2020 Year 5 Timed Practice Suggested Solutions

Section A

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Answer	D	B	C	C	A	A	D	D	A	A	D	B	B	C	C

Question 1 (D)

A	Incorrect. Molar mass has units of g mol^{-1}, while relative molecular mass has no units.
B	Incorrect. In 12.0 g of carbon-12, there is 1 mole of atoms. However, compounds are made up of more than one type of atoms. Hence, one mole of a compound will contains more than 1 mole of atoms.
C	Incorrect. The correct expression for the relative atomic mass of fluorine should be the $\frac{\text{weighted average mass of 1 atom of fluorine}}{\frac{1}{12} \times \text{mass of 1 atom of carbon-12}}$
D	Correct. At room temperature and pressure, 1 mol of a gas occupies 24.0 dm^3. Amount of $O_2(g)$ = 12.0/24.0 = 0.5 mol Amount of O atoms = 2(0.5) = 1.0 mol Amount of Ar(g) = 24.0/24.0 = 1.0 mol Since the amount of O atoms and amount of Ar amount are the same, they contain the same number of atoms.

Question 2 (B)

Let the oxidation number of N in HNO_2 be x.
(+1) + x + 2(-2) = 0
x = +3

The oxidation number of N is N_2 is 0.

The oxidation number of N decreased from +3 in HNO_2 to 0 in N_2 i.e. the change in oxidation is –3.

Question 3 (C)

Mass of 1 mol of urea
= 1 x [2(14.0) + 4(1.0) + 12.0 + 16.0]
= 60.0 g

Mass of urea reacted = 60.0 – 6.0 = 54.0 g

Percentage of urea reacted = (54.0/60.0) x 100
= 90.0%

Question 4 (C)

There is a large increase between the 4th and 5th IE i.e. significantly more energy is required to remove the 5th electron compared to the 4th electron.
⇒ 5th electron is from an inner electronic shell
⇒ **Q** has 4 electrons in its valence shell
⇒ **Q** is a Group 14 element and has valence shell electronic configuration of $ns^2\ np^2$.
⇒ $\mathbf{Q^{2+}}$ has valence shell electronic configuration of ns^2.

Question 5 (A)

Let p_A and n_A be the respective number of protons and neutrons of element A and p_B and n_B be the respective number of protons and neutrons of element B.

1	Correct. For mirror nuclei, $p_A = n_b$ and $p_b = n_A$. Mass number of A = $p_A + n_A$ = $n_B + p_b$ = mass number of B.
2	Correct. ^{11}O has 8 protons ⇒ it has 11 – 8 = 3 neutrons ^{11}Li has 3 protons ⇒ it has 11 – 3 = 8 neutrons Since number of protons of ^{11}O = number of neutrons of ^{11}Li and number of protons of ^{11}Li = number of neutrons of ^{11}O, they are mirror nuclei.
3	Incorrect. ^{40}Ar has 18 protons ⇒ it has 40 – 18 = 22 neutrons ^{40}Ca has 20 protons ⇒ it has 40 – 20 = 20 protons Since number of protons of ^{40}Ar is not equals to the number of neutrons of ^{40}Ca, they are not mirror nuclei.

© Raffles Institution 2020

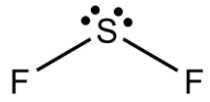
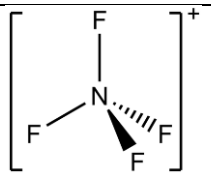
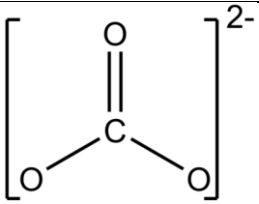
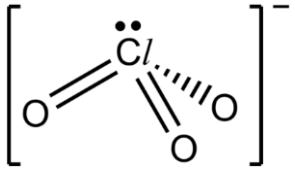
Question 6(A)

The carbon-nitrogen triple bond is made up of 1 σ and 2 π bonds. There are 3 also B–H σ bonds. The dative bond from carbon to boron is a single bond and hence is also 1 σ bond. Hence, there is a total of 5 σ bonds and 2 π bonds.

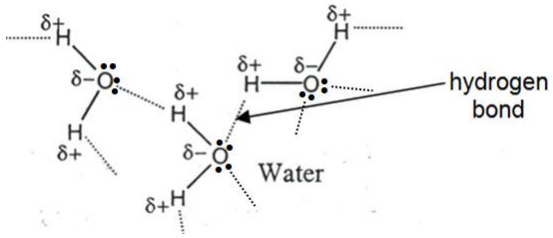
Question 7(D)

To answer this question, students must be able to

1. Draw the dot-&-cross diagram / structural formula for each species quickly.
2. Deduce the electron pair geometry and angle around the central atom.
3. Deduce the shape (molecular geometry) and bond angle around central atom.

