ molecule is polar.




Compare the two possible shapes of the $BrCl_3$ molecule to identify which shape would result in the $BrCl_3$ molecule being polar.

Your answer should refer to bond polarity and the arrangement of the bond dipoles.

~~The central Br atom has 5 areas around the central Br. These areas repel in 3D and arrange themselves to have the least repulsion between the areas of~~

There are 5 areas of electron density around the central Br atom. These areas arrange themselves, by repeling in 3D, to minimise repulsion between themselves. So $BrCl_3$ has an electron geometry of trigonal ~~bipyramidal~~ bipyramidal.
3 Cl atoms ~~of the 5~~ are bonded to the Br central atom. So there are 2 non-bonding pairs of electrons. The Cl-Br bonds create bond dipoles due to the difference in electronegativity.
for the molecule to be polar the bond dipoles can't cancel out.
In the molecule shape Trigonal planar the bond dipoles do cancel
So Trigonal planar Shape is not polar due to Symetry
In the T-shape molecule shape the Cl-Br bonds are arranged asymetricly around the Br atom so the bond dipoles do not cancel leading to a polar molecule.

## QUESTION THREE

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

| Substance | Boiling point / °C | Attractive forces |
|---|---|---|
| Ammonia, $NH_3$ | –33 | Temporary dipole forces (TDF)<br>Permanent dipole forces (PDF)<br>Hydrogen bonding (HB) |
| Sulfur dioxide, $SO_2$ | –10 | TDF<br>PDF |
| Pentane, $CH_3CH_2CH_2CH_2CH_3$ | 36 | TDF |

(ii) Explain the difference in the boiling points of ammonia and sulfur dioxide.

Both $NH_3$ and $SO_2$ have PDF. ~~Both~~ PDF are similar strength in both molecules since both molecules are Polar.

$NH_3$ has a molar mass smaller than $SO_2$. So $SO_2$ has a larger electron cloud hence $SO_2$ has a greater strength TDF than $NH_3$.

$NH_3$ has HB due to the large difference in electronegativity between N atom and H atom.

The total intermolecular force strength is greater in $SO_2$ due to the large TDF.

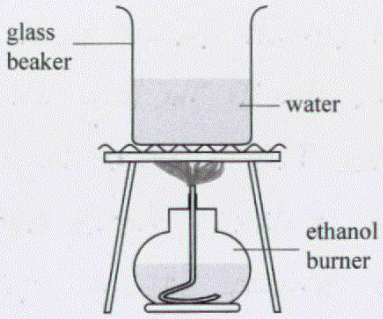
Boiling ~~point~~ point is when (l) → (g) and all inter molecular forces break. So stronger intermolecular forces means higher boiling point as greater heat / kinetic energy is required to break the ~~bond~~ forces. So $SO_2$ has a higher boiling point.

(iii) Explain why the boiling point of pentane is higher than that of sulfur dioxide.

Pentane has a very large mass and so has large electron cloud (much larger than $SO_2$). This allows greater strength TDF. due to the long shape there is more opportunity for TDF hence TDF is very large.
So although pentane does not have PDF as $SO_2$ does pentane has much stronger total inter molecular forces.
Since boiling point is at the point when all inter molecular forces break. Pentane has a higher boiling point due to having stronger total inter molecular forces so take more energy as heat (kinetic energy) to break.

*Question Three continues on the next page.*

(b) The enthalpy of combustion of ethanol, $C_2H_5OH$, was determined experimentally using the apparatus below. The ethanol was completely combusted to heat some water in a beaker.




The following data was recorded:

- initial water temperature = 22.1 °C
- final water temperature = 31.2 °C
- initial mass of burner and ethanol = 59.2 g
- final mass of burner and ethanol = 58.7 g

The student calculated the experimental enthalpy change for the combustion of liquid ethanol, $\Delta_c H(C_2H_5OH(\ell))$, to be –770 kJ mol$^{-1}$.

The specific heat capacity of water is 4.18 J g$^{-1}$ °C$^{-1}$.

$M(C_2H_5OH)$ = 46.0 g mol$^{-1}$

(i) Use the information provided to calculate the mass of the water that was in the beaker.

$\Delta T = 9.1°C$

$n.(ethanol) = \frac{59.2 - 58.7}{46.0} = 0.0109$ mol

$\Delta_r H° = \frac{-q}{n} = \Delta_c H$

$\Delta_r H \times n = -q$

$q = -(-770 \times 0.0109) = 8.36$ kJ $= 8369.5$ J

$q = mc\Delta T$ $\quad c = 4.18$ $\quad m = ?$ $\quad \Delta T = 9.1$

$m = \frac{q}{c\Delta T}$

$m = \frac{8369.6}{4.18 \times 9.1} = 220$ g

Mass of water is 220 g (3 S.f.)

(ii) Which of these quantities calculated would have been a source of error in the calculated enthalpy value?

Circle your answer.

**temperature change of water** **mass of fuel combusted**

Explain your choice.

The Temperature change of water is the ammount of heat absorbed from the burner but heat is lost to the surroundings. Heat is may be lost to the surroundings by conduction and convection due to poor insulation

Since heat is lost to the surroundings. not all the energy from reaction is converted to heat in the water. Therfore the reading is innaccurate.

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

QUESTION NUMBER

Q2.a. ~~Ar~~ N therefore has the greatest first ionisation energy due to having the least shielding.

Moving down a period to Ar increases shielding so first ionisation energy decreases.

~~From~~ moving across groups left and the period in table. from Ar → P. Number of valence electrons ~~increases~~ decreases

So first ionisation energy decreases.

This is because first ionisation energy is the energy required to remove 1mol of electrons from 1mol of gaseous particles. So the harder it is to remove an electron ~~the~~ the greater the first ionisation energy is

# Merit

**Subject:** Chemistry

**Standard:** 91390

**Total score:** 16

| Q | Grade score | Marker commentary |
|---|---|---|
| One | M5 | Correctly applied Hess' Law to calculate the enthalpy change for a reaction and explained aspects of entropy changes during a chemical reaction. |
| Two | M5 | Explained the polarity of the T-shaped structure and explained the trends in 1st ionisation energy. |
| Three | M6 | Explained the differences in boiling points by comparing the strength of the intermolecular forces, including linking the strength of temporary dipole attractions to the molar mass/ larger electron cloud and greater surface area /linear shape of the molecules. Calculated the mass of water correctly. |