2021 H2 Chemistry Y6 Term 3 Common Test Suggested Solutions

Section A

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

Question 1 (C)

$n_{estradiol} = \frac{76/1000}{(18\times12.0+24\times1.0+2\times16.0)} = 2.794\times10^{-4}$ mol

$$ROH + Na \rightarrow RO^{-}Na^{+} + \tfrac{1}{2}H_2$$

1 mol of alcohol reacts with Na to produce 0.5 mol of H_2. Since there are 2 –OH groups in estradiol, 1 mol of estradiol produces 1 mol of H_2.

amt of H_2 formed = 2.794×10^{-4} mol

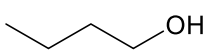
volume of H_2 formed at s.t.p.
= $2.794 \times 10^{-4} \times 22.7$
= 0.00634 dm^{3+}
= 6.34 cm^3

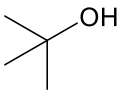
Question 2 (B)

	no. of protons	no. of electrons	no. of neutrons
$^{2}_{1}D$	1	1	1
$^{11}_{5}B$	5	5	6
$^{12}_{6}C$	6	6	6
$^{14}_{7}N$	7	7	7
$^{16}_{8}O$	8	8	8

	species	no. of electrons	no. of neutrons
A	$^{11}BD_4^-$	10	10
B	CD_3^-	10	9
C	ND_4^+	10	11
D	D_3O^+	10	11

Question 3 (C)





butan-1-ol ($C_4H_{10}O$) 2-methylpropan-2-ol ($C_4H_{10}O$)

Butan-1-ol is a straight-chain isomer of $C_4H_{10}O$ and has a greater surface area for instantaneous dipole–induced dipole (id-id) interactions to occur compared to 2-methylpropan-2-ol which is a branched-chain isomer of $C_4H_{10}O$.

Thus, id-id interactions are stronger in butan-1-ol than in 2-methylpropan-2-ol. (**Option 1 is correct**)

The strength of the hydrogen bonds in both molecules are the same as the hydrogen atom involved in hydrogen bonding is bonded to the same element, oxygen. The extent of hydrogen bonding is also the same as they have same number of lone pairs and number of H atoms attached to O. (**Options 2 and 3 are incorrect**)

Question 4 (D)

The enthalpy change of the neutralisation reaction between KOH and HNO_3 is –57.3 kJ mol^{-1}.

Since KOH and HNO_3 have the same concentrations and KOH has a lower volume, KOH is the limiting reagent. Hence,

$$\Delta H = -\frac{q}{n} \Rightarrow -57300 = -\frac{q}{2(y/1000)}$$

$$q = 114.6y \text{ J}$$

Also, q = mcΔT = (25.0 + y)(4.18)(10.0)

Therefore, (25.0 + y)(4.18)(10.0) = 114.6y
y = 14.35 cm^3

Question 5 (B)

By combining the 2 equations, you can obtain the overall equation for the decomposition of 1,2-dioxetanedione (C_2O_4).

$$C_2O_4 \rightarrow 2CO_2 + \text{light}$$

Δ*H* : (–). Due to formation of the *more stable* CO_2, the reaction is exothermic.

Δ*S* : (+). Due to the formation CO_2 *gas* from liquid 1,2-dixetanedione, there is an increase in entropy.

Δ*G*: (–). Since the reaction occurs when the chemicals are mixed, it is spontaneous. Alternatively, you can derive the sign of Δ*G* using Δ*G* = Δ*H* – TΔ*S* and the signs for Δ*H* and Δ*S* deduced previously.

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Question 6 (A)

Since the decomposition of **X** follows first-order kinetics, $t_{½} = \ln 2 / k$.

$t_{½}$ $= \ln 2 / k$
$= \ln 2 / (7 \times 10^{-2})$
$= 9.90$ years

Let n be the number of half-lives in 3 years.

$n \times t_{½} = 3$ years
$n = 3 / 9.90$
$= 0.303$

$[X] = (½)^n [X]_{initial}$
$[X] / [X]_{initial} = (½)^{0.303}$
$= 0.811$

Hence 81.1% of X remains after 3 years.

Question 7 (C)

A	**Incorrect**. The chemical equation does not provide any information about the order of a reaction. No other information is provided as well.
B	**Incorrect.** If the order of reaction w.r.t. A is zero (or negative), increasing [A] does not increase the reaction rate.
C	**Correct**. A catalyst provides an alternative pathway of lower activation energy, increasing the rate of the reaction.
D	**Incorrect.** Removing **B**, a product, does not impact the reaction rate.

Question 8 (D)

A	**Incorrect**. There are 0.015 mol of CH_3COO^- and 0.030 mol of H^+ from HC*l* i.e. H^+ is in excess. Since $CH_3COO^- + H^+ \rightarrow CH_3COOH$, the resultant mixture contains 0.015 mol of H^+ and 0.015 mol of CH_3COOH. This is not a buffer solution.
B	There are 0.020 mol of CH_3COO^- and 0.010 mol of H^+ from HC*l* i.e. CH_3COO^- is in excess. Since $CH_3COO^- + H^+ \rightarrow CH_3COOH$, the resultant mixture contains 0.010 mol of CH_3COO^- and 0.010 mol of CH_3COOH. This is a buffer solution.
C	**Incorrect**. There are 0.010 mol of CH_3COOH and 0.020 mol of OH^- from NaOH i.e. OH^- is in excess. Since $CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$, the resultant mixture contains 0.010 mol of OH^- and 0.010 mol of CH_3COO^-. This is not a buffer solution.
D	There are 0.030 mol of CH_3COOH and 0.015 mol of OH^- from NaOH i.e. CH_3COOH is in excess. Since $CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$, the resultant mixture contains 0.015 mol of CH_3COOH and 0.015 mol of CH_3COO^-. This is a buffer solution.

Comparing the buffer solutions in **B** and **D**, the solution in **D** contain greater amounts of the buffering species (i.e. CH_3COOH and CH_3COO^-) to react with any small amounts of acid or base added.

Hence, for the same amount of acid or base added, the pH change in **D** will be smaller, making it more effective in resisting pH change.

Question 9 (D)

Silver chloride is a sparingly soluble salt.

$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$ – eqm (1)

A	**Incorrect**. $AgNO_3(aq)$ provides a high $[Ag^+(aq)]$, causing the position of eqm (1) to shift to the left, reducing the amount of AgC*l* that can dissolve.
B	**Incorrect.** $NH_4Cl(aq)$ provides a high $[Cl^-(aq)]$, causing the position of eqm (1) to shift to the left, reducing the amount of AgC*l* that can dissolve.
C	**Incorrect**. $HNO_3(aq)$ does not affect $[Ag^+(aq)]$ and $[Cl^-(aq)]$. Thus, it does not affect the solubility of AgC*l*.
D	**Correct.** The presence of NH_3 causes another equilibrium to be established which forms a soluble complex, $[Ag(NH_3)_2]^+$. $Ag^+(aq) + 2NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+(aq)$ – eqm(2) The position of eqm (2) lies very much to the right, significantly lowering $[Ag^+(aq)]$, causing the position of eqm (1) to shift to the right. This results in more AgC*l* dissolving.

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Question 10 (A)

Since $E^{\ominus}(NiOOH/Ni(OH)_2)$ is more positive than $E^{\ominus}(Cd(OH)_2/Cd)$, NiOOH undergoes reduction and Cd undergoes oxidation.

Cathode:

$NiOOH + 2H_2O + 2e^- \rightarrow Ni(OH)_2 + 2OH^-$

Anode:

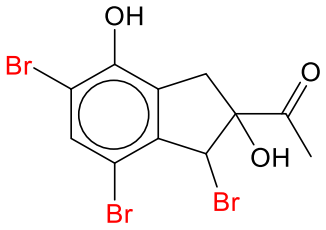
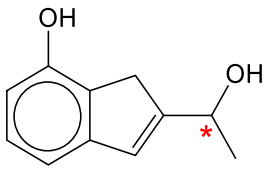
$Cd + 2OH^- \rightarrow \underline{Cd(OH)_2} + 2e^-$

Since electrons are released at the $Cd(OH)_2/Cd$ half-cell, Cd is the negative electrode. $Cd(OH)_2$ is formed at the negative electrode.

