2023 Year 6 H2 Chemistry Common Test Suggested Solutions

Section A

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

Question 1 (A)

Angle of deflection $\alpha \frac{\text{charge}}{\text{mass}}$

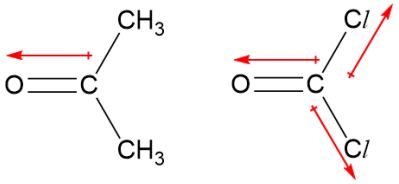
Since the electron has the smallest mass ($\frac{1}{1840}$ that of proton), it has the largest angle of deflection.

Question 2 (C)

There is a large increase from the 7th to 8th ionisation energy. Significantly more energy is required to remove the 8th electron as it is located in an inner shell. Hence, the element has 7 valence electrons i.e. chlorine.

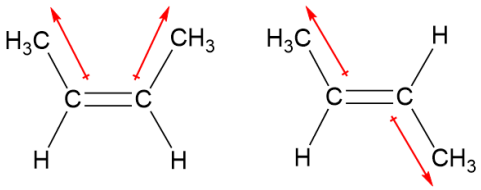
Question 3 (D)

Since the dipole moment of the highly polar C=O is not completely cancelled out in X and Y, X and Y have greater polarity than W and Z, which have no highly polar bonds i.e. polarity of W, Z < X, Y.



X Y

Since the dipole moment of the C=O in Y is partially cancelled out by the dipole moments of the 2 C–C*l* bonds, the overall dipole moment in Y is lower than in X i.e. polarity of Y < X.



W Z

The dipole moments in Z are exactly cancelled out, while the dipole moments in Y are not. Hence, Z is less polar than W i.e. polarity of Z < W.

Question 4 (A)

Comparing expts 2 and 3, when $[H^+]$ x 2, rate x 4 i.e. order of reaction wrt H^+ = 2.
Comparing expts 3 and 4, when $[BrO_3^-]$ x 2, rate x 2 i.e. order of reaction wrt BrO_3^- = 1.
Comparing expts 1 and 3, when $[Br^-]$ x 2 , rate x 2 i.e. order of reaction wrt Br^- = 1.

Question 5 (D)

1	Correct. As HBr is formed, [HBr] in the denominator of the rate equation increases, causing the rate to decrease i.e. rate slows down.
2.	Incorrect. In a propagation step, a radical is consumed as a reactant and another radical is produced as a product. Hence, step 2 is also a propagation step, in addition to steps 3 and 4.
3.	Incorrect. $[Br_2]$ appears in both the numerator and denominator. Doubling its concentration does not double the rate due to the powers which each $[Br_2]$ is raised to.

Question 6 (B)

From the initial buffer provided,

$4.46 = pK_a + lg\frac{[ethanoate]}{[ethanoic\ acid]}$

$4.46 = pK_a + lg(\frac{1}{2})$ --- (1)

Let x be the no. of mols of NaOH added to the buffer to achieve pH 4.60.

Amt / mol	CH_3COOH	+	NaOH	⟶	$CH_3COO^-Na^+$	+	H_2O
Initial	2(2)		x		2(1)		--
Change	–x		–x		+x		--
final	4–x		0		2+x		

After adding x mol of NaOH,

$4.60 = pK_a + lg(\frac{2 + x}{4 - x})$ --- (2)

Equation (2) – (1) gives:

$4.60 - 4.46 = lg(\frac{2 + x}{4 - x}) - lg(\frac{1}{2})$

$0.14 = lg(\frac{2 + x}{4 - x} \div \frac{1}{2})$

$10^{0.14} = \frac{2(2 + x)}{4 - x}$

x = 0.4503 mol

mass of NaOH = 0.4503 x 40.0 = 18.0 g.

Question 7 (B)

A	Incorrect. If HA is a weak acid, then K_a(HA) x K_b(conjugate base of HA) = K_w. This is because $K_a = \frac{[H^+][A^-]}{[HA]}$ and K_b(conjugate base of HA) = $K_b(A^-) = \frac{[HA][OH^-]}{[A^-]}$. K_a(HA) x K_b(conjugate base of HA) = $\frac{[H^+][A^-]}{[HA]} \times \frac{[HA][OH^-]}{[A^-]} = [H^+][OH^-] = K_w$. For this statement involving water to be correct, it should read either • $K_a(H_2O) \times K_b(OH^-) = K_w$, or • $K_a(H_3O^+) \times K_b(H_2O) = K_w$.
B	Correct. When an excess of a weak base reacts with a strong acid, the resultant solution contains a mixture of unreacted weak base and the conjugate acid of the weak base, resulting in a buffer solution.
C	Incorrect. When large volumes of water are added to an acidic buffer, the pH gradually approaches the pH of water.
D	Incorrect. Sulfuric acid is considered a strong acid. When titrated against NaOH(aq), only one region of rapid pH change (i.e. one equivalence point) will be observed.

Question 8 (A)

A	Correct. While the addition of concentrated HC*l* increases [C*l*$^-$] and should cause more AgC*l* to precipitate, the AgC*l* ppt dissolves instead. Students need to recognise that this increase in solubility of the ppt must be due to the formation of a soluble complex, even if they do not know the formula of the complex. In this case, the soluble complex formed is [AgCl_2]$^-$.
B	Incorrect. Cations, such as Ag^+, form complexes with neutral species (e.g. NH_3) or anionic species (e.g. C*l*$^-$), not cations.
C	Incorrect. The common ion effect, exerted by the presence of the C*l*$^-$ common ion, would have caused more ppt to form.
D	Incorrect. AgC*l* does not react with H^+.

Question 9 (A)

A	With the lowest 1st IE, this suggests that element R is Na.
B	Since the chloride of R reacts with water to give an acidic solution, element R could be Mg, A*l*, Si or P.
C	Since the oxide of R is a solid at room temperature, element R could be Na, Mg, A*l*, Si or P.
D	The chlorides of Na, Mg and A*l* dissolve in water to form the corresponding cations and chloride ions. For SiCl_4, the following reaction occurs to form its corresponding oxide: SiCl_4 + 2H_2O → SiO_2 + 4HC*l*. PCl_5 reacts with water to form H_3PO_4 and HC*l*. This option implies that element R is Si.

Hence, option A does not fit with the other three.

Question 10 (D)

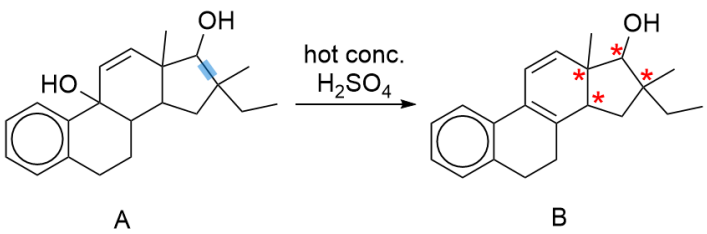
To obtain the structure of the octapeptide, align the overlapping sections of the dipeptide and tripeptide fragments.

Gly-Asn-Tyr
Tyr-Asn-Tyr
Tyr-Leu-Tyr
Tyr-Arg

Gly-Asn-Tyr-Asn-Tyr-Leu-Tyr-Arg

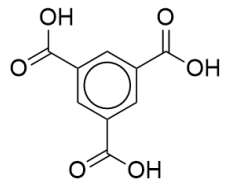
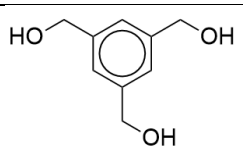
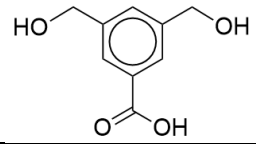
Question 11 (C)

Reaction with excess concentrated H_2SO_4 causes some alcohols to undergo elimination. The carbon next to the carbon bearing the -OH group needs to contain a hydrogen for elimination to take place.



Question 12 (B)

The products of reaction with the stated reagents and conditions are shown.

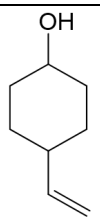
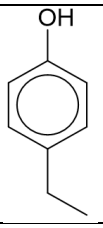
1		Correct. The aldehyde and primary alcohol are oxidised by hot acidified $K_2Cr_2O_7$ to form –COOH.
2.		Correct. The aldehyde and carboxylic acid are reduced by LiA/H_4 to form the corresponding primary alcohols.
3.		Incorrect. $NaBH_4$ reduces carbonyl compounds only and hence the aldehyde is reduced to the corresponding primary alcohol. However, $NaBH_4$ is unable to reduce the carboxylic acid.