 2 bond pairs + 2 lone pairs (similar to that of H_2O) ⇒ bond angle = ~105°	 4 bond pairs + no lone pairs ⇒ bond angle = 109.5°
 3 bond pairs + no lone pairs ⇒ bond angle = 120°	 3 bond pairs + 1 lone pair (similar to that of NH_3) ⇒ bond angle = ~107°

Question 8(D)

1	Correct.  As a result of the polar O–H bonds and the lone pair of electrons on each O atom, water molecules are capable of forming intermolecular hydrogen bonds. More energy is required to overcome the stronger hydrogen bonds between the H_2O molecules than the id-id interaction between CH_4 molecules, leading to the higher boiling point of H_2O.
2	Incorrect. While the O–H bond is stronger than the C–H bond, boiling does not involve breaking the O–H nor the C–H bonds.
3	Incorrect. H_2O contains 8 + 2(1) = 10 e^- while CH_4 contains 6 + 4(1) = 10 e^-. Therefore, they have very similar electron cloud sizes and have similar strengths of id-id interactions. This does not help to explain the higher boiling point of H_2O.

Question 9(A)

$$pV = nRT$$

$$pV = \frac{mass}{\text{molar mass}}RT$$

Since pV is the x-axis and there is no pressure term on the right side of the equation,

$$x = \frac{mass}{\text{molar mass}}RT = \text{constant}$$

The graph would be a vertical line, intersecting the x-axis at a value corresponding to $\frac{mass}{\text{molar mass}}RT$.

For the same mass, if **X** has a higher molar mass than **Y**, then the value of $\frac{mass}{\text{molar mass}}RT$ is smaller for **X** than **Y** i.e. the x-intercept for **X** is smaller than that of **Y.**

Question 10(A)

The increase in pressure when gas **B** was added is due to the presence of gas **B**.

Partial pressure of **A** in the mixture remains at 1.00 atm since the volume of the vessel is fixed.

partial pressure of B + partial pressure of A = final pressure

partial pressure of B = 2.50 – 1.00 = 1.50 atm

From solutions to question 9,

$$pV = \frac{mass}{\text{molar mass}}RT$$

$$\text{molar mass} = \frac{(mass)RT}{pV}$$

© Raffles Institution 2020

molar mass of A : B

$$= \frac{(mass_A)RT}{p_A V} : \frac{(mass_B)RT}{p_B V}$$

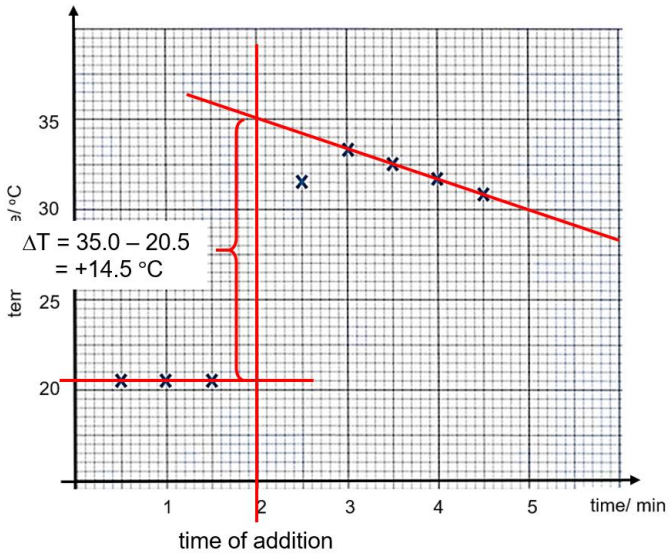
$$= \frac{mass_A}{p_A} : \frac{mass_B}{p_B}$$

$$= \frac{2.00}{1.00} : \frac{3.00}{1.50}$$

$$= 1:1$$

Question 11(D)

1	Correct. Since the temperature rose after mixing, the reaction is exothermic i.e. heat is released from the reaction. This means that products are at a lower energy and are more energetically stable than the reactants.



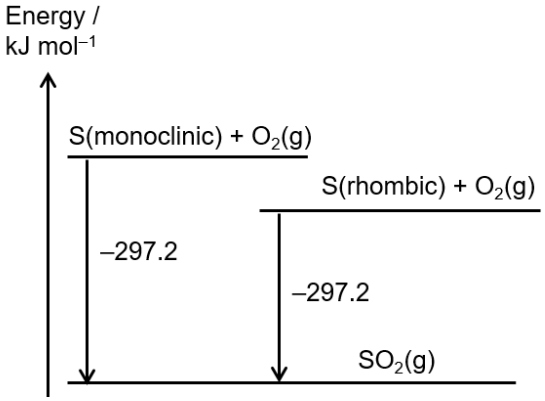
2	Incorrect. Heat loss to the surroundings is accounted for by extrapolating to the time of addition of the solid i.e. 2.0 min.
3	Incorrect. From the graph. ΔT = +14.5 °C Heat change = $mc\Delta T$ = (250)(4.18)(14.5) = 15150 J = +151 kJ

Question 12(B)

