Name: …… ( ) Class: ……..
Date: …….

Raffles Institution
Year 6 H2 Chemistry 2025

Set A T2W7 – Halogen Derivatives, Hydroxy and Carbonyl Compounds

☐— Pre-ChemFocus Activity —☐

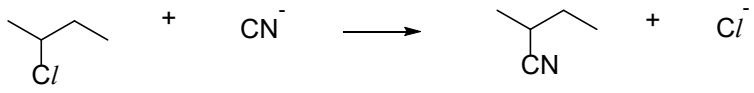
- Familiarise yourself with the following mechanisms: Nucleophilic Substitution (S_N1, S_N2), Nucleophilic Addition
- To view infopack at IVY > C2025 – H2 CHEMISTRY > Pages > [ChemFocus] Y6 T2W7 Halogen Derivatives, Hydroxy and Carbonyl Compounds > **FIRST VIDEO**

Notes:
Nucleophilic substitution mechanisms

Self-Check Questions

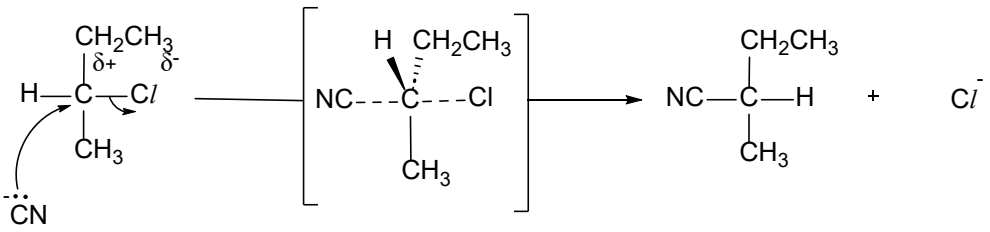
Check your answers at IVY > C2025 – H2 CHEMISTRY > Pages > [ChemFocus] Y6 T2W7 Halogen Derivatives, Hydroxy and Carbonyl Compounds > Remaining videos

1 When an optically pure solution containing 2-chlorobutane reacts with NaCN under alcoholic conditions, the resulting solution was optically active.



2-chlorobutane

(a) A description of the reaction mechanism is illustrated below. Circle and annotate on the diagram to indicate how the mechanism is drawn incorrectly.



Learning points:

(b) 2-chloro-2-methylbutane also undergoes nucleophilic substitution reaction with NaCN under alcoholic conditions. However, the overall order of reaction was found to be 1 instead of 2. Explain why.

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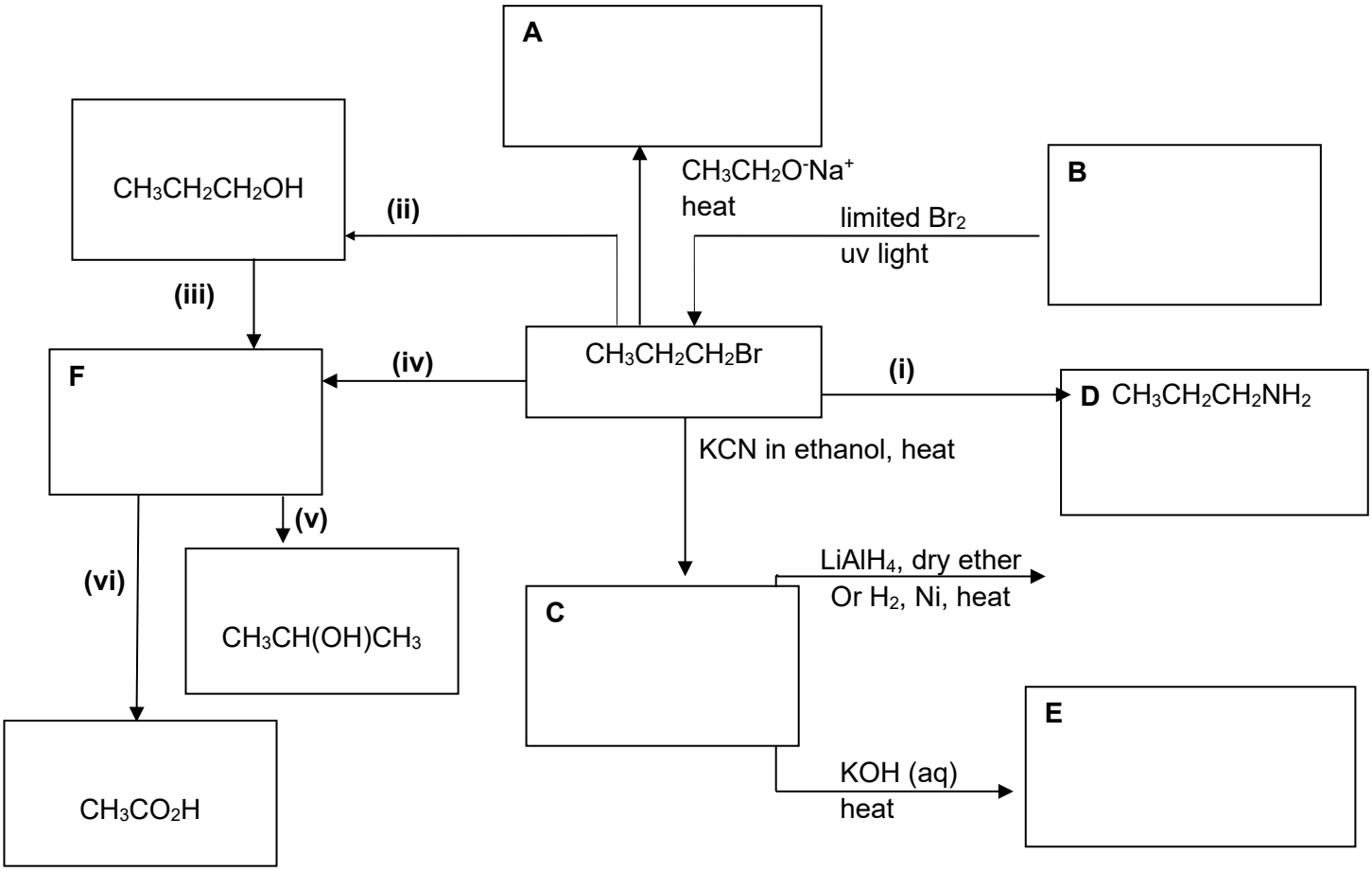
……..[2]