Question 13 (B)

The energy profile diagram has two peaks, indicating that the reaction proceeds via a two-step mechanism.

1	Correct. $(CH_3)_3CCl$ is a tertiary chloroalkane. Hence, its reaction with KOH proceeds via the two-step S_N1 mechanism.
2.	Incorrect. CH_3CH_2Cl is a primary chloroalkane. Hence, its reaction with KOH proceeds via the S_N2 reaction which is a one-step mechanism.
3.	Correct. The reaction between CH_3CHO and HCN is a nucleophilic addition reaction which proceeds via a two-step mechanism.

Question 14 (D)

			
1	Incorrect	The 2° alcohol and alkene undergoes oxidation, decolourising the purple $KMnO_4$.	The ethyl side chain undergoes oxidation, decolouring the purple $KMnO_4$.
2	Correct	The 2° alcohol undergoes oxidation, causing the orange $K_2Cr_2O_7$ to turn green.	The ethyl side chain is not oxidised by $K_2Cr_2O_7$. Hence, there is no colour change.
3	Correct	There is no phenol group present. Hence, there is no colour change.	The neutral $FeCl_3$ reacts with the phenol group, producing a violet colouration.
4	Incorrect	The alkene undergoes electrophilic addition with $Br_2(aq)$, decolourising the orange $Br_2(aq)$.	The phenol group undergoes electrophilic substitution with $Br_2(aq)$, decolourising the orange $Br_2(aq)$.

Question 15 (B)

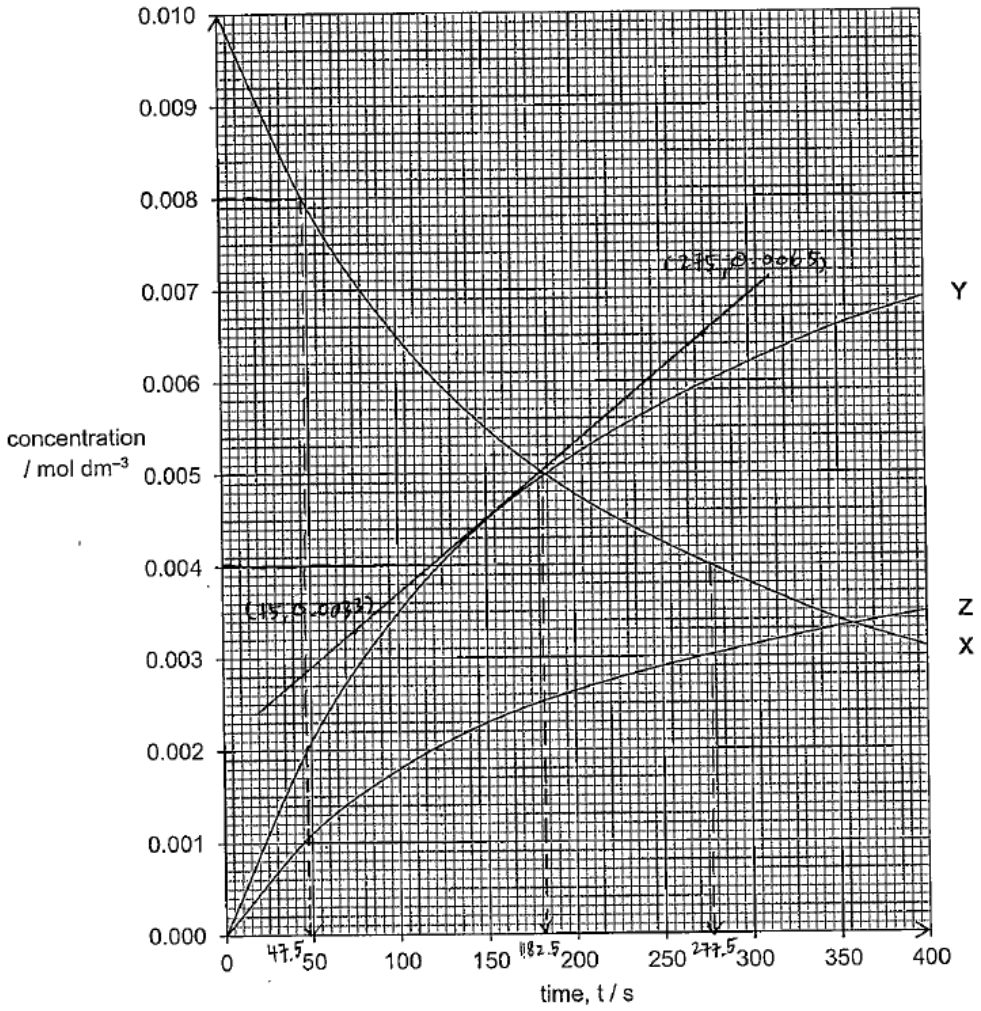
1	Incorrect. To form an ester with phenol, an acyl chloride needs to be used. Phenol does not react directly with carboxylic acids.
2.	Correct. Amides are formed from the reaction between an acyl chloride and a primary or secondary amine.
3.	Incorrect. Acyl chlorides do not react with tertiary amines.

Section B

1 (a) (i) The half-life ($t_{1/2}$) of a reaction is the time taken for the concentration of a reactant to decrease to half its initial value / to be halved.

Examiners' Comments
- This was generally well done.
- For definitions, candidates should follow what is given in notes, as more often than not, when candidates rephrase, a different meaning to what is being described surfaces.

(ii)



time taken for [X] to decrease from 0.010 mol dm^{-3} to 0.005 mol dm^{-3}
= 182.5 s

time taken for [X] to decrease from 0.008 mol dm^{-3} to 0.004 mol dm^{-3}
= 277.5 – 47.5
= 230 s

Since half-life is not constant, the order of reaction with respect to X is not one.

Examiners' Comments
- Most candidates were able to show proper construction lines – these form part of the working and cannot be missing from one's presentation.
- To determine half-lives using concentration of *reactants*, many candidates did

not realise that the half-lives do not need to be taken based on "consecutive" concentration pairs i.e. there is no necessity to find the half-life for (0.010 to <u>0.005</u> mol dm^{-3}) followed by (<u>0.005</u> to 0.0025 mol dm^{-3}). Any pair of concentrations whereby one is half the other is fine.
- When using graphs, candidates should never extrapolate beyond the grid that is given. In this question, as the data on the graph given does not have any values lower than 0.0031 mol dm^{-3}, no information can be obtained beyond 400 s. (Hence, a concentration of 0.0025 mol dm^{-3} should not form part of the analysis or working in this question.)
- The question asked specifically to determine half-life values, which means actual numerical values must be clearly shown. Any other method that does not follow this instruction is not acceptable.
- Some candidates read the values incorrectly and hence miscalculated the half-lives.
- Do note that "constant" is not the same as "consistent" – please use the correct terminology to compare the half-lives.

(iii) 1.7×10^{-5} mol dm^{-3} s^{-1}

Examiners' Comments
- Many candidates forgot that rate of reaction is a positive quantity (refer to lecture notes).
- Some candidates made mistakes with the units.

(iv) At t = 150 s,
gradient of tangent (for Y) = (0.0065 – 0.0033) / (275 – 75)
= 1.60×10^{-5} mol dm^{-3} s^{-1}

	rate of decomposition of X		rate of formation of Y		rate of formation of Z
	1.7×10^{-5}		1.60×10^{-5}		7.8×10^{-6}
	$\frac{1.7\times10^{-5}}{7.8\times10^{-6}} = 2.18$	:	$\frac{1.6\times10^{-5}}{7.8\times10^{-6}} = 2.05$	:	$\frac{7.8\times10^{-6}}{7.8\times10^{-6}} = 1.00$
$\approx$	2	:	2	:	1

$2X \longrightarrow 2Y + Z$

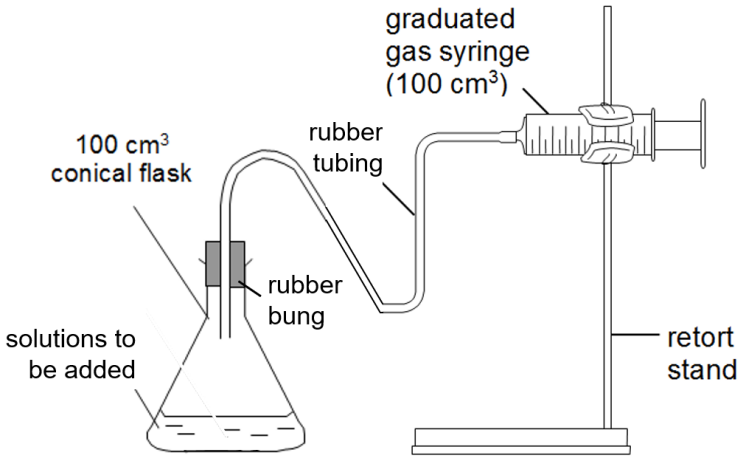
Examiners' Comments
- Some did not read the question carefully and found the gradient at t=0 instead.
- The working to deduce the balanced equation needs to be shown clearly.