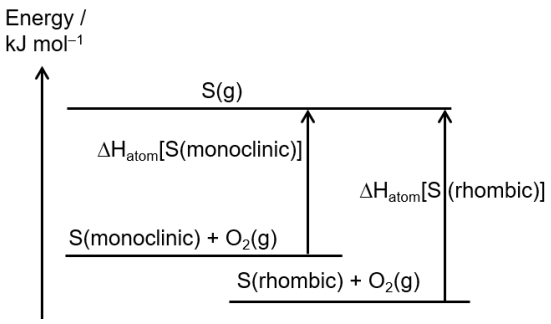
ΔH = 6BE(P–P) + 3BE(O=O) – 12BE(P–O)
= 6(200) + 3(496) – 12(340)
= –1392 kJ mol^{-1}

Question 13(B)

The following energy level diagram can be drawn from the information provided, taking into account the fact the combustion of both give the same product.



The energy level of each form of sulfur can be deduced by taking reference from the energy level of the common product.

1	Correct. From the above diagram, since S(rhombic) is at a lower energy level than S(monoclinic), S(rhombic) is more stable.
2	Correct. Since S(rhombic) is at a lower energy level than S(monoclinic), energy is required to convert S(rhombic) to S(monoclinic) i.e. it is an endothermic process.
3	Incorrect. Since S(rhombic) is at a lower energy level than S(monoclinic) and atomisation is an endothermic process which produces S(g) as a common product, the following energy level diagram can be drawn.  From the diagram, less energy is required to atomise 1 mol of monoclinic sulfur.

© Raffles Institution 2020

Question 14(C)
A negative change in entropy would involve a process where there is a decrease in disorder.

A	Incorrect. There is an increase in disorder since liquid water is more disordered than solid water.
B	Incorrect. There is an increase in disorder since the ions are no longer held in the giant ionic lattice and are free to move in the aqueous state.
C	Correct. There is a decrease in disorder since the liquid reactant, with higher disorder, was consumed to formed a solid product, with lower disorder.
D	Incorrect. There is an increase in disorder due to the production of highly disordered gaseous products, H_2.

Question 15(C)
Rearranging $\Delta G = \Delta H - T\Delta S$ gives $\Delta G = (-\Delta S)T + \Delta H$ which is of the form $y = mx + c$ where

m = gradient = $-\Delta S$
c = y-intercept = ΔH

1	Correct. Since the y-intercept is below the origin, ΔH is a negative value i.e. the reaction is exothermic.
2	Incorrect. Since the gradient of the graph is positive, gradient = $(-\Delta S)$ is positive i.e. ΔS is negative. There is decrease in disorder during the reason.
3	Correct. As T increases, ΔG becomes less negative i.e. the reaction becomes less exergonic.

Section B

General examiner comments

- The examiner comments written are intended to help students improve across their two years by highlighting the do's and don'ts. Please learn from the feedback and do not repeat such mistakes in future examinations.
- Students should be mindful of the appropriate use of significant figures and units. Excessive or insufficient significant figures in their working will be penalised. The same applies for missing units or incorrect units.
- Students should describe enthalpy changes as more / less endothermic or more / less exothermic **or** refer explicitly to their magnitudes. Terms like "enthalpy change increases / decreases" are vague and imprecise and no credit will be given.
- When answering questions, students should apply concepts to the specific reaction / chemical species. They should not give broad statements / principles in response to questions on specific questions / chemical species. Credit will not be given for such cases.

B1 (a) (i) Lattice energy (LE) of an ionic compound is the energy released when one mole of the solid ionic compound is formed from its constituent gaseous ions under standard conditions of 298 K and 1 bar.

Examiner Comments

- Students need to specifically state that lattice energy refers to energy *released* instead of using a generic term such as energy change.
- Note that 'lattice' does not imply the presence of an ionic compound, and hence 'lattice' and 'ionic' are not interchangeable terms. Simple covalent molecules can form lattice structures in the solid state too.
- A number of students did not quote the applicable conditions.

© Raffles Institution 2020

(ii) $|L.E.| \propto |(q_+q_-) / (r_+ + r_-)|$

The charges of the ions and the radius of the anion are the same in both compounds. Since the ionic radius of Na^+ is smaller than the radius of K^+ ion, the inter-ionic distance of NaC*l* is smaller than that of KC*l*. Therefore the magnitude of LE of NaC*l* is larger than KC*l*.

Examiner Comments
- Students need to compare ionic radius of Na^+ and K^+ ion instead of atomic radius of Na and K.
- Students should also be careful to refer to the correct chemical species in their answers – Na^+, not Na; K^+, not K.
- Some students erroneously used charge density. Note that charge density should not be used to explain lattice energy as there is no simple mathematical relationship between these terms.

(iii) Since LE of NaC*l* is larger in magnitude, more energy is required to overcome the stronger ionic bonds of NaC*l*, and thus the melting point of NaC*l* is higher than KC*l*.