Question 11 (A)

1	**Correct**. • **M** (A*l*) has the highest melting point of the 3 elements. • Oxide of **K** (P_4O_{10}) is an acidic oxide that dissolves in dilute KOH. • pH of the chlorides in water decrease in the following order. **L** > **M** > **K** $MgCl_2$ > $AlCl_3$ > PCl_5 6.5 3 2
2	**Incorrect.** • **K** (Si) has the highest melting point of the 3 elements. • Oxide of **K** (SiO_2) is only dissolves in <u>concentrated</u> OH^-. • pH of the chlorides in water decrease in the following order. **L** > **M** > **K** $NaCl$ > $MgCl_2$ > $SiCl_4$ 7 6.5 2
3	**Incorrect**. • **M** (Si) has the highest melting point of the 3 elements. • Oxide of **K** (Al_2O_3) is an amphoteric oxide that dissolves in dilute KOH. • pH of the chlorides in water decrease in the following order. **L** > **K** > **M** $MgCl_2$ > $AlCl_3$ > $SiCl_4$ 6.5 3 2

Question 12 (A)

1	**Correct**. Both the phenol and alkene reacts with $Br_2(aq)$ to form the following major product. 
2	**Incorrect.** The –COOH group, which reacts with Na_2CO_3 to form CO_2 gas, is absent. Phenol does not react with Na_2CO_3 to form CO_2 gas.
3	**Incorrect**. $LiAlH_4$ reduces only the ketone functional group in the compound to form the following product, which contains only 1 chiral centre. 

Question 13 (D)

The energy profile diagram has one peak and represents a reaction with only one step in the mechanism.

A	**Incorrect**. Chlorobenzene does not undergo nucleophilic substitution with cyanide ion due to the partial double bond character of the C–C*l* bond, which strengthens the bond.
B	**Incorrect**. The nucleophilic addition of HCN to propanone occurs via a two-step mechanism.
C	**Incorrect**. The electrophilic addition of HBr to propene occurs via a two-step mechanism.
D	**Correct**. $C_6H_5CH_2CH_2Br$ is a primary bromoalkane and undergoes S_N2 reaction with hydroxide. The S_N2 mechanism is a single step mechanism.

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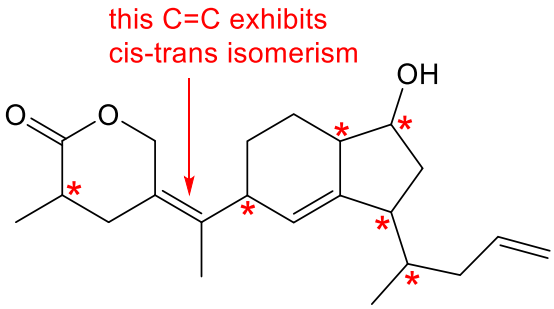
Question 14 (C)

Maximum number of stereoisomers = 2^{x+y}, where
x = number of chiral centres
y = number of C=C that exhibits cis-trans isomerism



Question 15 (B)

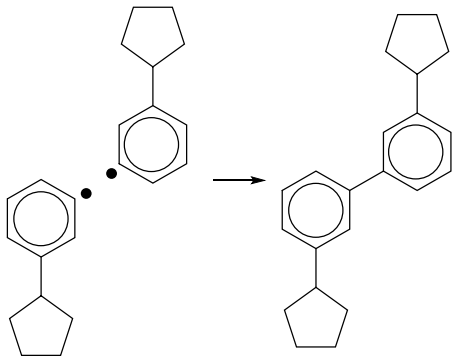
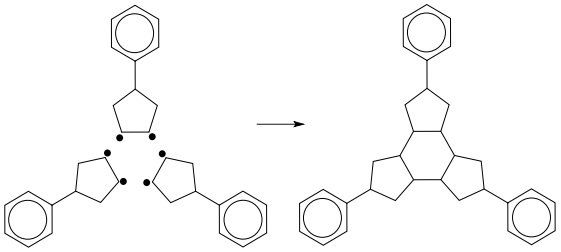
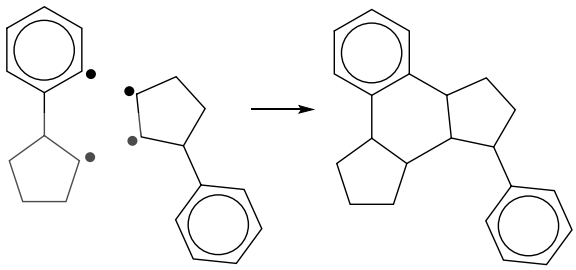
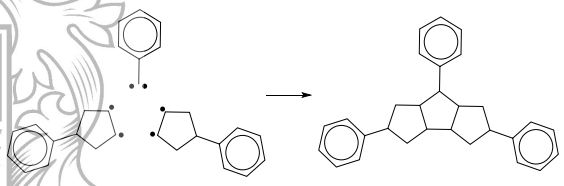
Cyclopentylbenzene undergoes free radical substitution with chlorine gas.

Chlorine radicals are generated in the initiation step, which go on to react with cyclopentylbenzene to generate cyclopentylbenzene radicals. The radicals are only formed on the cyclopentane side chain and not on the benzene ring.

In the termination step, the cyclopentylbenzene radicals can react with each other to form products.

This question tests you on the possible products which can be formed from the reaction of the cyclopentylbenzene radicals with each other in the termination step.

Approach this question by considering where the new bonds are formed and what radicals must be involved to form the new bonds.

A	**Incorrect**.  Benzene radicals cannot be formed in this FRS reaction. Hence, this product is not formed.
B	**Correct**.  The product can be visualised as being formed from the reaction of the three alkyl radicals.
C	**Incorrect**.  This product requires a benzene radical to form. Benzene radicals cannot be formed in this FRS reaction.
D	**Incorrect**.  This reaction requires the presence of a methylbenzene reactant to be present. However, only cyclopentylbenzene and chlorine are present as reactants.

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Section B

The total marks for Question B2 and B3 have been adjusted to 13 and 10 marks respectively.

B1 (a) (i) $C_6H_5NH_3^+ + H_2O \rightleftharpoons C_6H_5NH_2 + H_3O^+$

Examiners' Comments

- This question was poorly done. Many students wrote the equation for the ionisation of the weak base phenylamine instead of its conjugate acid. **Read the question carefully.**
- Many students also wrongly used the irreversible arrow to represent hydrolysis.

(ii) $C_6H_5NH_3^+$ (aq) + H_2O (aq) $\rightleftharpoons$ $C_6H_5NH_2$ (aq) + H_3O^+ (aq)

$$K_a = \frac{[H_3O^+][C_6H_5NH_2]}{[CH_3NH_3{}^+]}$$

Since $C_6H_5NH_3^+$ is a weak acid with a small K_a,
$[C_6H_5NH_3^+]_{eqm} \approx [C_6H_5NH_3^+]_{initial} = 0.10$ mol dm^{-3}

$$\left[H_3O^+\right] = \sqrt{\frac{K_w}{K_b}\left[C_6H_5NH_3^+\right]} = \sqrt{\frac{1.0\times10^{-14}}{10^{-9.4}}\times0.10}$$
$$= 1.585\times10^{-3} \text{ mol dm}^{-3}$$

pH = –lg (1.585 x 10^{-3}) = 2.80

Examiners' Comments

- The conjugate acid would hydrolyse in water to form H^+ which makes the solution acidic, as illustrated by the equation in **(a)(i)**. Many students thought that the solution would be alkaline.
- Students should be able to manipulate the various equations involving K_a, pK_a, K_b, pK_b, K_w, pK_w, as well as pH and pOH.

(b) (1) is an amide while (2) is a secondary amine.

(1) has a larger pK_b value than (2).

In (1), the lone pair of electrons on the N (1) atom interacts with the π-electron cloud of the adjacent C=O group and is delocalised and hence not as available for co-ordination to a proton as compared to N(2).