(b) (i) amt of $C_6H_5N_2^+$ = (0.20)(20/1000)
= 0.004 mol
= amt of N_2 produced

At r.t.p., vol of N_2 produced = 0.004×24000
= <u>96 cm^3</u>

Examiners' Comments
- Many did not read the question carefully – the volume of nitrogen required is in "cm^3" and not "dm^3".

(ii) 1. Set up the apparatus as shown.



Determining a suitable volume of N_2 to be collected

20 cm^3 of 0.20 mol dm^{-3} $C_6H_5N_2^+$ produces 96 cm^3 N_2.
10 cm^3 of 0.20 mol dm^{-3} $C_6H_5N_2^+$ produces 48 cm^3 N_2. (refer to table in step 6)
Hence, collecting 15 cm^3 of N_2 is still reasonable even for the **lowest** concentration of $C_6H_5N_2^+$ used.

2. Using a 25 cm^3 measuring cylinder, transfer 20 cm^3 of $C_6H_5N_2^+$ into a 100 cm^3 conical flask.

3. Using a 10 cm^3 measuring cylinder, measure 10 cm^3 of hot water at 50 °C.

4. Pour the hot water into the conical flask. Replace the rubber bung, swirl the mixture and start the stopwatch immediately.

5. Record the time needed for 15 cm^3 of N_2 to be collected.

6. Repeat Steps 2–5 using the volumes for experiments 2–6 as shown below, using a 10 cm^3 measuring cylinder to measure the cold water required. The hot water is to be added only after the cold liquids have been placed in the conical flask.

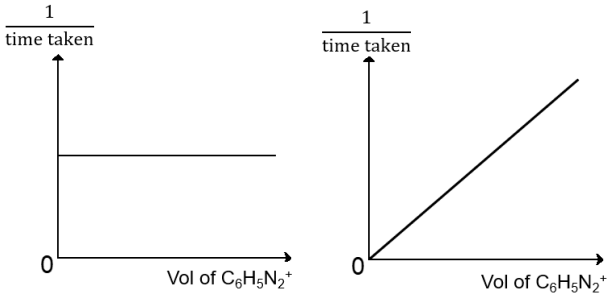
experiment	vol of $C_6H_5N_2^+$ / cm^3	vol of cold water / cm^3
1	20	0
2	18	2
3	16	4
4	14	6
5	12	8
6	10	10

7. The initial rate is estimated using the average rate as follows.
initial rate $\approx$ average rate
$$= \frac{\text{vol of } N_2 \text{ collected}}{\text{time taken}}$$

Since the vol of N_2 collected is the same for all experiments,
initial rate $\propto \frac{1}{\text{time taken}}$

8. Plot $\frac{1}{\text{time taken}}$ against volume of $C_6H_5N_2^+$.

9. The order of reaction can be determined as follows.



zero order first order

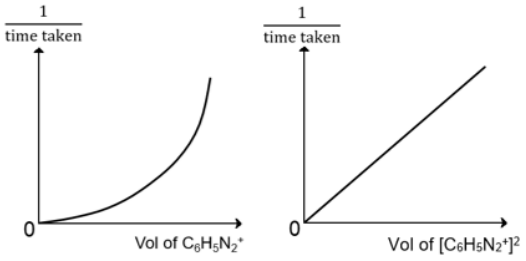
Note:

- In this experiment, the average rate is used as an estimate for the initial rate. The smaller the time interval, the better is the approximation. Hence, the volume of N_2 to be collected should be reasonably small but not so small such that it is too fast to measure the time taken.

- The total volume of cold solution used should be the same for all experiments. Similarly, the volume of hot water used should also be the same. If a larger volume of hot water was used each time, the temperature of the mixture would rise and reach 10 °C faster, which would then cause the decomposition to start earlier, adding inaccuracy to the time measured.

- It does not matter if the cold water or $C_6H_5N_2^+$ is added first, so long as the hot water is added last. However, if the hot water is added into the 100 cm^3 conical flask first, then the two cold solutions need to be added after **simultaneously**.

- Note that a curve (see below) does **not** mean it is second order, it only means that the order is neither 0 nor 1. To confirm second order, the graph of rate vs $conc^2$ should be plotted instead.



not zero or first order second order

Examiners' Comments

- In Chemistry, candidates should avoid using the word "amount" in **any** answer unless they are specifically referring to the amount of substance in moles e.g. in this case, do not use *amount* of gas when one means to talk about *volume* of gas.
- Please use a diagram for the setup as instructed in the bulleted point. A diagram depicts the setup more clearer than descriptions which are often incomplete or easily misinterpreted.
- Capacities of all apparatus / glassware used must be clearly stated in the plan

e.g. 100 cm^3 graduated gas syringe, 50 cm^3 measuring cylinder, 100 cm^3 conical flask. Please familiarise yourself with what you have used in the lab – do not create your own capacities which do no exist in reality. Some students used small syringes to measure the liquid volumes – these are NOT commonly used in Chemistry experiments for liquids; students should primarily use measuring cylinders, burettes and pipettes instead.

- At least five data points need to be collected (for plotting straight lines; seven data points for plotting curves), and hence at least five different volumes of $C_6H_5N_2^+$ stock solution should be used i.e. five different initial concentrations of $C_6H_5N_2^+$.
  - The total volume of stock solution used cannot exceed 100 cm^3 as given in the question. One of these five volumes must also be 20.0 cm^3 given in the question.
  - Quite a number also used 0.0 cm^3 of $C_6H_5N_2^+$ as one data point to collect – in this case, there is **no** reaction since $C_6H_5N_2^+$ is the only reactant – adding hot and cold water together does not produce N_2 gas.
  - It is not possible to increase the concentration of the given $C_6H_5N_2^+$ solution – we can only dilute and make concentrations lower than 0.20 mol dm^{-3}.
- In their procedure, some candidates only "set up their apparatus" **after** mixing all the solutions – N_2 gas would have escaped in the meantime.
- Please read the question carefully and follow the instructions – many candidates did not explicitly state or describe how they would estimate the initial rate. Simply having "1/t" in the table or using this term is not necessarily acceptable. Be clear and explicit in what you want to tell the examiners.
- Some candidates collected all of the N_2 gas produced (i.e. reaction completion), but it is not meaningful to do so here when it is the initial rate we are investigating.
- Some candidates switched axes and stated to plot conc against rate – this actually results in a vertical graph for order = 1. To minimise confusion, please keep to plotting "rate against conc".

2 (a) In order of increasing pK_b: ethylamine < phenylamine < ethanamide

(The basicity of each given compound depends on the availability of the lone pair of electrons on the nitrogen atom to form a dative covalent bond with a proton. The greater this availability, the greater the basicity of the compound.)

Phenylamine is <u>less basic</u> than ethylamine because of the <u>delocalisation of the lone pair of electrons on the nitrogen atom into the π electron cloud of benzene ring</u>**.** Ethylamine is a stronger base because the <u>ethyl (alkyl) group</u> bonded to the nitrogen atom is <u>electron-donating</u> and <u>this increases the electron density at the nitrogen atom</u>, making the lone pair of electrons on the nitrogen atom much <u>more</u> readily <u>available</u> to form a dative covalent bond with a proton**.**

Ethanamide is an amide and is the least basic (effectively neutral) because the <u>lone pair of electrons on the nitrogen atom interacts with the π electron cloud of the adjacent C=O bond</u> and is <u>delocalised</u>. As such, this lone pair is not available to form a dative covalent bond with a proton.