Examiner Comments
- The question only requires a relative comparison of melting points and not to propose specific melting points.
- All chemical bonds and interactions are electrostatic in nature. Hence, 'electrostatic forces of attraction' covers a variety of attractive forces between opposite charges of varying magnitudes, thus it is important to identify *ionic bonding* for this question.

(b) **(i)**

compound	lattice energy / kJ mol^{-1}	sum of $\Delta H_{hydration}$ of ions in compound	$\Delta H_{solution}$ / kJ mol^{-1}
LiC*l*	–860	–897	–37
NaC*l*	–787	–769	+4

Examiner Comments
- Students are reminded to include sign for ΔH.

(ii) Since the $\Delta H_{solution}$ is the most negative, LiC*l* is the most soluble in water.

Examiner Comments
- Students are reminded to refrain from using ambiguous phrases such as the "lowest $\Delta H_{solution}$".

(c) **(i)**

compound	$\mu_{observed}$	$\mu_{calculated}$	percentage ionic character
LiC*l*	7.13	9.70	73.5 %
NaC*l*	9.00	11.33	79.4 %

(ii) Ionic radius of Li^+: 0.060 nm; Ionic radius of Na^+: 0.095 nm

© Raffles Institution 2020

Li^+ has a smaller radius, resulting in higher charge density and higher polarizing power. Hence, Li^+ is able to distort the electron cloud of C*l*$^-$ to a larger extent, leading to higher covalent character and lower ionic character in LiC*l*.

Examiner Comments
- Students are required to quote the relevant ionic radii from the Data Booklet.
- The charge density of the cation determines the polarising power which causes distortion of the electron cloud of the anion. Some students were unfamiliar with the concept and incorrectly referred to the polarising power of the chloride anion.
- Students should recognise that LiC*l* and NaC*l* are predominantly ionic compounds, and as such, focus on identifying the factors influencing extent of covalent character. A number of students incorrectly attempted to explain the degree of ionic character in a Li–C*l* or Na–C*l* covalent bond instead.

B2 **(a)** First IE of As = 944 kJ mol^{-1}
Choose a value between that of P (1060 kJ mol^{-1}) and Ge (762 kJ mol^{-1})

Since IE decreases down the group and increases across the period, As should have an IE smaller than that of P and higher than that of Ge.

Examiner Comments
- Students need to be aware that predict a value for the IE of As requires the consideration of the trends across the period **and** down the group. Considering only one factor is incomplete and often leads to a prediction that is unreasonably far from the true value.

(b) $AsO_4^{3-}(aq) + 2I^-(aq) + H_2O(l) \rightarrow AsO_3^{3-}(aq) + I_2(aq) + 2OH^-(aq)$

Examiner Comments
- Students need to ensure the elements and total charge are balanced on both sides on the equation. The reaction was carried out in an alkaline solution, hence no H^+ ions should be present.

(c) **(i)** Amount of $S_2O_3^{2-}$ used in step III = 20.05/1000 x 1.00 x 10^{-5}
= 2.005 x 10^{-7} mol

$2S_2O_3^{2-} \equiv I_2 \equiv AsO_4^{3-} \equiv O_3$

Amount of O_3 required in step I = 2.005 x 10^{-7} ÷ 2 = 1.003 x 10^{-7} mol

Volume required for a 10 cm^3 water sample = 1.003 x 10^{-7} x 24
= 2.406 x 10^{-6} dm^3

Examiner Comments
- Using the correct mole ratio between the different species from the appropriate balanced equations proved to be tricky for some students.

(ii) Amount of As = Amount of AsO_3^{3-} = 1.003 x 10^{-7} mol
Mass of As = 1.003 x 10^{-7} x 74.9 = 7.509 x 10^{-6} g
Concentration of As in water = 7.509 x 10^{-6} ÷ 10.0/1000
= 7.51 x 10^{-4} g dm^{-3} > 1.0 x 10^{-5} g dm^{-3}

Hence the water sample analysed is not safe for drinking.

© Raffles Institution 2020

Examiner Comments
- The question required the comparison of arsenic's (As) mass concentration and not arsenite or arsenate.
- Student need to explicitly compare (higher or >) the mass concentrations of arsenic in their conclusion to be awarded the mark.

(d) Amount of As_2O_3 used = 27.5/ 197.84 = 0.139 mol
Amount of C used = 2.5/12.0 = 0.208 mol
Mole ratio (As_2O_3 : C) = 2:3

Since 3 mole of C has reacted, 3 mole of CO_2 will be formed i.e. all 6 mole of O from 2 mole of As_2O_3 will be used to from 3 mole of CO_2. This leaves As as the only other possible product.

$2As_2O_3 + 3C \rightarrow 4As + 3CO_2$

The grey solid is As.