Examiners' Comments

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- Many students either missed the first part of the question about naming functional groups or did not clearly specify the functional groups for (1) as amide and (2) as amine.
- Students should also use proper terminologies such as lone pair of electrons on N atom delocalise into the C=O group. This is a more important reason as to why the amide is effectively neutral (i.e larger pK_b, smaller K_b value), rather than the lone pair of electrons on N delocalising into the π electron cloud of the benzene ring.

(c) (i) As N is less electronegative than O, the lone pair of electrons on N is more available than the lone pair of electrons on O and therefore –NH_2 is a stronger nucleophile than –OH.

Examiners' Comments

- This question was poorly done. Many students recognised that the –NH_2 is a stronger nucleophile than –OH group based on the information given in the question but did not explain why this is so by comparing the electronegativity between N and O.
- Students need to understand that the lone pair of electrons on N or O would be donated to the electron deficient C=O of the acyl chloride in the reaction. Hence, they should focus on the availability of these lone pairs in their answer.

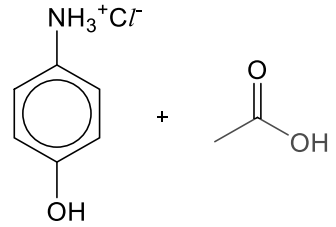
(ii) NaOH(aq) or Na(s)*

HC*l*(aq) or H_2SO_4(aq)**

Examiners' Comments

- *The yield of **C** could be increased by converting the –OH group of the phenol into a phenoxide ion which is a stronger nucleophile. Hence, Na(s) and NaOH(aq) could be used to form the phenoxide ion.
- **Alternatively, dilute acid could be used to protonate the basic phenylamine so that the lone pair of electrons on N is no longer available to act as a nucleophile in the reaction with the acyl chloride, decreasing the formation of **B** which in turns increases the formation of **C**.

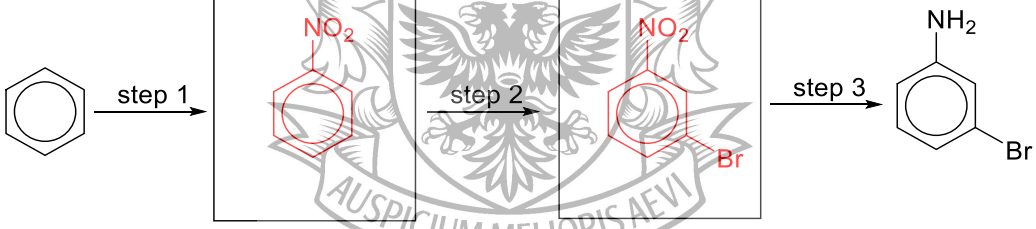
(iii)



Examiners' Comments

- Students need to recognise that the C–O bond in the ester linkage would broken during acidic hydrolysis. Also, since the medium is acidic, the basic phenylamine would react in an acid-base reaction with HC*l*(aq) to give the protonated ammonium salt.
- However, many did not include the counter-anion chloride in the ammonium salt product. Students should remember to include any counterion if the acid/base is specified in the question.
- Many students were able to draw the structure of ethanoic acid as one of the products.

(d)



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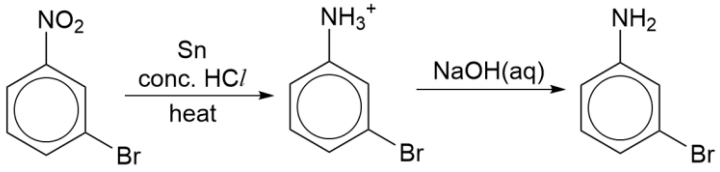
step 1 : conc. HNO_3, conc. H_2SO_4, heat
step 2 : Br_2, $FeBr_3$, heat
step 3 : Sn, conc. HC*l*, heat, followed by NaOH(aq)

Examiners' Comments

- Students are expected to give the reagent and condition for each step accurately.
- Students are also reminded to take into account the directing group of the substituents and hence the sequence of synthesis is not interchangable.
- For step 3, the addition of NaOH(aq) after reduction under acidic condition is required to deprotonate the product, which is protonated due to the highly acidic medium.

  Step 3:



product is protonated due to presence of excess acid

(e) (i) From experiment 1 to 2, R_1 becomes more electron withdrawing due to the presence of C*l*, hence, the C atom in the C=O group is more electron deficient and it attracts nucleophiles more strongly, resulting in a faster rate of reaction.

Examiners' Comments

- Students are reminded to use proper scientific terms and be specific in their answers. A phrase such as "chlorine atom causes the carbon atom to be more electron deficient" was not awarded any mark due to ambiguity.
- The process of hydrolysis involves a nucleophile attacking the electron deficient carbon atom in the C=O group of the amide and the breaking of C–N bond.
- Since R_1 is covalently bonded to C atom of the C=O group, a change in the electron withdrawing nature of R_1 will directly affect the magnitude of partial positive charge on the carbon of the C=O group.
- While the increase in the electron withdrawing nature of R_1 can also cause the weakening of C–N bond due to inductive effect, this effect is less pronounced as compared to the effect on the C atom of the C=O group which R_1 is directly attached to.

(ii) The relative rate for experiment 3 is larger than experiment 1 because the highly electron withdrawing R_2 will decrease the extent of partial double bond character of the C–N bond, weakening the C–N bond of the amide, making it easier to break.

Examiners' Comments

- This question was poorly attempted. Similar to e(i), many students did not use proper scientific terms in their answers.
- Since R_2 is covalently bonded to N atom of the amide group, the benzene ring and electron withdrawing C*l* atoms in R_2 causes the lone pair on N atom (which was originally delocalised only into the C=O of amide group) to now also delocalise into R_2. This decreases the extent of partial double bond character of the C–N bond, weakening the C–N bond of the amide.
- Discussions on steric hinderance of R_2 is not relevant in this context as the site where reaction occurs is trigonal planar and is not blocked by R_2.

(iii) The twisted amide has the longest C–N bond length and hence it is the easiest to break.

Examiners' Comments

- As stated by the question, students should refer to the C–N bond lengths given in the table and do a comparison among all the data given.
- Many students were able to relate the bond length to the bond strength and ease of breaking the bond.

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(iv) The C–N bond length of the twisted amide is similar to that of the C–N bond length of the amine. This indicates the loss of partial double bond character of the C–N bond in the amide group of Kirby's twisted amide.

This is because in the twisted amide, the orbital of nitrogen atom is no longer able to overlap with the pi-electron cloud of the adjacent C=O group.

Examiners' Comments

- This question was poorly done.
- Many students attributed the longer C–N bond in the twisted amide to ring strain. It is inappropriate to make use of ring strain to explain this observation. Ring strain is caused by abnormal bond angles which deviate significantly from the stable ideal bond angles.
- To solve this problem, students should observe from the data provided that the C–N bond length of the twisted amide is more similar to that of the C–N bond length of the first amine (methylamine) and not similar to the amides (the second and third molecules). This gives the hint that the C–N bond in Kirby's amide is more like a single C–N, without partial double bond character.
- Students can also deduce that the N atom in the twisted amide has 4 electron densities with tetrahedral arrangement and not trigonal planar.

- These deductions lead to conclusions that there is no partial double bond character in the twisted amide as opposed to usual amide due to the misalignment of the orbital of N atom containing the lone pair with the pi-electron cloud of C=O group.

B2 **(a)** **(i)** $\Delta H^{\ominus} = 2(-350.5) + 2(-296.8) - 2(-206) = -882.6 \approx -883$ kJ mol^{-1}

Examiners' Comments
- Generally well done.
- Students should use the equation $\Delta H_r^{\circ} = \Sigma n \Delta H_f^{\circ}$ **(products)** $- \Sigma m \Delta H_f^{\circ}$ **(reactants)**, rather than draw out the energy cycle as it is not required in this question.
- Note that $\Delta H^{\ominus}_f$, the **standard enthalpy change of formation** of an **element** in its standard state under standard conditions (i.e. 298 K and 1 bar) is **zero** i.e. $\Delta H^{\ominus}_f[O_2(g)] = 0$. Some students mistakenly used the bond energy of O=O in their calculations.