Examiners' Comments

- Some students were confused about how basicity, K_b and pK_b are related. To be clear, the stronger the base, the higher the K_b, the lower the pK_b.
- Most students were able to arrange the three compounds in order of increasing pK_b, or from the strongest base to weakest base. Do answer the

question completely, while presenting your answers in a clear and concise manner. For instance, some students were confused about the direction of the "<" sign.

- Some students stated the facts about the functional groups (e.g. amines are basic but amides are neutral) without providing the required explanations.
- Students should be mindful of using correct terminology. For instance, in the case of phenylamine and ethanamide, it is the orbital (and not the lone pair of electrons) on N that overlaps with the π electron cloud of benzene and C=O respectively. In ethylamine, the electron-donating ethyl group *is bonded to N*, and not simply "it has an electron-donating ethyl group".
- A number of students stated electron-donating groups "increased the negative charge" on the N. There is no negative charge on the N atom. There is a *partial* negative charge, but the main point should be increasing the availability of the lone pair of electrons.

(b) (i) rate = $k[CH_3CH_2CH_2Br][RNH_2]$

Examiners' Comments

- This reaction occurs via S_N2 mechanism as $CH_3CH_2CH_2Br$ is a primary halogenoalkane.
- Incorrect answers include:
  - Using "rate equation" (incorrect) instead of "rate" (correct)
  - missing rate constant, *k*
  - C_3H_7Br (ambiguous, may refer to 2-bromopropane)
  - variable/unknown reaction orders ('m' and 'n')

(ii) Diethylamine has two electron-donating alkyl groups but ethylamine only has one.
Hence the electron density on N increases / lone pair of electrons on nitrogen atom is more available in diethylamine, causing diethylamine to be a stronger nucleophile than ethylamine and thus a higher rate of reaction.

Examiners' Comments

- A comparison of the two compounds (two alkyl groups vs one) must be made, instead of mentioning only one of them.
- Students should recognise that the amines act as nucleophiles to attack the halogenoalkane.
- As mentioned in part (a), the N atom in amines do not have a "negative charge". While the N atom does possess a "partial negative charge", the main point is still the lone pair of electrons that allow amines to behave as a nucleophile.
- A number of students mentioned stability of carbocations in their answers. S_N2 mechanisms do not involve carbocations.
- A number of students mistook diethylamine (a secondary amine) to be methanediamine (a methane with two amine groups). The error also continued to the next part.

(iii) The nitrogen atom in triethylamine is attached to three alkyl groups and is more sterically hindered than in diethylamine which has two alkyl groups.
Hence the nitrogen atom in triethylamine reacts less readily with the electron deficient carbon atom in 1-bromopropane.

Examiners' Comments

- The classification of the amine nucleophile (primary, secondary or tertiary) is not considered in assigning the nucleophilic substitution mechanism. Hence, the reaction would still occur via S_N2 as 1-bromopropane is a primary halogenoalkane. The steric factor is relevant for both diethylamine and triethylamine.
- Similar to **(ii)**, both amines must be compared instead of simply mentioning that triethylamine is bulky.

(c) (i) Condensation

Examiners' Comments

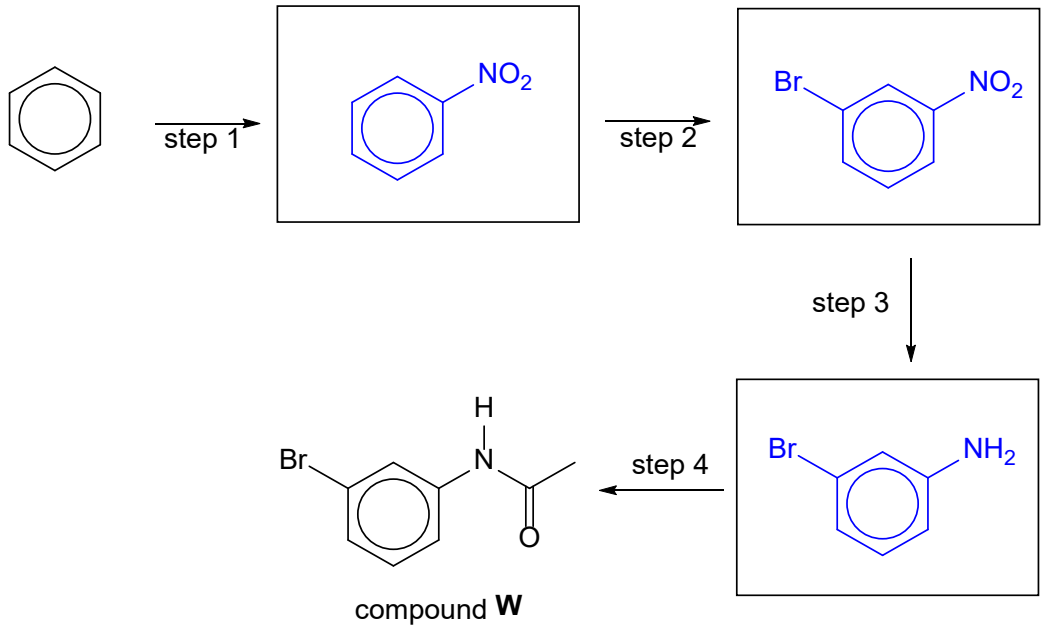
- Most students were able to answer this question.
- Condensation occurs when two compounds combine, with the production of a small molecule as a by-product. Contrast this with elimination reactions which occur within the same compound.
- Note the similarity with the condensation reaction between carbonyl compounds and 2,4-DNPH.

(ii)

Examiners' Comments

- The bond angle around the C atom of the C=N double bond should be 120°, showing a trigonal planar arrangement of the groups. Structures showing wedge and dashed bonds are not accepted. Structures showing 90° bond angles around the C or N atoms were also not accepted.
- The molecule has no chiral carbon and has an internal plane of symmetry, so enantiomerism does not arise.
- Many students incorrectly added a H atom bonded to N, resulting in four bonds on N.

(d)



compound **W**

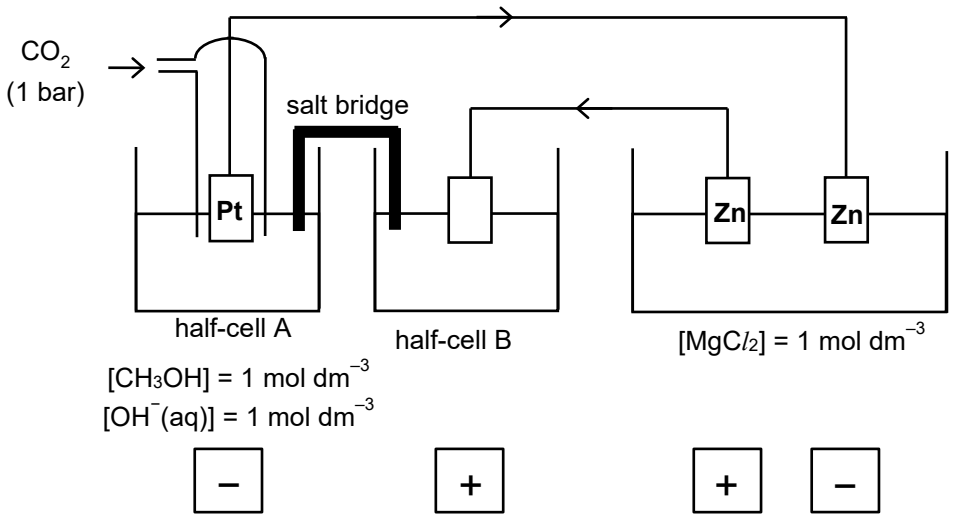
step 1: conc. HNO_3, conc. H_2SO_4, heat
step 2: Br_2, (anhydrous) $FeBr_3$, heat
step 3: Sn, conc. HC*l*, heat. Then add NaOH(aq)
step 4: CH_3COCl

Note: heat is required for step 2 as $–NO_2$ group is strongly deactivating.