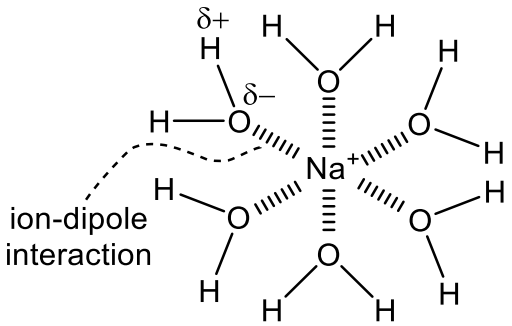
Examiner Comments
- Students need to realise that finding mole ratio is often an important step to determine the stoichiometry of a chemical reaction. An appropriate equation can be constructed from stoichiometric information.

B3 **(a)** Mg^{2+} has one more proton and hence a higher nuclear charge than Na^+. Na^+ and Mg^{2+} have the same number of electrons (isoelectronic) and hence their valence electrons experience the same shielding effect.

Consequently, the valence electrons of Mg^{2+} experience greater effective nuclear charge and are more strongly attracted by the nucleus, resulting in a small size of the electron cloud of Mg^{2+}.

Examiner Comments
- This is a straightforward "recall" type question.
- Students should make use of terms like nuclear charge and shielding in their answers and link the combined effect of the two factors to the attraction of the electrons by the nucleus.
- Students should compare the ionic sizes of Na^+ and Mg^{2+} specifically and avoid giving an answer based on the trend across a period.
- Students must be specific in specifying the object of their discussion. In this question, you should be discussing Mg^{2+} and not Mg; Na^+ and not Na.

(b)



Na^+ ion in water forms ion-dipole interactions with several water molecules and hence it has a larger overall size.

© Raffles Institution 2020

Examiner Comments
- Students should use " - - - - - - - " and not a blank space to indicate the ion-dipole interactions.
- The diagram should include
  - Na^+ cation
  - the structural formula of at least one water molecule
  - the dipoles of at least one water molecule.
  - the ion-dipole interactions between the Na^+ ion with at least 1 water molecule

  to gain full credit.

(c) Since the size of the water molecule is smaller than the pore size of the membrane, water molecules are able to pass through the pores of the membrane easily.

Since the size of the hydrated ions is larger than the pore size of the membrane, the hydrated ions are unable to pass through the pores of the membrane.

Examiner Comments
- Students should compare the pore size of the membrane with both the sizes of the hydrated ions and the size of the water molecule and conclude accordingly.

(d) **(i)** The ion-dipole interactions in a small amount of the ions were broken, which allowed the naked ions, which have ionic sizes smaller than the pore size of the membrane, to pass through the pores.

Examiner Comments
- This question was poorly answered.
- Answers which involved the idea that there are always naked ions in solution which are not hydrated were not accepted – all ions are hydrated in aqueous solution.

(ii) Sample answer for Mg^{2+} and Ca^{2+}
Higher percentage separated for Mg^{2+}. Although Mg^{2+} and Ca^{2+} have the same charge, Mg^{2+} has a smaller size, resulting in higher charge density and stronger ion-dipole interactions than Ca^{2+}. This makes it harder to shed the water molecules of the hydrated Mg^{2+}

Sample answer for Mg^{2+} and Na^+
Higher percentage separated for Mg^{2+}. With a smaller size and higher charge, Mg^{2+} has higher charge density than Na^+. Mg^{2+} has stronger ion-dipole interactions making it harder to shed the water molecules of the hydrated Mg^{2+}.

Examiner Comments
- Many students did not notice the hint provided in the question to consider the charge and size of the cations in their discussion.

(iii) Amount of chloride = 0.0815 + 0.00242 + 2(0.00119) + 2(0.00113)
= 0.08856 = 0.0886 mol

Examiner Comments
- As hinted in the question, students need to consider charge balance here. The amount of chloride should balance the amount of positive charges from the cations.
- A common mistake was to forget that 2 moles of chloride is required to balance the charge of 1 mole of Mg^{2+} or 1 mole of Ca^{2+}.

© Raffles Institution 2020

(e) **(i)** When brine is introduced into sea water, NaC*l* concentration of sea increases, the amount of dissolved oxygen available for marine life decreases.

Examiner Comments
- Students who attempted this question answered well.

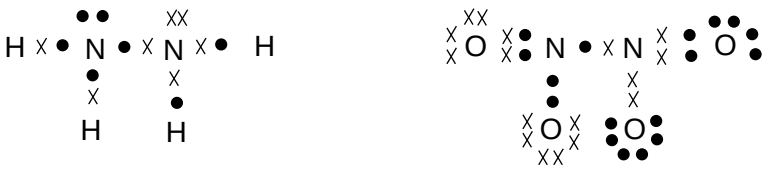
(ii) With more NaC*l*, more water molecules are involved to form the stronger ion-dipole interactions with Na^+ and Cl^- than in forming instantaneous dipole-induced dipole (id-id) interactions with O_2. Hence, reducing the solubility of O_2 in water with increasing concentration of NaC*l*.

OR

When concentration of NaC*l* is higher, more water molecules will be involved in the hydration of the ions, hence, less water molecules available to form id-id interactions with O_2 molecules.

Examiner Comments
- Students should include the correct interactions here.
- The interactions formed between water molecules and oxygen molecules are not hydrogen bonds.