(ii) $\Delta S^{\ominus} = -147$ J K^{-1}mol^{-1}

$\Delta S^{\ominus}$ is negative as the reaction results in a decrease in the number of moles of gas particles, which reduces entropy.

Examiners' Comments
- To "comment" requires students to make a judgement from the context of the question. The context being the equation of the reaction in step 1, in this case.
- From the equation, students should observe the decrease in number of moles of gas particles to be the cause of the decrease in entropy.
- Some students simply mentioned that a negative entropy change indicts a decrease in entropy, which is insufficient.

(iii) $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus} = -882.6 - (1850)(-147/1000) = -611$ kJ mol^{-1} $= -611000$ J mol^{-1}

Examiners' Comments
- Many students did not leave theirs answer in J mol^{-1}, as required by the question.
- In solving questions involving $\Delta G^{\ominus}$, $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$, students need to make sure that the units of the quantities they use are consistent i.e. convert from kJ mol^{-1} to J mol^{-1} (or vice versa) when necessary.

(iv) Step 1: $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$

Oxidation state of S increased from -2 to $+4$.
Hence, the number of moles of electrons transferred in the equation, n = 6x2 = 12 since 2 mol of S were involved in the reaction.

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$$\Delta G^{\ominus} = -nFE^{\ominus}$$

$$E^{\theta} = -\frac{\Delta G^{\theta}}{n F} = -\frac{(-611000)}{12x96500}$$

$$= +0.528 \text{ V}$$

Examiners' Comments
- Many students have difficulty finding the value of n. Do take into account the coffiecients on **2**ZnS and **2**SO_2.
- In order to apply the formula $\Delta G^{\ominus} = -nFE^{\ominus}$, $\Delta G^{\ominus}$ must be converted to J mol^{-1}. Likewise, if the values of n, F (i.e. 96500) and $E^{\ominus}$ (in V) are computed to obtain $\Delta G^{\ominus}$, $\Delta G^{\ominus}$ will be in J mol^{-1}.

(b) **(i)** In part(a), additional steps must be taken to remove SO_2 before releasing the waste gases in part(a) as it is a pollutant.

In part (b), the SO_2 is reused by using it to produce sulfuric acid which then reacts with zinc to form zinc sulfate solution for electrolysis.

The dangerously high temperatures required in a blast funace is not required in electrolysis.

The reactions in a blast furnace produces CO_2, which is a greenhouse gas, contributing to global warming. No greenhouse gas is produced in electrolysis.

Examiners' Comments

- Students should try to find information from the question stem whenever possible. In this case we are unable to deduce which one uses more energy/cost more as electrolysis also requires electrical energy and incur costs.

(ii) $Zn^{2+} + 2e^- \rightleftharpoons Zn \quad E^\ominus = -0.76$ V

$Fe^{2+} + 2e^- \rightleftharpoons Fe \quad E^\ominus = -0.44$ V

For reaction of Zn with Fe^{2+}, $E^\ominus$ cell = $-0.44 + 0.76$ V = +0.32V

Examiners' Comments

- Some students chose incorrect half-equations for their calculations. Read the question carefully! Impurities like iron (II) ions are reduced back to their metallic form i.e. to Fe.
- Do note that Fe^{3+} is not present as reactant.
- Some students incorrectly interpreted this question as connecting two half-cells to form a battery.

(c) **(i)** **Anode (oxidation):**

$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l) \quad E^\ominus = +1.23$ V

Reaction at anode: $\mathbf{2H_2O \rightarrow O_2 + 4H^+ + 4e^-}$

Cathode (reduction):

$Zn^{2+} + 2e^- \rightleftharpoons Zn \quad E^\ominus = -0.76$ V

$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq) \quad E^\ominus = -0.83$ V

Reaction at cathode: $\mathbf{Zn^{2+} + 2e^- \rightarrow Zn}$

Examiners' Comments

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- At the cathode, reduction process takes place; at the anode, oxidation process takes place. The arrow using the equations should show the direction in which the reaction is proceeding in. For reactions at the cathode and anode, the single arrow $\rightarrow$ should be used, not $\rightleftharpoons$.
- The solution is neutral. Hence, water is oxidised at the anode, not OH^-.
- Some students did not notice that inert electrodes were used at the anode. No oxidation of Zn to Zn^{2+} is possible.
- Students need to compare competing cathode reactions using $E^\ominus$ to determine which species is more likely to be reduced.

(ii) The H^+ produced at anode can migrate to the cathode where it is preferentially discharged (to form H_2 gas) instead of Zn^{2+}, causing the yield of zinc to fall.

The H^+ produced at anode can migrate to the cathode where it reacts with the Zn metal on the electrode, removing the Zn formed.

Examiners' Comments

- Students need to recognise that H^+ is produced at anode, which is why the pH needs to adjusted by adding alkali.
- Many students have the misconception that H^+ formed at the anode would cause "the position of equilibrium of the reaction at the anode to shift to the left". This is incorrect because this is an electrolytic setup where the battery drives the anodic and cathodic reactions.
- The external battery draws electrons from the anode obtained from the oxidation of water and pushes the electrons through the circuit to the cathode for reduction to take place. The H^+ formed at the anode does not affect any position of equilibrium because there is no equilibrium present. The external battery dictates the flow of electrons.
- The setup is not that of a electrochemical cell (a.k.a. battery) where concentrations of species in each half-cell affect the reduction potential of each half cell, affecting the natural tendency of the flow of electrons through the circuit from higher potential to lower potential.
- Some students discussed how SO_4^{2-} can be reduced at the cathode. Take note that, in an electrolytic cell, the cathode is negatively charged and will repel anions such as SO_4^{2-}.

(iii) Amount of Zn deposited = 2.00 ÷ 65.4
= 0.03058 mol

$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$

$n_e = 2(0.03058) = 0.06116$ mol

Since $Q = It = n_eF$

$$I = \frac{n_eF}{t} = \frac{(0.06116)(96500)}{30x60}$$
$$= 3.28A$$

Examiners' Comments

- For the equation $Q = It = n_eF$, n_e refers to the number of moles of electrons required for the reaction, not the coefficient of electrons in the half-equation.
- Students need to make use of the half-equation for the reduction of Zn^{2+} to determine the mole ratio between Zn and electrons. The number of moles of electrons required for the reaction is twice the number of moles of Zn. Many students omitted this step, leading to an incorrect answer of 1.64 A.

B3 (a) The thermal stability of the hydrogen halides decreases down Group 17.

Down Group 17, there is less effective orbital overlap between the 1s orbital of H and the valence p orbital of the halogen (as the size of the halogens gets bigger and the valence orbital used for bonding is more diffuse).

Hence, the H–X bond strength decreases down group, and HI is thermally less stable than HCl.

Examiners' Comments

- This question was generally well done. Students should look at the number of marks as an indication of thow much they should write.
- Some students mistakenly thought that the HX in the question were ionic compounds. Generally only in HX(aq) would we find H^+ and X^-.
- It is effective *orbital* overlap, not "bond" or "electron cloud". Also, the overlap is between the valence orbitals, not any or all orbitals.
- Some students confused the context being asked here i.e. covalent bond strength with inter-molecular forces of attraction (id-id, pd-pd etc), which are relevant for discussing properties such as boiling point, volatility.

B3 (b) Preparation of **FA3**

- Using a metal spoon, crush two Vitamin C tablets (on a piece of filter paper) into as fine a powder as possible.
- Using the spoon, scrape and transfer the crushed powder into a 100 cm^3 beaker containing 60 cm^3 of deionised water.
- Stir the mixture continuously for about 2-3 min (or use a magnetic stirrer).
- Using a filter funnel, filter the suspension into another 100 cm^3 beaker. Label this beaker as **FA3**.