Examiners' Comments

- The directing effects of the existing group on benzene must be considered when designing the synthesis steps. Many students assigned an incorrect sequence of the synthesis.
- An example of an incorrect sequence: if step 1 was bromination, the Br substituent (2,4-directing) is bonded to the ring and during the step 2 nitration step, $–NO_2$ will be substituted in the 2- or 4- positions. This does not give the desire product.
- Since the final product (compound **W**) is a 1,3-disubstituted benzene, $–NO_2$ (a 3-directing substituent) should be formed in step 1.
- Another incorrect sequence: many students reduced nitrobenzene to phenylamine before bromination. Do recall that bromination of phenylbenzene using Br_2(aq) results in 2,4,6-tribromophenylamine.
- Other common errors included missing details in the reagents and conditions (e.g. students omitted "concentrated" or "heat"). When anhydrous conditions are required, reagents should *not* be aqueous, e.g. Br_2(aq) is *not* anhydrous.
- For concentrated acids, it is *incorrect* to use, for example, "conc. H_2SO_4(aq)" – aqueous sulfuric acid implies a diluted sulfuric acid.

3 (a) (i)



Examiners' Comments

- This was poorly attempt.
- Half-cells A and B form a fuel cell (i.e. a battery) that is used to power the electrolysis in cell C. This information was provided in the question.
- The oxidation of methanol at half-cell A shows that electrons are releasd from half-cell A i.e. it should have a negative charge. These electrons flow through the wires to the connected Zn electrode on the right. Due to the flow to electrons to that Zn electrode, it has a negative charge.
- The anode of the fuel cell (half-cell A) should be directly connected to the cathode of the electrolytic cell. The cathode of the fuel cell should be directly connected to the anode of the electrolytic cell. Electrons should flow from the anode to the cathode of the fuel cell.

Type of Cell	Electrochemical (or Voltaic) Cell		Electrolytic Cell	
Electrode	Anode	Cathode	Anode	Cathode
Half-equation	Oxidation	Reduction	Oxidation	Reduction
Sign	–	+	+	–

(ii) At the anode, three oxidation reactions are possible.

$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$ $\quad E^\ominus = +1.23$ V
$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$ $\quad E^\ominus = +1.36$ V
$Zn^{2+} + 2e^- \rightleftharpoons Zn$ $\quad E^\ominus = -0.76$ V

Since $E^\ominus$ (Zn^{2+}/Zn) is the <u>most negative / least positive</u>, Zn is preferentially oxidised to form <u>Zn^{2+}</u> at the anode.

Examiners' Comments

- Many students were unaware that Zn is an active electrode. Hence, students need to consider the possibility of the oxidation of H_2O (electrolyte), Cl^- (electrolyte) and Zn (active electrode) at the anode. While Mg^{2+} is found in the electrolyte, it is repelled by the positively-charged anode. (Also, it is not possible for Mg^{2+} to be oxidised.)
- Students need to refrain from using adjectives like bigger or smaller when comparing electrode potential values. You should use either more/less positive or more/less negative to describe.

(iii) <u>White precipitate of $Mg(OH)_2$</u> and <u>effervescence of H_2 gas</u> will be formed.

Examiners' Comments

- Students are reminded to describe the observations, not just state the products.
- Some students stated the chemical test for H_2 instead of the observations. Effervescence of H_2 is observed before the decision to conduct the test

(iv) At electrolytic cell C:
$E^\ominus_{cell} = -0.83 - (-0.76) = -0.07$ V

For the reaction to occur, the $E^\ominus_{cell}$ of the fuel cell must be > 0.07 V.
$E^\ominus_{cathode} - (+0.03) > +0.07$ V
$E^\ominus_{cathode} > +$<u>0.10 V</u>

Examiners' Comments

- Generally poorly done.
- Many students seem to miss a important statement that clearly stated that "For electrolysis to occur, the $E^\ominus_{cell}$ of the fuel cell must be greater than the **magnitude** of $E^\ominus_{cell}$ of the electrolytic cell."
- Hence, $E^\ominus_{cathode} - (+0.03) > 0.07$ V.

(v) For the fuel cell to be able to supply sufficient electrical energy to allow the electrolytic process to take place, E_{cell} > +0.07 V.

However, as time passes, the concentration of methanol (in the fuel cell) decreases.

This shifts the position of equilibrium of equation 1 to the right.
Consequently, E_{anode} in half-cell A becomes more positive.

Since $E_{cell} = E_{cathode} - E_{anode}$,, E_{cell} of the fuel cell will fall below 0.07 V and the electrolysis stops.

Examiners' Comments

- Some students did not recognise that the concentration of the 'fuel' in the fuel cell (which is methanol in this case) will decrease with time.
- Students need to refrain from using adjectives like bigger or smaller when comparing electrode potentials. You should use either more/less positive or more/less negative to describe.

(vi) $Q = n_eF$

$n_e = \frac{3 \times 10^5}{96500} = 3.109$ mol

$n_e : n_{CH_3OH} = 6 : 1$

$n_{CH_3OH} = 0.5181$ mol

At standard conditions, the concentration of methanol is 1 mol dm^{-3}.

Therefore, V_{CH_3OH} = 0.5181 mol ÷ 1 mol dm^{-3} = 518 cm^3 (3.s.f)

Examiners' Comments

- Generally well done.
- Some students are unable to calculate the volume of methanol as they are unaware that the concentration of methanol (1 mol dm^{-3}) is given on page 16 in Fig. 3.1. The question also mentioned that this setup was run under standard conditions.
- Some students also incorrectly thought that methanol is a gas at room temperature.

(b) Lead-acid:
Low cost / good lifespan
It is able to handle more charge cycles thus less frequent battery replacement and reducing wastage.
Less toxic materials will be less damaging to the environment.

Nickel-metal hydride:
Less toxic materials / good lifespan / moderate energy density / moderate cost
It can handle the most charge cycles thus least frequent battery replacement and reducing wastage.
Less toxic materials (compared to Lithium-ion batteries) will be less damaging to the environment.

Lithium-ion (generally not a good choice based on the data):
Despite having lowest number of charge cycles, it has the highest energy density. Hence the lithium-ion battery is able to deliver the most energy throughout its life span thus least frequent battery replacement and reducing wastage.

Examiners' Comments
- Generally well done.
- Students should make explicit link as to how the factors relate to a environmentally sustainable battery, as required by the question.

(c) $\underline{Al_2O_3 + 2NaOH + 3H_2O \longrightarrow 2Na[Al(OH)_4]}$

Examiners' Comments
- Generally poorly done. Many students cannot balance the equation as they are unclear about the correct identity of the product formed.

Section C

1 (a) (i) K_{sp} of $Ca(OH)_2 = \underline{[Ca^{2+}][OH^-]^2}$

Examiners' Comments
- This question was well done. A few students incorrectly wrote Ca or Ca^+ instead of Ca^{2+}, and incorrectly included the concentration of $Ca(OH)_2$ in the expression.

(ii) $OH^-(aq) + HCl(aq) \rightarrow H_2O(l) + Cl^-(aq)$

Amount of OH^- in 25.0 cm^3 filtrate

= Amount of HCl used = $\frac{20.0}{1000} \times 0.050 = 1.00 \times 10^{-3}$ mol

$[OH^-]$ in the filtrate = $\frac{1.00 \times 10^{-3}}{25.0} \times 1000 = \underline{0.0400 \text{ mol dm}^{-3}}$

Examiners' Comments
- This question was well done. A few students left their answer as amount of OH^- instead of concentration of OH^-. Students should read the question carefully.

(iii) Let the solubility of $Ca(OH)_2$ in 0.010 mol dm^{-3} NaOH be y mol dm^{-3}.

Concentration/mol dm^{-3}	$Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$	
Initial	-	0.010
Change	+y	+2y
Equilibrium	y	(0.010 + 2y)

K_{sp} of $Ca(OH)_2 = [Ca^{2+}][OH^-]^2 = (y)(0.010 + 2y)^2$

$\Rightarrow \quad 0.010 + 2y = 0.0400$

$y = 0.0150$

K_{sp} of $Ca(OH)_2 = (y)(0.0400)^2$

$= (0.0150)(0.0400)^2 = \underline{2.40 \times 10^{-5}} \text{ mol}^3 \text{ dm}^{-9}$

Examiners' Comments

- Common errors include
  - Using 0.0200 instead of 0.0150 for $[Ca^{2+}]$. Students should recognise that the total concentration of OH^- of 0.0400 came from two sources – NaOH and $Ca(OH)_2$. As such, students should subtract 0.01 from 0.04 to find the $[OH^-]$ contributed by $Ca(OH)_2$ first, before dividing this value by 2 to obtain $[Ca^{2+}]$.
  - Using 0.03 instead of 0.04 for $[OH^-]$. The correct value to substitute into the K_{sp} expression should be the total $[OH^-]$ in the filtrate.