C1 **(a)** **(i)**



Examiner Comments
- Students need to show different symbols between electrons from different atoms.
- Students need to understand that N cannot expand their octet configuration and consciously check it in their structures.
- Students need to fill in the remaining non-bonding electrons for O.

(ii) For N_2H_4, around each N centre, there are 3 bond pairs and 1 lone pair of electrons. For N_2O_4, around each N centre, there are 3 regions of electron density. Since electron pairs are placed as far apart as possible to minimise repulsion, N_2H_4 is trigonal pyramidal with respect to each N centre while N_2O_4 is trigonal planar with respect to each N centre.

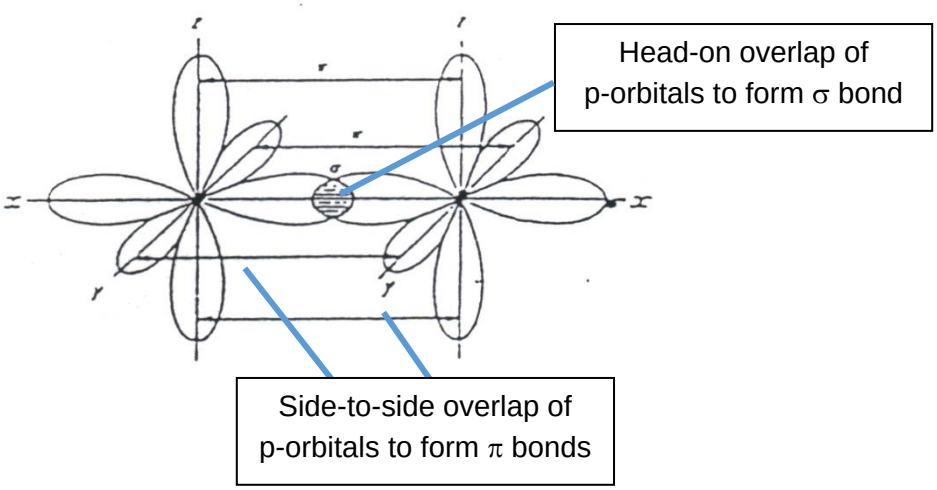
Examiner Comments
- Given the criteria to "state, and explain, with reference to the Valence Shell Electron Pair Repulsion Theory…", students need to make reference to VSEPR theory in their answers and not expect the description of number of regions of electron densities and lone pairs to fulfil this criterion.

(iii) With 4 regions of electron density and the fact that lone-pair–bond-pair repulsion is greater than bond-pair-bond pair repulsion, the N-N-H bond angle is about 107°.

Examiner Comments
- Students were required to explain their bond angle value. This should be based on the concept that lone pair-bond pair repulsion is greater than bond pair-bond pair repulsion, and not an result of the molecular shape.
- In this case, please note that there is no lone pair-lone pair repulsion.

© Raffles Institution 2020

(iv)



Examiner Comments

- Students need to provide a clearly labelled diagram and realize that the question required a single diagram.
- Students need to understand that the top and bottom side-on overlap of 2 p-orbitals constitute a single π bond and not 2 π bonds.
- Appropriate lines need to be drawn which represent the side-on overlap between the p-orbitals to form π bonds.

(b) At moderately high pressure, negative deviation is observed. Both CO_2 and N_2 molecules form instantaneous dipole-induced dipole interaction. CO_2 has more electrons and a larger electron cloud which is more easily polarised, thus CO_2 molecules form stronger instantaneous dipole-induced dipole interactions. CO_2 deviates more from ideality than N_2.

At very high pressure, positive deviation is observed. The intermolecular repulsive force between CO_2 molecules is more significant than that of N_2 / as the volume of CO_2 molecules is larger than that of N_2 molecules. Thus, CO_2 deviates more from ideality than N_2.

Examiner Comments

- Students need to frame their explanations in terms of the different pressure conditions so that their explanations for deviations make sense.
- One important point to note is that the explanations are meant to explain the deviation from ideal gas behaviour under *moderately high* and *very high* pressure conditions. Some students attempted to explain the deviation under low and high pressure conditions. This is not correct as gases approach ideal gas behaviour at low pressure.
- Many students incorrectly thought that CO_2 was polar and deduced pd-pd interactions as the predominant intermolecular force. Such questions points to the importance of having a strong foundation in Chemical Bonding.

(c) **(i)** From the graph, gradient = $\dfrac{(0.062-0.001)x10^{6}}{(50-1)x10^{5}} = 0.0124$ g m^{-3} Pa^{-1}

Examiner Comments

- Students need to read the units of the graph axes and notice that there are "10^{x}" terms on the axes to understand that the actual magnitude of values that they are reading off the axes.

© Raffles Institution 2020

(ii) $pV = nRT = \frac{m}{M}RT$

$d = \frac{M}{RT}p$

$M_r = 0.0124 \times 8.31 \times 453 = 46.9$

Gas is CO_2

Examiner Comments

- Students need to read the question carefully to realize that it is requesting for M_r instead of molar mass as well as an identity for the gas. Many students forgot to identify the gas despite getting the M_r correct.