Determination of order or reaction wrt H_2O_2

1. Using a 10 cm^3 measuring cylinder, measure out 10 cm^3 of H_2O_2 (**FA1**) into a 100 cm^3 beaker. Label this beaker as **A**.
2. Using a 3.0 cm^3 syringe, measure out 2.5 cm^3 of starch solution and add it to the H_2O_2 in **A**.
3. Using a 50 cm^3 measuring cylinder, measure out 50 cm^3 of KI (**FA2**) into another 100 cm^3 beaker. Label this beaker as **B**.
4. Using a 3.0 cm^3 syringe, measure 2.5 cm^3 of **FA3** and add it to the KI in **B**.
5. Transfer the contents of **B** to **A**. At the moment when all of **B** is added, start the stopwatch.
6. Swirl the mixture once and place it on a white tile. Record the time taken for the dark blue colour to appear to the nearest second.
7. Repeat steps 1 to 6 with the following volumes of solutions, using a 10 cm^3 measuring cylinder to measure the deionised water needed.

Expt	Beaker **A**			Beaker **B**		Total volume / cm^3	t / s	$\frac{1}{t}$ / s^{-1}
	Vol. of H_2O_2 / cm^3	Vol. of H_2O / cm^3	Vol. of starch / cm^3	Vol. of KI / cm^3	Vol. of **FA3** / cm^3			
1	10	0	2.5	50	2.5	65		
2	8	2	2.5	50	2.5	65		
3	6	4	2.5	50	2.5	65		
4	4	6	2.5	50	2.5	65		
5	2	8	2.5	50	2.5	65		

Proposed graph to be plotted

Plot a graph of $\frac{1}{t}$ against volume of H_2O_2 used.

If a straight line passing through the origin is obtained, the reaction is first order wrt H_2O_2.

Examiners' Comments

- Most students were able to produce a powdered form of the tablets (e.g. using mortar and pestle or the metal spoon provided), or employed heating, to speed up the dissolving process. The maximum volume of solvent (i.e. 60 cm^3) should be used to extract the maximum amount of Vitamin C from the tablets *before* filtration takes place. Addition of water directly to the filtrate *after* filtration (e.g. add water to top up to 60 cm^3) would have diluted FA3 to a concentration much lower than that specified in the question. Heating should also not be at boiling temperatures, as the (prolonged) high heat may cause some degradation to the organic Vitamin C molecules. Filtration was done to remove the insoluble components and produce a *clear* solution.
- All capacities for the apparatus used should be clearly stated, i.e. for measuring out solutions (e.g. measuring cylinders) or for containing them (e.g. beaker / conical flasks). The capacities should be based on your knowledge and experience from practical work, and not any random capacities you think are available. We will usually choose a (standard) capacity that is either equal or larger than the volume that needs to be measured so that we do not need to measure more than once, e.g. use a 50 cm^3 measuring cylinder to measure 50 cm^3, and not a 10 cm^3 measuring cylinder. To prevent contamination and reaction, we should use separate apparatus to measure out different reagents.
- FA1 and FA2 should be prepared in separate containers since reaction begins once H_2O_2 and KI are in contact with each other, and the stopwatch needs to be started at this moment of contact. Some students mixed all four solutions (from separate containers including

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syringes) and started the stopwatch *simultaneously*, which is physically challenging (i.e. to pour + squeeze syringes + start stopwatch all at the same instant) to achieve successfully without, e.g. spillage or time delay, and is hence inappropriate as a procedural step. We should also not add the starch as a step *after* FA1 and FA2 have already been mixed, and then start the stopwatch after adding the said starch). [In this answer, before mixing, Vitamin C was not placed in the same container as H_2O_2 in case some degree of oxidation of Vitamin C takes place, but this was not a marking point here.]

- The decision to stop the stopwatch is based on the instant the dark blue colour appears, and *not* to "obsure" a cross placed at the bottom of the reaction vessel, nor to wait until the entire solution turns dark blue. Students should follow the details given in the question carefully, and not assume based on their memory of past work done (e.g. dark blue, not blue-black; 2.5 cm^3 of starch, not a few drops of starch).
- From the information in the question (see "first set of the series of experiments"), the total volume of the solution is already fixed at 65 cm^3 – students should not add water to this and subsequent experiments, and create their own new total volume, but refer to the given quantities in the question in this case.
- The experiment is to determine the order wrt H_2O_2, and hence only the concentration of this reagent should be varied – some students erroneously varied the [KI] instead, or [KI] simultaneously with [H_2O_2].
- Presentation-wise, a table showing the volumes used (especially H_2O_2 and water here) would be clearer and usually more efficient when describing the specific volumes to be used in the planned experiments. Just saying to "vary" the volume of FA1 is insufficient, as "vary" can mean to increase or decrease the volume.
- Some students impractically included a volume of H_2O_2 to be used as "0 cm^3", which means no reaction actually takes place when the solutions are mixed, and so the stopwatch will be stopped at time = infinity.
- For a planned experiment, when one wants to determine a *relationship* between variables, it is not scientifically sound to make a conclusion based on just two (or three) data points. Since there are no real or given contraints to the number of experiments that can be practically carried out, a *trend* should be established, rather than what many students did – to just compare two specific data points and thereafter decide that the relationship is (in)valid. Experimental error alone could have led to a correct or incorrect conclusion when only just two points are used. [Of course, in a given (non-planning) question in the exams, e.g. MCQ with a given set of data of rates and [reactant], we can go ahead and compare two experiments and determine the order mathematically or by inspection, but that is because you have no access to further data or info than what is given in the question.] Note: a rough guide: to collect (at least) 5 data points for a straight line and (at least) 7 data points for a curve.
- The "time" here is the time taken for the solution to change from faint-yellow to dark blue (i.e. time taken for the dark blue to first appear), and which is to be used in the determination of the *initial rate* of the reaction. This "time" is different from the "time" in a *continuous* experiment whereby one may start an experiment, and let the [reactant] decrease and the reaction proceed indefinitely or until the end of the experiment, e.g. refer to a [A] vs time graph. Some students mistakenly thought that the half-life concept could be applied in this question.
- The question only required you to confirm that the order was one, hence in this case, it is not really necessary for the answers to include a discussion of the cases for the orders 0 or 2. If you were instead asked to determine the order, then yes, a discussion of the 0, 1, 2 cases most would likely be required.
- Note that when discussing the first order case, the phrase "straight line passing through the origin" is sufficient and both ideas are needed. Errors:
  - Just the words "straight line" alone could mean a horizontal line.
  - Just the words "positive gradient" alone could mean the line has a non-zero y-intercept.
  - Just the words "constant gradient" alone could mean the two cases above, or a line with a negative gradient.
  - No need to say "linear straight line" as a straight line is definitely linear.

  A simple sketch with the correct axes and the correct graph would make it very clear what you actually mean.

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Section C

C1a) Atomic radii of Mg and Ca are 0.160 nm and 0.197 nm respectively. The valence electrons in Ca are further away from the nucleus and hence less attracted to the nucleus, thus Ca is more reactive than Mg. OR

Sum of 1st and 2nd ionisation energies of Mg and Ca are + 2186 kJ mol^{-1} and +1740 kJ mol^{-1} respectively. Less energy is required for Ca to form Ca^{2+} than Mg to form Mg^{2+}, thus Ca is more reactive than Mg.

Examiners' Comments

- Many students did not quote relevant data from the *Data Booklet* to support their explanations.
- The use of the ionic radii of Ca^{2+} and Mg^{2+} is not useful in the discussion about the loss of 2 valence electrons from Ca and Mg.
- Ca and Mg are Group 2 elements with 2 valence electrons, hence both 1st and 2nd ionisation energies are required in the discussion involving ionisation energies.
- $E^{\ominus}$ values should not be used because the ions in the equations accompanying the $E^{\ominus}$ values refer to aqueous ions (see bottom of page 48 of *Data Booklet*), which is not the case in this question

C1b)(i) $K_{sp} = [Mg^{2+}][OH^-]^2$

units: $mol^3\ dm^{-9}$

Examiners' Comments

- Generally well done, although a number of students forgot to give units or gave wrong expressions such as $[Mg][OH]^2$ or $[Mg^{2+}][2OH^-]^2$.

C1b)(ii) Let the solubility of $Mg(OH)_2$ in water be s mol dm^{-3}.