(b) **(i)** $[OH^-]$ at 305 K = $1.70 \times 10^{-14} / 10^{-11.7}$ = $\underline{8.52 \times 10^{-3} \text{ mol dm}^{-3}}$

Examiners' Comments

- Students should recognise that K_w changes with temperature and should use the K_w or pK_w values at 305 K and not at 298 K. Hence, the use of the equation 14 = pH + pOH is incorrect here since 14 is the value of pK_w at 298 K, not 305 K.

(ii) At a <u>higher temperature</u>, $[OH^-]$ decreases. Hence, there must be <u>lesser extent of dissolution</u> of $Ca(OH)_2(s)$ at a higher temperature.

Since an increase in temperature will favour the endothermic reaction. Therefore, the <u>dissolution of $Ca(OH)_2$ is exothermic</u>.

Examiners' Comments

- This question was well done. Students should include the equation for the dissociation of $Ca(OH)_2$ in their answers before concluding the direction of the shift in equilibrium position.

(c) **(i)** In the resultant solution before adding solid KF,
$[Ba^{2+}] = (½)(0.100) = 0.0500 \text{ mol dm}^{-3}$

(**Note**: To ppt out max. amount of CaF_2 with no BaF_2 ppt, ionic product of BaF_2 cannot exceed K_{sp} of BaF_2 i.e. $[F^-]$ in the solution is just high enough to make the ionic product of BaF_2 = K_{sp} of BaF_2.)

$K_{sp} = [Ba^{2+}][F^-]^2$

$[F^-] = \sqrt{\frac{K_{sp}}{[Ba^{2+}]}} = \sqrt{\frac{1.84 \times 10^{-7}}{0.0500}}$ = $1.918 \times 10^{-3} \text{ mol dm}^{-3}$ = $\underline{1.92 \times 10^{-3} \text{ mol dm}^{-3}}$

Examiners' Comments

Common errors include

- Not noticing that the total volume of the mixture has doubled. Hence, the $[Ba^{2+}]$ in the mixture before adding F^- would be halved that of the initial.
- Using the K_{sp} value of CaF_2 to calculate part **(i)**. Students should recognise that to precipitate the *maximum amount* of CaF_2 *without precipitating* BaF_2,
  1. the ionic product of CaF_2 would have already exceeded its K_{sp}.
  2. since we would not be precipitating BaF_2, we need to consider when ionic product of BaF_2 first equals to K_{sp} of BaF_2.

(ii) When $[F^-] = 1.918 \times 10^{-3}$ mol dm^{-3},

$$K_{sp} = [Ca^{2+}][F^-]^2$$

$$[Ca^{2+}] = \frac{K_{sp}}{[F^-]^2} = \frac{3.45\times10^{-11}}{(1.918\times10^{-3})^2} = \underline{9.38 \times 10^{-6} \text{ mol dm}^{-3}}$$

Examiners' Comments

- Generally well done with most students recognising that the K_{sp} value of CaF_2 should be used in this part.

2 **(a)** In order of increasing acidity, ethanol < phenol < ethanoic acid.

In CH_3COO^-, the negative charge on oxygen is dispersed over the two highly electronegative oxygen atoms resulting in two equivalent resonance structures. Hence, CH_3COO^- ion is resonance-stabilised to a larger extent than $C_6H_5O^-$ ion.

In $C_6H_5O^-$, the p-orbital of O overlaps with the pi electron cloud of the benzene ring so that lone pair on O is delocalised into the benzene ring, dispersing the negative charge and stabilising the $C_6H_5O^-$.

In $CH_3CH_2O^-$, the electron-donating alkyl (ethyl) group intensifies the negative charge on O atom, which destabilises $CH_3CH_2O^-$ ion. Therefore, $CH_3CH_2O^-$ is the least stable.

Examiners' Comments

- This question was generally well done.
- A common mistake was omitting the key phrase "two highly electronegative oxygen atoms". The negative charge is delocalised over two highly electronegative O atoms in carboxylates, explaining why the extent of resonance stabilisation is greater than in phenoxides, where resonance occurs over O and less electronegative C atoms.
- Some students mistakenly described "the dispersal of negative charge over two electronegative O atoms" as a consequence of inductive effect, instead of resonance.
- Many students mistakenly stated that phenol is more acidic than ethanoic acid – please revise. Although there are more atoms involved in resonance in phenoxide than in ethanoate, the extent of stabilisation that arise is greater when an electronegative atom like oxygen is involved.
- Many students failed to obtain full credit due to the common errors:
  - Explaining phenoxide and carboxylate in isolation, without *comparing* their extents of stabilisation.
  - Stating that for phenol, "the lone pair of electrons of O overlaps with the pi electron cloud of benzene". It is the p orbital of O that overlaps with the pi electron cloud of benzene, not the electrons.
  - Stating that for phenol, "the p orbital of O overlaps with benzene". The p orbital of O overlaps with the pi electron cloud (p orbitals of C) of benzene, and it is not sufficient to write only "benzene".

(b) **(i)** The additional ketone group (at C–4) withdraws electron density from the carboxylate group in the levulinate ion, dispersing the negative charge on $–COO^-$ and stabilising the levulinate ion to a greater extent.

Examiners' Comments

- Many students described an "additional electronegative O atom" which helped to disperse the negative charge, without describing its electron-withdrawing effect. This is insufficient for full credit.
- Many students wrongly stated that pentanoic acid has "one C=O group" while levulinic acid has "two C=O groups". Levulinic acid only has one C=O (ketone) group, while the other group is a carboxylic acid.
- Some students wrongly described C=O as "electronegative" when it should be electron-withdrawing. Only atoms can be described as electronegative.
- Some students wrongly explained that the negative charge in levulinate can be "delocalised over two C=O groups". This is not true as the additional C=O group withdraws electrons by inductive effect, and not resonance.
- Some also wrongly suggested the presence of hydrogen bonding in the levulinate ion in an attempt to justify the greater acidity of levulinic acid – there is no H bonded to a highly electronegative atom in the levulinate ion.

(ii) $\underline{C_5H_7O_3^- + H_2O \rightleftharpoons C_5H_7O_3H + OH^-}$

Examiners' Comments

- Many students wrongly drew an irreversible arrow. A reversible arrow is essential as this reaction involves the partial hydrolysis of the conjugate base of a weak acid (i.e. the levulinate anion behaves like a weak base).
- Many students failed to recognise this as a salt hydrolysis reaction. Clues such as the name "levulinate" and the molecular formula "$C_5H_7O_3Na$" shows that levulinate is a salt, which would then become a basic solution only upon hydrolysis.

(iii) pK_b of $C_5H_7O_3^-$ = 14 – 4.65 = 9.35

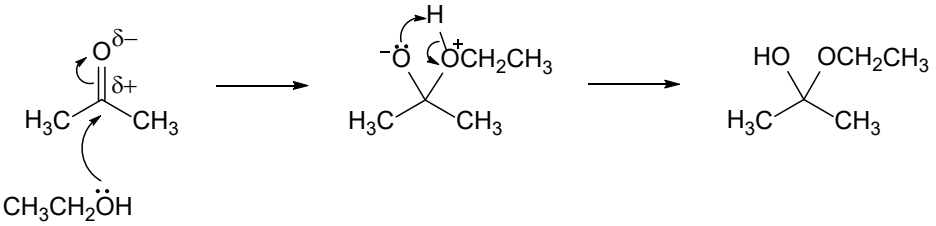
$[OH^-] = \sqrt{K_b \times [C_5H_7O_3^-]} = \sqrt{10^{-9.35} \times 0.200} = \underline{9.452 \text{ x } 10^{-6} \text{ mol dm}^{-3}}$

pOH = –lg(9.452 x 10^{-6}) = 5.024
pH = 14 – 5.024 = 8.98

Examiners' Comments

- Students who provided a wrong equation in part (ii) were often unable to do this question. Understanding that this is a salt hydrolysis reaction which produces OH^- will strongly aid in doing the correct calculations.
- The production of OH^- shows the need for the use of K_b, and not K_a. We usually calculate $[H^+] = \sqrt{K_a \times [HA]}$. Likewise, we can calculate $[OH^-] = \sqrt{K_b \times [A^-]}$, from which we can find pOH and subsequently pH.
- Students should check their final answers. A pH <7 would be very telling of an incorrect answer as the solution should be basic. There were many careless attempts that mistook sodium levulinate as a strong base, or a weak acid.