(d) **(i)** The atmospheric pressure on Mars is much lower than that on Earth. Hence, gas particles are very far apart and can be considered to have negligible volume compared to the volume of the gas. The intermolecular attractive forces between the widely spaced gas molecules are negligible**.** Hence, gases are more likely to obey the Ideal Gas Equation on Mars.

OR

The temperature on Earth is higher than that on Mars. Hence, gas molecules possess sufficiently high kinetic energy to overcome the intermolecular attractive forces/the intermolecular forces of attraction on Mars is weaker than that on Earth. The intermolecular attractive forces can be considered negligible. Hence, gases are more likely to obey the Ideal Gas Equation on Earth.

Examiner Comments

- Students need to know that the pressure on Earth (101325 Pa) is higher than that on Mars (given as 600 Pa in the question).
- It is therefore important to map the correct reason to their choice of planet.
- Poor descriptions such as “the volume of the gas is negligible” were not given credit. This statement implies that the whole sample of gas does not take up any volume, which is not true. A gas takes up the volume of the container it is placed in.
- The accurate description is “the volume of the gas particles is negligible compared to…”. This points to the volume of each and every gas particle taking up an insignificant volume compared to the volume of the entire space that it can travel in.

(d) **(ii)** V_{O2} needed at r.t.p. = $\frac{20.95}{100}$ x 2625 = 550 dm^3

$$\frac{600 x V x 10^{-3}}{213} = \frac{101325 x 550 x 10^{-3}}{293}$$

$V_{O2} = 6.75 \times 10^4$ dm^3

Volume of air needed per day in Mars = $\frac{100}{0.13} \times 6.75 \times 10^4 = 5.19 \times 10^7$ dm^3

OR

Vol. of O_2 needed at r.t.p. = $\frac{20.95}{100}$ x 2625 = 550 dm^3

Amount of O_2 needed at r.t.p. = $\frac{550}{24}$ = 22.9 mol

$V_{O2} = \frac{22.9 x 8.31 x 213}{600}$ = 67.6 m^3 = 6.76×10^4 dm^3

Volume of air needed per day in Mars = $\frac{100}{0.13} \times 6.76 \times 10^4$

= 5.20×10^7 dm^3

© Raffles Institution 2020

Examiner Comments

- Students need to realize that 2625 dm^3 refers to volume of air instead of oxygen and that different planets have different percentage of oxygen in air. This information is provided to students on page 20.
- Students need to understand that 1 dm^3 of gas on Earth will not occupy the same volume on Mars given the different conditions of temperature and pressure.
- This question requires clarity in presentation. Students need to state clearly which planet they are calculating for. A lack of clarity impedes understanding and affects your performance.

C2 **(a)** The standard enthalpy change of combustion of $CH_3CH_2OH(l)$ is the energy released when one mole of $CH_3CH_2OH(l)$ is completely burnt in excess oxygen under standard conditions of 298 K and 1 bar

Examiner Comments

- Students need to specify that the substance is ***completely*** burnt in excess oxygen.
- Some students are confused between standard conditions (298 K and 1 bar) and standard temperature (0 °C).

(b) **(i)** The temperature change of water is similar to keep variables, such as heat loss to surroundings, constant for both experiments.

Examiner Comments

- Students who wrote that temperature change of water is similar to keep the amount of heat produced for both experiments constant were not given credit because the heat produced by each reaction is dependent on ΔH and the amount of fuel used.

(b) **(ii)** q = (100)(4.18)(55-22)
= 13794 J = 13800 J

Amount of ethanol combusted = $\frac{85.6 - 83.1}{46}$ = 0.05435 mol

Apparent ΔH_c of ethanol = $-\frac{13794}{0.05435}$
= − 253799 J mol^{-1}
= − 254 kJ mol^{-1}

Examiner Comments

- Students mistakenly substituted the mass of ethanol combusted as m in the $q=mc\Delta T$ formula. This is incorrect as m is the mass of the substance to which the temperature change occurs (i.e. water).
- A few students wrongly added 273 to ΔT. The temperature can be expressed in K, but the ***change*** in temperature would still be 33 K.
- A few students wrongly used 0.1 instead of 100 for the value of *m*. Note that the units for *m* is grams where density of water is assumed to be 1.00 g cm^{-3}.
- Due to the instruction to refer to the *Data Booklet*, some students made use of bond energy data to calculate the enthalpy change. The instructions were also specific to make use of information in (b) i.e. temperature change, mass change of fuel, volume of water in setup, etc. The reference to the *Data Booklet* was for students to obtain the value of the specific heat capacity of water.