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$$

At equilibrium in the saturated solution, $[Mg^{2+}] = s$ mol dm^{-3}

$[OH^-] = 2s$ mol dm^{-3}

K_{sp} of $Mg(OH)_2 = [Mg^{2+}][OH^-]^2 = (s)(2s)^2 = 1.8 \times 10^{-11}$

$4s^3 = 1.8 \times 10^{-11}$

$s = 1.65 \times 10^{-4}$ mol dm^{-3}

Examiners' Comments

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- Generally well done, although a number of students forgot to consider that $[OH^-]$ is twice of $[Mg^{2+}]$.

C1b)(iii) $CaH_2(s) + 2H_2O(l) \rightarrow Ca(OH)_2(s) + 2H_2(g)$

$Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$

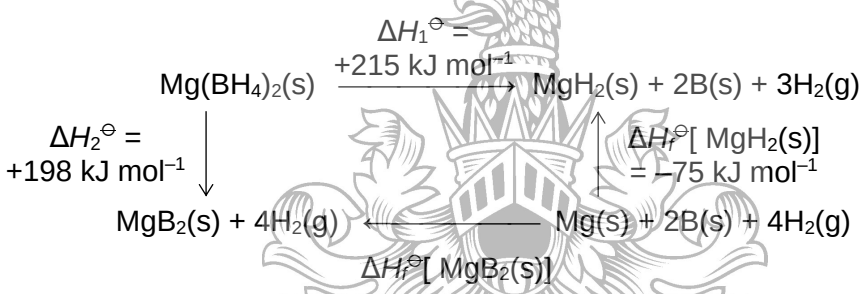
$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$ ----- (1)

When CaH_2 is added, $Ca(OH)_2$ is formed which increases the $[OH^-]$ momentarily. The OH^- ions from $Ca(OH)_2$ exerts a common ion effect and causes the equilibrium position of (1) to shift left in accordance to Le Chatelier's principle, reducing the solubility of $Mg(OH)_2$ in water. OR Since the $[OH^-]$ in the solution increases momentarily, the ionic product of $Mg(OH)_2$ will exceed the K_{sp} of $Mg(OH)_2$ and hence less $Mg(OH)_2$ dissolves and the solubility of $Mg(OH)_2$ decreases.

Examiners' Comments

- Many students overlooked the statement that CaH_2 reacts with water to form a metal hydroxide and hydrogen, instead giving errorenous equations that involved the formation of H^+ or H^-; these equations will not be charge balanced.
- The formation of $Ca(OH)_2$ is due to the reaction of CaH_2 with water and not from the reaction between Ca^{2+} and OH^- thus $[OH^-]$ increases instead of decreases.
- Some students had the misconception that since water is consumed in the reaction, volume of water decreases thus $Mg(OH)_2$ precipitates out hence solubility of $Mg(OH)_2$ decreases. While the slight decrease in volume of water and precipitation of a small of $Mg(OH)_2$ takes place, this does not mean that solubility of $Mg(OH)_2$ decreases as solubility is expressed as amount of solute / volume of water, if volume of water decreases, amount of solute also decreases to make solubility the same at the same temperature. This can be better understood by considering a saturated solution of $Mg(OH)_2$ left uncovered, water will evaporate and some $Mg(OH)_2$ will precipitate out over time but solubility of $Mg(OH)_2$ remains unchanged.
- Concentration of water is constant since it is a solvent in this reaction.
- Reversible arrows should be used in the dissolution equilibrium equations and state symbols should be shown.
- A number of students did not include the effect on the solubility of $Mg(OH)_2$ in their answers.

C1c)



By Hess' Law,

$\Delta H_f^{\ominus}[\ MgB_2(s)] = \Delta H_f^{\ominus}[\ MgH_2(s)] - \Delta H_1^{\ominus} + \Delta H_2^{\ominus}$

$= -75 - (+215) + 198$

$= -92\ kJ\ mol^{-1}$

Examiners' Comments

- Students are reminded to include state symbols and label their energy cycles. Enthalpy changes for each step should be shown clearly and not combined together.
- The standard states of hydrogen and magnesium are $H_2(g)$ and Mg(s) respectively so H(g) and $Mg^{2+}(g)$ should not be involved in $\Delta H_f^{\ominus}$ of the compounds.
- Students should not subtract substances in their energy cycles and should instead place the substances in their appropriate positions after the arrowhead.
- Students need to understand that each equation should be mass balanced (ie same number of each elements before and after the arrow). Many students did not consider this and conveniently placed "$+H_2(g)$" and "$+3H_2(g)$" on the equation arrows. These substances on the equation arrows actually belong the reactant side of the equations (before the start of the arrow).

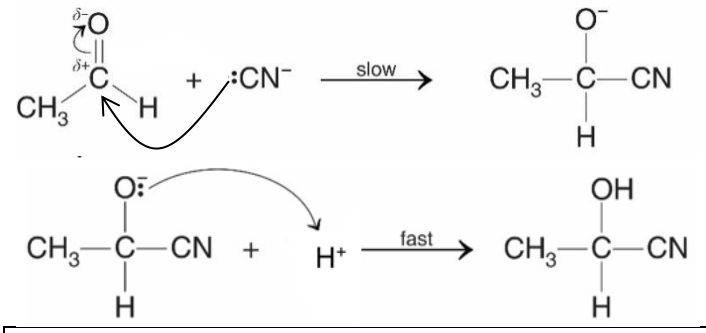
C1d) $Ca(BH_4)_2$ will decompose at a higher temperature. Ca^{2+} ion has a larger ionic radius as compared to Mg^{2+} ion resulting in a lower charge density and weaker polarising power. Hence, Ca^{2+} distorts the electron cloud of the BH_4^- ions to a smaller extent and thus weakens the covalent bonds within BH_4^- ions to a smaller extent as compared to Mg^{2+} ion. This results in more heat energy and a higher temperature required for decomposition of $Ca(BH_4)_2$.

Examiners' Comments

- Generally well done for students who have prepared for this explanation.
- Lattice energy should not be used to explain decomposition temperature as it is a measure of the attraction between ions and hence relevant in the explanation of melting points of ionic compounds. Decomposition involves the breaking of covalent bonds in the polyatomic anions.

C2(a)(i) Name of mechanism: Nucleophilic Addition

$KCN \rightarrow K^+ + CN^-$



Examiners' Comments

- Generally well done.
- Common mistakes include incorrect direction of arrow pushing, lone pair(s) involved not drawn, missing slow/fast step labels, missing δ+ / δ– labels.
- A lone pair of electrons from the C atom (not from the N atom) of the CN^- nucleophile isused to form a C–C bond with the carbonyl carbon.
- As the reaction was performed in an acidic medium, H^+ is the preferred source of protonation in the second step.

C2(a)(ii) HC*l*(aq) or H_2SO_4(aq), heat

Examiners' Comments

- Heating is necessary for the acidic hydrolysis of nitrile.
- 'H^+' is not acceptable when a reagent is required to be identified.

C2(a)(iii) Oxidation state of the nitrile carbon remains unchanged at +3 after it is converted to a carboxylic acid group.

Examiners' Comments

- Many students did not specify the particular atom which underwent transformation. Saying that "there is no change in oxidation state of *carbon*" is ambiguous as there are three carbon atoms in the molecule. On the other hand, saying that "there is no change in oxidation state in *all the atoms*" does not demonstrate understanding of which particular atom should be examined, and could be interpreted as merely rephrasing the information in the question.

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C2(a)(iv) The ketone at C3 of pentane-2,3,4-trione has the most electron deficient carbon atom due to the electron withdrawing effects of two adjacent ketone / C=O groups compared to one for C2/C4, thus making it most susceptible to nucleophilic attack by CN^-. OR

Anionic intermediate of D1 is more effectively stabilised by two electron withdrawing C=O groups which disperses the negative charge on the O atom to a larger extent, compared to one for the intermediate of D2. OR

The carbonyl carbon at C3 is least sterically hindered for nucleophilic attack as it is surrounded by planar carbonyl groups on both sides, compared to the other carbonyl carbons at C2 and C4 which are next to a tetrahedral methyl group.