(c) **(i)**



Examiners' Comments

- Many students obtained partial or no credit for this question.
- Common mistakes include:
  - Omitting the partial charges on the ketone
  - Omitting the lone pair on O in ethanol
  - Omitting the positive charge on O in the zwitterionic intermediate. Take note that O atoms with three bonds should have a positive charge. (N atoms with four bonds also have a positive charge).
  - Attacking the ketone with a deprotonated ethoxide nucleophile, which will not result in a zwitterionic intermediate. Students are advised to follow the description of the mechanism closely.
- In drawing mechanisms, it is helpful to remember that full arrows represent the movement of electron pairs, and should therefore always come from either lone pairs of electrons or bonds (essentially electrons), and not from atoms.

(ii) In the protonated form of propanone, the positively charged O atom withdraws electron density from the carbonyl C to a greater extent, causing the carbonyl C to be more electron-deficient.

Examiners' Comments

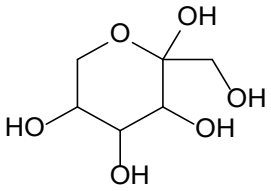
- This question was poorly done.
- Many students described the O atom to be electron-deficient, therefore increasing the molecule's susceptibility to nucleophilic attacks. Students must remember that the carbon centre is the one being attacked, and hence explain that C is more electron-deficient instead.
- Many students also wrongly explained that since O is positively charged, it attracts nucleophiles better (electrostatic attraction). This, once again, fails to recognise C as the electrophilic centre.

(iii) The –OH group (at C–5) can attack from either side of the trigonal planar carbonyl carbon (at C–2), giving rise to two stereoisomers.

Examiners' Comments

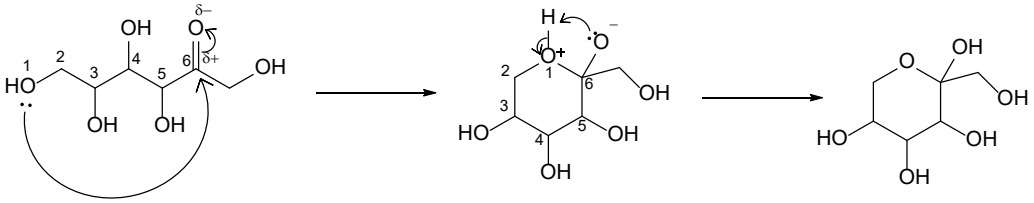
- Students need to specify that the nucleophile attacks the planar carbonyl carbon. It is correct to describe the geometry about the *carbonyl carbon* in fructose as trigonal planar, but incorrect to describe the geometry of fructose as trigonal planar.
- Students should consider the nucleophilic addition mechanism whereby the nucleophile attacks the carbonyl C, forming a tetrahedral zwitterionic intermediate. A carbocation intermediate is not formed.
- Note that **structural isomers** (not stereoisomers) are formed as products when –OH on different C atoms in linear fructose attacks the carbonyl C.
- In reality, the –OH group did not attack either side of the trigonal planar carbonyl carbon with *equal probability*. Do read the question carefully – there is no mention of *equal proportion* of stereoisomers obtained.

(iv)

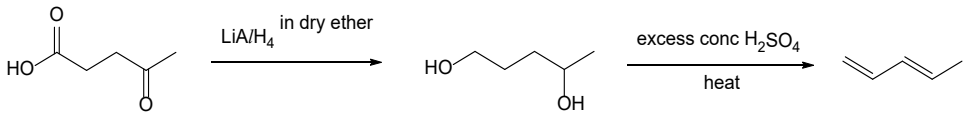


Examiners' Comments

- This question was poorly attempted. Students need to count the number of atoms carefully and consider which atoms bond together in the product. A useful technique involves numbering the atoms involved in forming the ring. See the diagram below with the numbering of atoms shown:



(d) **(i)**



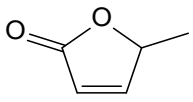
Examiners' Comments

- This question was generally well answered.
- It is important to note that –COOH <u>cannot be</u> reduced by $NaBH_4$ or H_2, Ni, heat. Also, heat is not required for reduction using $LiAlH_4$.
- Note that it is incorrect to describe the concentrated H_2SO_4 as (aq), because (aq) suggests a dilute solution.
- Use of Al_2O_3, heat is also acceptable for the elimination reaction.
- Note that hot ethanolic KOH is used for elimination of HX, not H_2O.

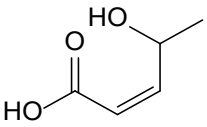
(ii)

Evidence	Deductions
A $\xrightarrow[\text{heat}]{H_2SO_4\ (aq)}$ **B**	**A** undergoes <u>acidic hydrolysis</u> **A** contains a cyclic <u>ester</u> functional group **B** contains an <u>alcohol</u> and a <u>–COOH</u> group
B $\xrightarrow[\text{heat}]{\text{acidified } KMnO_4}$ **C** $(C_3H_4O_3)$ only organic product	**B** undergoes <u>strong oxidation / oxidative cleavage</u> **B** contains <u>C=C bond/ alkene</u> functional group Loss of two carbons as CO_2 Further <u>oxidation of</u>

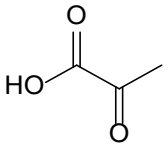
	ethanedioic acid to CO_2 occurred
C $\xrightarrow[\text{heat}]{\text{alkaline } I_2}$ yellow ppt	**C** undergoes oxidation **C** contains –$COCH_3$ / methyl ketone group
C reacts with sodium carbonate	**C** undergoes acid-base / neutralisation reaction. CO_2 gas produced. **C** contains a –COOH group



A



B



C

Examiners' Comments

- The deductions were generally well answered.
- To obtain full credit for deductions, students are reminded to include:
  - the type of reaction that took place (e.g. strong oxidation/acid hydrolysis)
  - the type and number of functional groups which took part in the above reaction.
- Some students mistakenly suggested the reaction between **A** and hot $H_2SO_4(aq)$ is electrophilic addition of alkene to form alcohol. Note that electrophilic addition of an alkene to form alcohol involves the use of **cold** conc. H_2SO_4.
- When stating the functional group, note that "double bond" is too vague, do specify "C=C bond".
- When **C** reacts with alkaline aqueous iodine to give a yellow ppt, students need to specifically deduce that **C** contains a $-COCH_3$ group. This is because it is not possible for **C** to contains the $-CH(OH)CH_3$ group since **C** is a product from strong oxidation.
- The reaction between the carboxylic acid **C** and Na_2CO_3 must be described as an acid-base reaction and not an acid-carbonate reaction. Also, note that the gas produced is CO_2, not H_2.
- Most students were able to deduce the structure of **C** correctly, but found difficulty in deducing the structures of **A** and **B**.
- During the deduction for the structure of **A**, many students missed out on a piece of key evidence: **A** contain a chiral centre. When deducing structures, a good practice would be to check again whether all the proposed structures match the list of evidence and given molecular formula.

3 EITHER

(a) Down Group 2,

- cationic radius increases, resulting in a decreasing charge density and weaker polarising power of the cations.
- consequently, there is decreasing extent of distortion of electron cloud in CO_3^{2-} anion, causing less weakening of C–O (covalent) bond within CO_3^{2-} anion
- hence, thermal stability of the Group 2 carbonates increases.

Examiners' Comments

- Generally well done.
- Students are reminded to use correct terminologies (e.g. cationic radius, polarising power) and express their understanding of the concepts clearly.
- Ambiguous phrasing or poor expressions or contradicting concepts will result in loss of marks. E.g. distortion of CO_3^{2-} anion will gain no credit; it is the *electron cloud* of CO_3^{2-} anion that gets distorted by the cation.

(b) **(i)** A nucleophile is an electron pair donor.