© Raffles Institution 2020

(b) (iii) As the number of carbon atoms in an alcohol chain increases, its ΔH_c becomes more exothermic. Apparent ΔH_c of heptanol = −915 kJ mol^{-1}

Examiner Comments
- Students should not use imprecise terms such as "ΔH_c *increases*" or "ΔH_c *decreases*". Phrasing in this manner makes the statement ambiguous as ΔH_c is negative. The more precise term in this question would be more or less exothermic.
- A small range of values were accepted for the apparent ΔH_c of heptanol.
- The apparent ΔH_c of heptanol can be approximated using the average difference between the ΔH_c of the other alcohols in the table.

(b) (iv) Two of the following:

(1) Due to the distance between the spirit burner and the copper calorimeter. Some energy released from the combustion of pentanol was lost to the surroundings and not used to heat up the water.

(2) The specific heat capacity of the copper calorimeter was not included during calculations. The copper calorimeter absorbed some heat released from the combustion of pentanol and was unaccounted for.

(3) Incomplete combustion of pentanol took place.

(4) Continual evaporation of alcohol from the wick after it was extinguished.

Examiner Comments
- This student requires students to explain the discrepancy between experimental ΔH_c and true ΔH_c by considering experimental limitations.
- Attempting to explain this using Chemical Bonding concepts points to a lack of understanding of the context of the question (both the apparent and true values were obtained from experiments – any differences must be due to difference in experimental factors).
- As a general guide, Chemical Bonding concepts are usually used when comparing experimental results with theoretical predictions.

(c) (i) The entropy of a chemical system is a measure of the disorder in a system / different ways a system can arrange itself.

Examiner Comments
- Students attempted this question well.

(c) (ii) $\Delta S^{\ominus}$ is negative as there is a decrease in number of gaseous molecules from reactants to products.

Examiner Comments
- Students are expected to describe the factor affecting entropy of this particular chemical system in order to justify why $\Delta S^{\ominus}$ is negative i.e. answers should describe and make reference to this particular reaction.
- Students who merely stated that the product is less disordered compared to the reactants were not given credit.

© Raffles Institution 2020

(c) **(iii)** $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$

$= (-137) - (298)(\frac{-319}{1000})$

$= -41.9$ kJ mol^{-1}

Examiner Comments

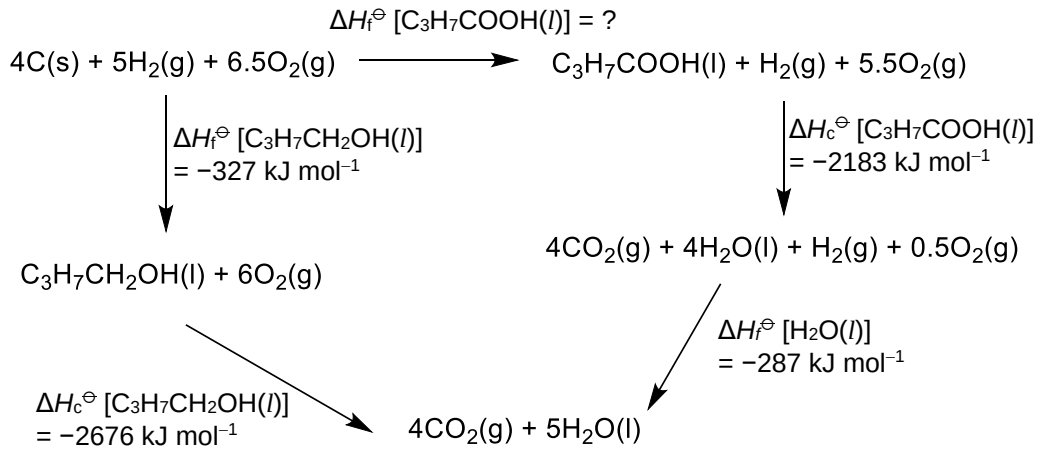
- Students used values of 293 K or 273 K for T. Note that temperature at standard conditions = 298 K.
- Some students did not notice that the entropy change was given in J mol^{-1} K^{-1} and hence the need to convert it to a unit (e.g. kJ mol^{-1} K^{-1}) which was consistent with the other quantities in the equation.

(c) **(iv)** Both $\Delta S^{\ominus}$ and $\Delta H^{\ominus}$ are < 0. At higher temperatures, the positive $-T\Delta S$ outweighs the negative ΔH. Thus, ΔG becomes more positive and the OXO reaction is less spontaneous at higher temperatures.

Examiner Comments

- Students must bring in the idea of **positive $-T\Delta S$ outweighing the negative ΔH** at higher temperatures before commenting on ΔG. Many students only focused on $-T\Delta S$ becoming more positive at higher temperatures, with no comparison to ΔH.
- Students should state the relationship between ΔG and the spontaneity of the reaction.

(d)



$\Delta H_f^{\ominus}$ [$C_3H_7COOH(l)$] = $(-327) + (-2676) - (-287) - (-2183)$

$= -533$ kJ mol^{-1}

Examiner Comments

- Students did not manage to construct an energy cycle with balanced thermochemical equations. This question was poorly done.

© Raffles Institution 2020