Examiners' Comments

- In a comparison type of question, students need to point out the differences in the extent of electronic stabilisation / steric effect **between** the compounds, instead of describing the structure of one compound.
- There is no resonance stabilisation of the anionic intermediate as the oxygen bearing the negative charge is bonded to a sp^3 C and is not adjacent to any π system.

C2(b)(i) Grignard reagents, being extremely basic, hydrolyses/are destroyed in aqueous acid as they react with H^+/H_2O to form alkanes.

Examiners' Comments

- Students can apply acid-base principles to deduce that the CH_3^- species is extremely basic, being the conjugate base of an alkane, which is extremely low in acidity. This causes the Grignard reagent to be protonated by H^+/H_2O, rendering it ineffective towards the step-up reaction.

C2(b)(ii) Grignard reagents can allow for a large increase in the number of carbon atoms in synthesis, compared to HCN which only allow an increase by one carbon atom.

C-Mg bond is more polar than the H-CN bond, so C in C-Mg is more nucleophilic / CH_3^- is a stronger nucleophile than CN^- , thus the reaction will be faster.

Examiners' Comments

- It is insufficient to point out the greater reactivity of the Grignard reagent, without suggesting an advantage due to that i.e. faster reaction
- Answers which suggested that it is advantageous to add an alkyl group without the nitrogen atom, were not accepted because it may be an advantage instead to have other atoms like N, as it allows for easy conversion to the required functional group in the product.

C2(b)(iii) Electronegative nitrogen atom creates a partial positive charge on the nitrile carbon atom, making it susceptible towards attack by nucleophiles. OR

The C in CN is electrophilic due to the electron withdrawing N atom, creating a partial positive charge on the nitrile carbon atom, making it susceptible towards attack by nucleophiles.

Examiners' Comments

- Generally done well, but some students were not clear in explaining why the nitrile carbon is electron deficient.
- There was a common misconception that the "CN group is electron rich, hence it reacts with nucleophiles". This is incorrect as nucleophiles are electron rich too and they would repel. The nucleophilic reaction occurs because of an electron deficient atom present in the nitrile group.
- "δ+" is a symbol to denote the presence of partial positive charge on an atom. Please write it clearly.

C2(b)(iv)

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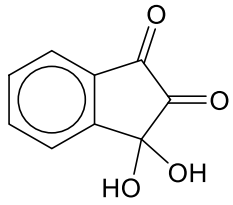
Examiners' Comments

- Students did well if they realised they could apply the example of the reaction between Grignard reagents and nitriles here.
- For step 2, the covalent bond from benzene to Mg must be clearly shown.

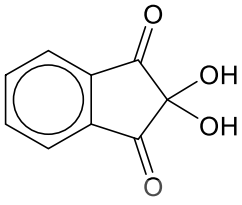
C2(c)(i) Deductions :

Evidence / Information	Deduction and explanation
E has a high C : H ratio	Benzene ring likely to be present
E reacts with 2,4-DNPH	Condensation reaction. **E** contains carbonyl functional group.
1 mol **E** gives 1 mol H_2 with Na	Redox reaction. Two –OH groups present in **E**.
E does not react with sodium hydroxide	No acid-base reaction. N does not contain phenol or carboxylic acid.
E $\xrightarrow{\text{hot acidified } KMnO_4}$ **F** ($C_8H_6O_4$)	Oxidation of benzene side chains. 2 –COOH groups in **F** suggest 2 side chains in **E**.

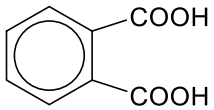
Structures:



E-1



E-2



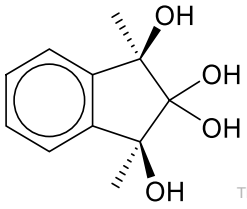
F

Examiners' Comments

- Students found difficulty in proposing the possible structures of **E**, which prevented them from answering part (ii). The correct structure of **E** relies on the need to deduce all the functional groups present, while checking for the correct number of atoms.
- The name of reaction should be included under deductions. The reaction involving **E** and Na is not "acid-base" as it involves an oxidation state change. The reaction involving **E** and 2,4-DNPH is not "oxidation" as there is no change in oxidation state in the reaction.
- Possible functional groups present/absent were not always detailed, especially for the reaction of **E** with NaOH.
- When given the mole ratio of two substances in a reaction, one should be able to deduce the **number** of reactive functional groups present.

C2(c)(ii) **E2** is the correct structure of **E**.

G:



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Presence of plane of symmetry makes this stereoisomer unable to exhibit enantiomerism.

Examiners' Comments

- This question was not well answered due to the incorrectly proposed structures of **E**.
- For some students who managed to identify the correct **G**, the stereochemistry about the chiral centres were not shown.

C3 EITHER

(a) (i) $Cr_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \longrightarrow 2NaCr(OH)_4(aq)$

Examiners' Comments

- Many students are not familiar with this concept from Periodic Table I. Thus, many do not realise that Cr_2O_3, like Al_2O_3, is amphoteric. Cr_2O_3 reacts with NaOH to form a solution of $NaCr(OH)_4$.

(ii) $CrCl_3(aq)$ exists as $[Cr(H_2O)_6]^{3+}(aq)$ and $Cl^-(aq)$.

$[Cr(H_2O)_6]^{3+}$ hydrolyses in water to give an acidic solution. This takes place because Cr(III) has a high charge density, so it distorts the electron cloud of H_2O and weakens the O-H bond which undergoes heterolytic fission to liberate H^+.

$$[Cr(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Cr(H_2O)_5(OH)]^{2+} + H_3O^+$$

Examiners' Comments

- Many students are also not familiar with this concept from Periodic Table I.
- It is an important exam technique to be able to properly describe the hydrolysis of $[M(H_2O)_6]^{3+}$by using the correct terminologies.

(b) (i)

H **J** **K**

Examiners' Comments

- **K** was correctly identified by most students.
- **J** is 3-methylbutanone.

mixture of 2 products with no stereoisomers

- Many overlooked the fact that **J** reduces to give a chiral compound which gets dehydrated to form a mixture of two alkenes with no stereoisomers.

Two common incorrect structures of **J** are shown here.

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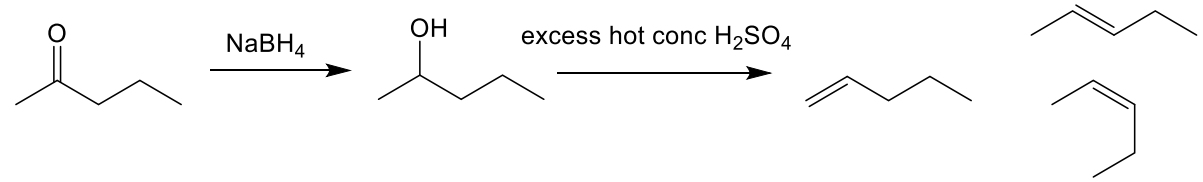
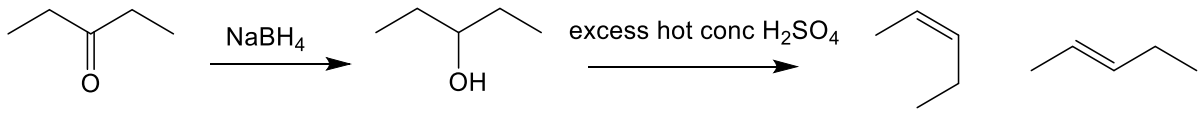
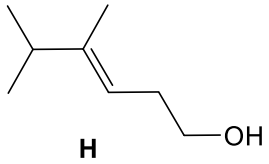


mixture of 2 products with stereoisomers



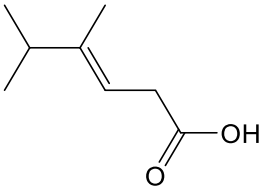
1 product with stereoisomers

- Working backwards from the structures of **J** and **K**, **H** is identified.