Examiners' Comments

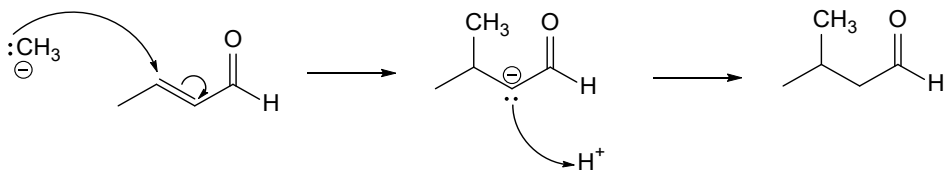
- The electron pair may or may not be from a *lone pair* of electron. Take note that the *pi electrons* in C=C can act as nucleophile too. For example, in the electrophilic addition mechanism between alkenes and X_2, it is the pi electron in the C=C that gets donated to the electrophile X_2.

(ii) The p-orbitals in C=C and C=O overlap continuously to form a delocalised π electron cloud. The highly electronegative O pulls the electron cloud towards itself leaving the β-carbon electron deficient allowing for nucleophilic attack by CH_3^-.

Examiners' Comments

- Many students are still unable to describe the side-on overlap of p-orbitals for delocalisation of electrons to take place. Many attempts were awkward and had strange cause-and-effect relationships – please revise this and talk to your tutors if you are unsure.
- This question requires good conceptual understanding of delocalisation, electronic effects and electronegativity to explain why β-carbon is susceptible to nucleophilic attack.
- The idea of p orbitals in C=C and C=O overlapping to form a delocalised π electron cloud should be clearly described first before the electronic effects by the highly electronegative O on the delocalised π electron cloud can come into play to give β-carbon a partial positive charge (i.e. electron deficient).

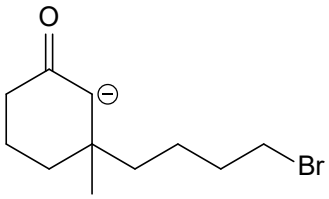
(iii)



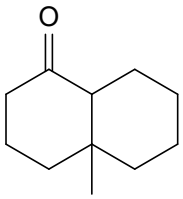
Examiners' Comments

- Fairly well done.
- In step 1, the lone pair on CH_3^- must be clearly indicated, with a curly arrow starting from lone pair towards β-carbon, and another curly arrow illustrating the breaking of π bond of C=C towards α-carbon to generate anion at α-carbon must be shown.
- In step 2, the correct anion structure with the negative charge and the lone pair on α-carbon must be shown, and a curly arrow from this lone pair to H^+ must be clearly drawn.
- Students need to follow the instructions described in the question when they draw the mechanisms. Some students based the mechanisms on their own knowledge, which differed from what was described. This recalled mechanism often does not allow the "negative charge on alpha carbon" to be achieved in one step.

(iv)



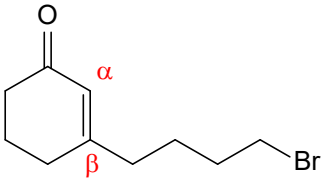
carbanion



Y

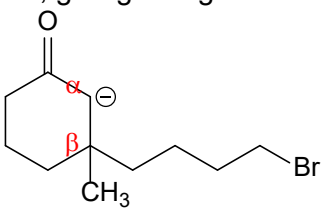
Examiners' Comments

- This is a pattern recognition question where students are expected to use the information in Fig. 3.1 and apply it to a new context.
- First, identify the α-carbon and β-carbon in **X**.

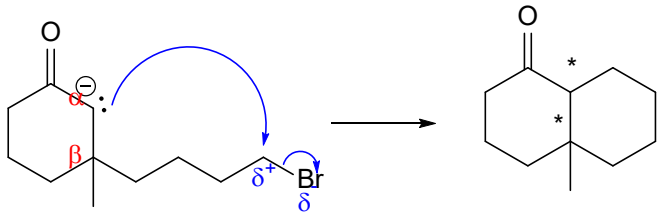


X

Then applying the chemistry given in question where nucleophilic attack by CH_3^- occurs at the β-carbon, giving a negative charge on the α-carbon:



From the molecular formular of **Y**, $C_{11}H_{18}O$, it can be deduced that an intramolecular nucleophilic substitution has occurred to give **Y**, a carbonyl compound with 2 chiral carbon.



3 OR

(a) Hydrogen chloride is thermally stable (does not decompose). Hydrogen bromide and hydrogen iodide thermally decompose to give hydrogen gas and their respective halogens as shown in the following equation.

$$2HX \rightleftharpoons H_2 + X_2 \text{ (where X = Br and I)}$$

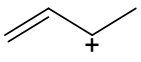
Since the bond energy decreases from HC*l* to H–Br to HI, the bond strength decreases in the same order. Thus, the thermal stability of the hydrogen halides decreases from H–C*l* to H–Br to H–I.

Examiners' Comments
- Many students failed to give a complete *description* of the thermal decomposition of the hydrogen halides to give form the products, H_2 and X_2 (where X = Br and I). Note that HC*l* is thermally stable and does not decompose to give H_2 and Cl_2
- In explaining the variation of thermal stability, full credit is given to answers that shows clear understanding that thermal stability is related to *bond strength* of HX.
- Students should clearly state the trend of *thermal stability*, instead of that of decomposition temperatures or ease of thermal decomposition.

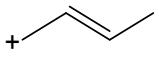
(b) **(i)** An electron-deficient species with an empty low-lying/energetically accessible orbital to accept an electron pair.

Examiners' Comments
- This definition was tested in the March timed practice. The same mistakes were still observed here. Students need to learn and improve.
- The electron pair may or may not be from a *lone pair* of electrons. Take note that the *pi electrons* in C=C can act as nucleophile too. For example, in the electrophilic addition mechanism between alkenes and X_2, the electrophile X_2 accepts pi electrons from the pi bond in C=C.

(ii)



carbocation **X'**

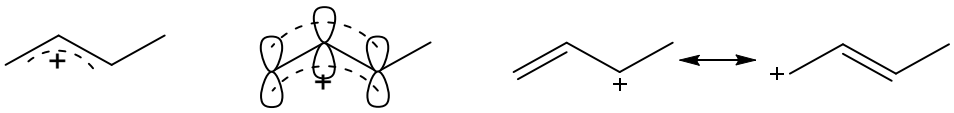


carbocation **Y'**

Examiners' Comments
- Straightforward and generally well done.

(iii) Carbocations **X'** and **Y'** are resonance-stabilised due to the overlap of the p-orbital on the positively-charged carbon with the pi-electron cloud of the C=C double bond, delocalising the positive charge **OR** thus the pi electrons delocalise onto the empty p-orbital of the positively-charged carbon, dispersing the positive charge.

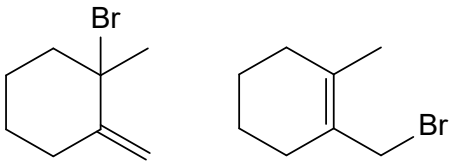
Possible diagrams



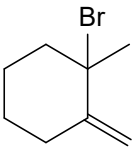
Examiners' Comments

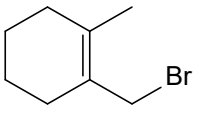
- Full credit was only given to students who showed an appreciation that X' and Y' are resonance structures of each other and were able to explain the resonance phenomenon clearly. For answers that only explain resonance in Y' alone (and not in X') will not receive any credit.
- Many students did not support answers with relevant diagrams as required by the question.

(iv)

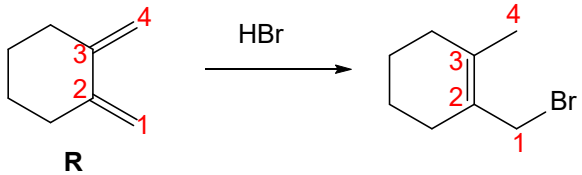


Examiners' Comments

- This is a pattern recognition question where students are expected to use the information in Fig. 3.2 and apply it to a new context.
- Most were able to obtain only 1 structure correct, 

.Some incorrect answers gave stereoisomers of the same product.
- The second structure 

proved to be harder for many students. To obtain this, follow the same pattern to obtain compound **Y** in Fig 3.2, where Br is added to the first carbon and the C=C shifted position the 2nd and 3rd carbon:



R