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91390

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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.

Achievement

TOTAL 10

Cl^{2-} ×4

Se

Pro

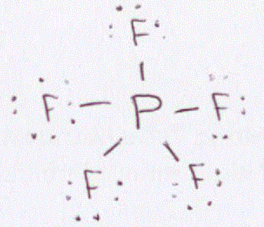
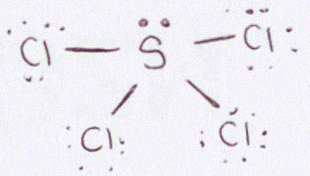
F×5

P

Pro

QUESTION ONE

(a) Complete the table below.

	PF_5	$SeCl_4^{2-}$
Lewis structure		
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 $\Delta_rH°$ for the reaction, given the following data.

3 ×2	$N_2H_4(\ell) + O_2(g) \rightarrow N_2(g) + 2H_2O(\ell)$	$\Delta_rH° = -623$ kJ mol^{-1}
2× 2×	$2ClF_3(g) + 2NH_3(g) \rightarrow 6HF(g) + N_2(g) + Cl_2(g)$	$\Delta_rH° = -1200$ kJ mol^{-1}
	$4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(g)$	$\Delta_rH° = -1270$ kJ mol^{-1}
	$H_2O(\ell) \rightarrow H_2O(g)$	$\Delta_{vap}H° = 40.7$ kJ mol^{-1}

$2N_2H_4$

A [illegible]

$3N_2H_{4(l)} + 4ClF_{3(g)} \longrightarrow 3N_{2(g)} + 12HF_{(g)} + 2Cl_{2(g)}$

so times first row by 3, and second by two, and you end up with

$\Delta_rH° = (3 \times -623) + (2 \times -1200) + -1270$

$= -1869 + -2400 + -1270$

overall $\Delta_rH° = -27139$ kJ mol^{-1}

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

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

The reaction is explosive, and so it ~~w~~ is an exothermic reaction as it releases heat into the surroundings. The entropy inside the chemical reaction increases, as it goes from a more closely knitted liquid formation with two molecules, into a much more chaotic and busy gas molecules with 3 of them now. This means that the entropy inside the system increases. The heat from the explosive heats up outside the system as well, making the experiment exothermic, as the dispersion of molecules outside the system in the surroundings and enviroment increases so does the entropy with the surroundings as the kinetic/heat energy increases. The reaction is spontaneous, and so there is no help for reaction to happen from external things. The ~~e~~entropy from the outside outweighs the entropy inside the reaction, as so it is spontaneous, and exothermic.

and kinetic/heat energy is what makes into gas to create entropy

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 the shell that its on

p the subshell that its on

6 The amount of electrons on the subshell

(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's first ionisation is larger than Ar's, because as you go down a group the ionisation energy decreases. This is because you gain shells and sub-shells to shield the valence electrons from the protons positive force in the nucleus. The negatively charged shells but a buffer so the valence electrons ~~do~~ have a lower electrostatic attractions to the nucleus / protons, making the first ionisation energy lower.

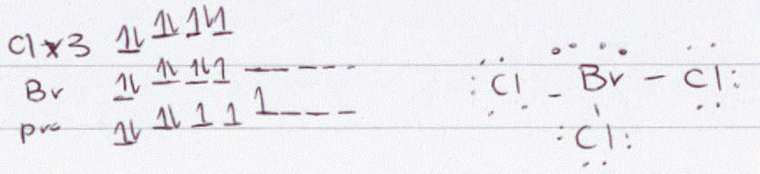
Ar's ~~is~~ First ionisation energy is larger that P's, because it grows going across a period. This is because you don't gain inner shells to shield if the atoms are in the same period, meaning there isn't any ~~no~~ gained negative energy (apart from one electron which doesn't help much due to its small mass) to combat the gained positive energy from the protons that are gained as you go across a period. This proton with its positive charge increases the electrostatic attraction between the nucleus/protons and valence electrons, so the first ionisation energy grows, hence why Ar's first ionisation energy is better than P's.

(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.



BrCl3 has five regions of negative charge around the central Br atom. These regions repel for maximum seperation into a triagonal bipyramidal arrangement with bond angles of 90° and 120°. Three of the regions are bonded, two are lone pairs of electrons. So overall, BrCl3 has ~~is~~ a T-shaped molecular arrangement.

There are three Br–Cl polar bonds and two lone pairs of electrons, ~~thus~~ Br is more electronegative, making a bond dipole in the molecule. The molecule is asymmetrical so ~~b~~ the bond dipoles do not cancel and the ~~arrangem~~ molecule becomes polar.

If ~~the~~ BrCl3 were to be triagonal planar, then the molecule would be symmetrical, so the bond dipoles from the polar bonds would cancel each other out, and the molecule would become non-polar.

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 attraction, permanent dipole attraction, Hydrogen bonding
Sulfur dioxide, SO_2	–10	Temporary dipole attraction, permanent dipole attraction
Pentane, $CH_3CH_2CH_2CH_2CH_3$	36	Temporary dipole attraction

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

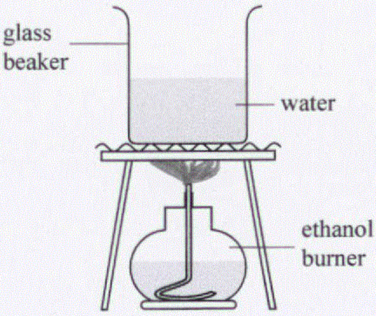
~~Am~~ NH_3 would usually have a higher boiling point due to its hydrogen bonding, where the difference in electronegativity between the N and H would be so different that N would just steal the electrons and H would practically become a proton. But the electron cloud is much smaller than that of sulfur dioxide (SO_2), and so due to the mass increase of SO_2 its boiling point is higher, and so SO_2 has a higher boiling point, even though it has ~~per~~ only permanent and temporary dipole attractions, permanent because it is a polar molecule, and so the dipole attractions are always there.

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

The boiling point of pentane is much higher than SO_2 due to its vastly larger mass. The electron cloud is very big surrounding this large molecule, and so it has a much higher boiling point than SO_2, which has a small mass in comparsion to pentane, and therefore a ~~smaller~~ smaller electron cloud, and therefore a smaller boiling point. Although theroretically if they had the same mass, then pentane would have a lower boiling point, because of the weak ~~in~~ temporary ~~ab~~ dipole attractions. These are weak because its a non-polar molecule, meaning the dipoles are only made by the electrons moving around as they always do, making small dipole forces that are constantly breaking and reforming due to the constant movement of the electrons.

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.

$n = m/M$

$= 59.2 - 58.7 / 46$

$= 0.01088$

$m = q / c\Delta T$

$m = -770 / 4.18 \times (22.1 - 31.2)$

$= -770 / 4.18 \times -9.1$

$= 20.24g$

(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.

Because the room wasn't at standard conditions in temperature before it started.

Achievement

Subject: Chemistry

Standard: 91390

Total score: 10

Q	Grade score	Marker commentary
One	A3	Drew the Lewis structure and named the shape correctly, knew to multiply 2 values to find the enthalpy, and recognised that the reaction was explosive and released heat into the surroundings.
Two	A4	Wrote the correct order and electron configuration notation and identified electrostatic attraction and shielding as a factor affecting trend in ionisation energy. Recognised the correct polarity of both shapes.
Three	A3	Identified attractive forces, that a large mass has a bigger electron cloud that affects boiling point. Calculated moles correctly.