H

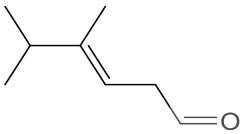
(ii)



Examiners' Comments

- Many students recognised that hot acidified $K_2Cr_2O_7$ does not oxidise C=C bonds but oxidise the primary alcohol to a carboxylic acid.

(iii)



Examiners' Comments

- Many students also recognised that **M** is an aldehyde as it gives a positive test with Tollen's Reagent, $[Ag(NH_3)_2]NO_3$.

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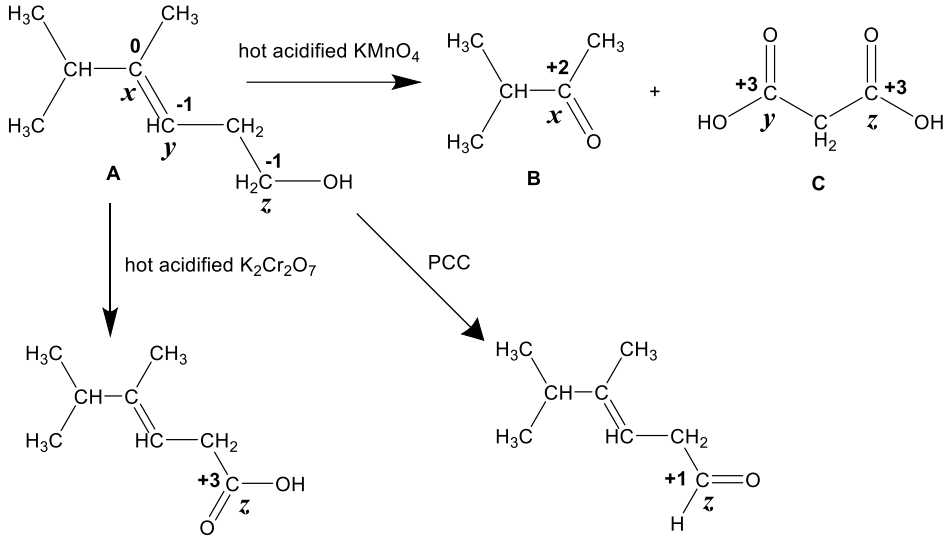
(iv)



With hot acidified $KMnO_4$, the C=C bond is broken and the changes in oxidation states of the carbon atoms are:

Oxidation state of C	Before oxidation	After oxidation
x	0	+2
y	-1	+3
z	-1	+3

With hot acidified $K_2Cr_2O_7$, the C=C bond is not broken and the change in oxidation state of C_z increases from -1 to +3. Hence, the oxidising strength of hot acidified $K_2Cr_2O_7$ is less than that of hot acidified $KMnO_4$.

With PCC, the C=C bond is not broken and the change in oxidation state of C_z increases from -1 to +1. Hence, the oxidising strength of PCC is less than that of hot acidified $K_2Cr_2O_7$.

Oxidising strengths: PCC < hot acidifed $K_2Cr_2O_7$ < hot acidified $KMnO_4$.

Examiners' Comments

- This question is an example of a "free response" question. Students are encouraged to present their answers creatively, yet systematically. However, many are unsure how to present their thought processes clearly.
- This part was poorly done. A handful of students omitted the initial oxidation states and only stated the final oxidation states when the question clearly stated to refer to changes in oxidation states.
- Many students also fail to realise that the two carbons of the alkene (C_x and C_y) do not share the same oxidation states. i.e. 0 and -1 respectively.

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C3 OR

(a) (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^5$

Examiners' Comments

- Many students did not realise that being a Group 17 element, iodine would have a valence electronic configuration of ns^2np^5.
- In addition, iodine is an element in Period 5, hence it has a valence electronic configuration of $5s^25p^5$.
- Students who realise all these will avoid the error of filling the 4f orbital after $4d^{10}$.
- Students are also reminded to write the electronic configuration with its proper notation – number of electrons are in superscript ($1s_2$ is incorrect), no punctuation between each subshell ($1s^2$, $2s^2$ is incorrect).

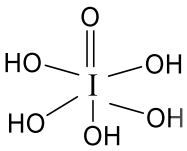
(ii) The first ionisation energies decrease from F to I.

Down the group from F to I, the number of electronic shells increases, (or the distance between the nucleus and the valence electrons increases). The electrostatic attraction between the nucleus and the valence electrons decreases, resulting in a decrease in the energy required to remove a valence electron.

Examiners' Comments

- This part is generally well done.
- A handful of students referred to an increase in the number of orbitals instead of electronic shells. The increase in orbitals could still suggest being in the same electronic shell. e.g. an increase from 2s to 2p orbitals but all in the n=2 electronic shell, which is not a relevant discussion in this case (trend down a group). Increase in number of electronic shells would, however, certainly suggest the valence electrons being further away from the nucleus.

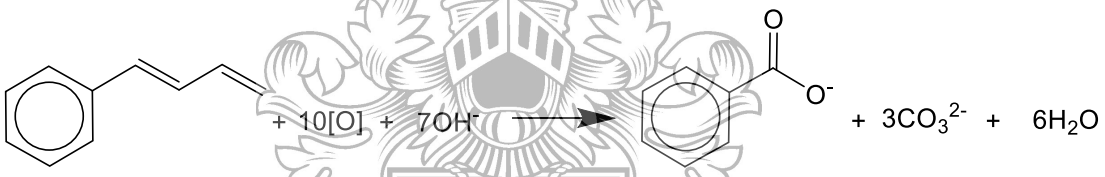
(iii)



Examiners' Comments

- Some students drew the dot-and-cross diagram instead of the structure, as required by the question.

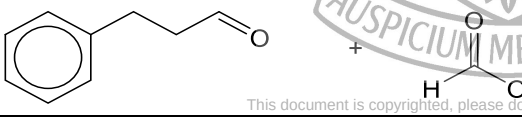
(b)



Examiners' Comments

- This is not done well. Students did not pay attention to the fact that the oxidation was carried out in an alkaline medium. This means that benzoate and carbonate are formed instead of benzoic acid and carbon dioxide.
- Students are reminded to make sure that the equation written is balanced. Hence, there is a need to add OH^- to balance the equation.

(c)



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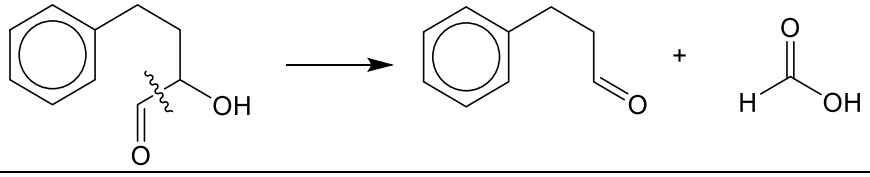
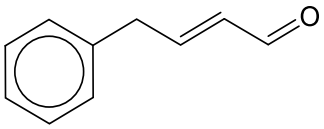
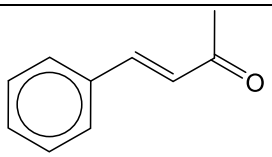
Examiners' Comments

- This part requires pattern recognition skill.



(d) To each compound, separately add a few drops of Tollens' reagent. Heat the mixtures separately in a water bath.

 **P**	 **Q**
Silver mirror	No silver mirror

Other accepted answers:
Fehling's solution, heat;
I_2 and NaOH heat;
$K_2Cr_2O_7$ and dilute H_2SO_4, heat.

Examiners' Comments

- Many students managed to choose the correct reagents and conditions. However, students need to ensure that they learn to describe a chemical test clearly.
- Many students who used Tollens'/ Fehling's forgot to include heat.

(e) Examples of possible structures of **R**. Note that there are many others.

Examiners' Comments

- Since **R** is an isomer of **P**, it should have the molecular formula of $C_{10}H_{10}O$.
- Since **R** is optically active, **R** must have a chiral carbon.
- **R** reacts with PCl_5, hence **R** cannot be a phenol. Hence, **R** must contain an aliphatic alcohol.
- **R** decolourises $Br_2(aq)$, so **R** contains a C=C bond.
- **R** has to be a cyclic alcohol in order to obtain the correct molecular formula.

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