2

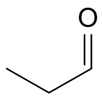
(a) In the boxes **A** to **F** below, draw the structural formula of organic compounds formed.



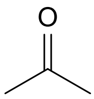
(b) In the table below, suggest the reagents and conditions for reactions **(i)** to **(vi).**

Reaction	Reagents and Conditions
(i)	
(ii)	
(iii)	
(iv)	
(v)	
(vi)	

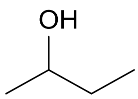
3 Mark with a (✓) if the following compounds gives a positive test with each of the following chemical test.



	2,4-dinitrophenylhydrazine
	Fehling's solution, heat
	Tollens' reagent, heat
	I_2(aq), NaOH(aq), heat



	2,4-dinitrophenylhydrazine
	Fehling's solution, heat
	Tollens' reagent, heat
	I_2(aq), NaOH(aq), heat



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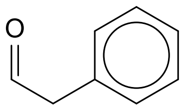
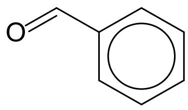


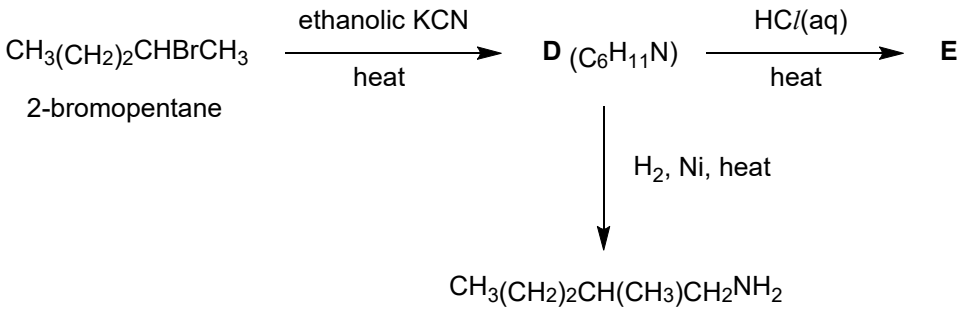
	2,4-dinitrophenylhydrazine
	Fehling's solution, heat
	Tollens' reagent, heat
	I_2(aq), NaOH(aq), heat



	2,4-dinitrophenylhydrazine
	Fehling's solution, heat
	Tollens' reagent, heat
	I_2(aq), NaOH(aq), heat

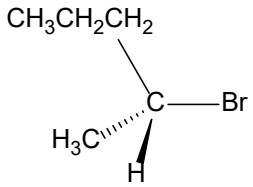
Tutorial Discussion Questions (to complete before Chemfocus session)

1a A reaction scheme involving 2-bromopentane, $CH_3(CH_2)_2CHBrCH_3$, is given below.



A student investigated the kinetics of the conversion of 2-bromopentane into **D**.
The rate equation of the reaction was found to be: rate = k [2-bromopentane] [CN^-].

The sample used in the reaction contained only the following isomer of 2-bromopentane.
There was an inversion of configuration in this reaction.



(i) Describe the mechanism of the conversion of 2-bromopentane into **D**. Show relevant lone pairs, charges and dipoles, and use curly arrows to indicate the movement of electron pairs.
You may represent 2-bromopentane as $CH_3CH_2CH_2$–$CHBrCH_3$.

[3]

(ii) Suggest a structure for organic product **E**.

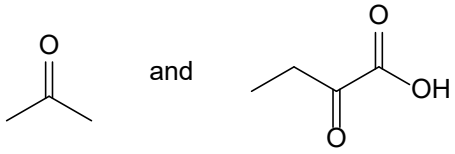
[1]

2a Carbonyl compounds such as ethanal react with hydrogen cyanide, in the presence of trace amount of sodium cyanide, to form cyanohydrins.

(i) Draw the mechanism of this reaction. Show all charges and relevant lone pairs and show the movement of electron pairs by using curly arrows.

[3]

(ii) For the following pair of compounds, describe one simple chemical test which would enable you to distinguish between them. State clearly how each compound behaves in the test.



propanone 2-oxobutanoic acid

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……..[2]

3a Suggest two reasons why phenol has a larger K_a than cyclohexanol.

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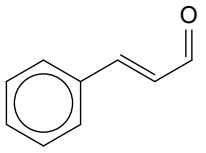
……...[2]

Tutorial Practice Questions (to be attempted **IN CLASS**)

1b Describe the mechanism for the reaction of bromoethane with ammonia, showing curly arrows, charges, dipoles and relevant lone pairs.

[3]

2b **(i)** Describe the mechanism of the reaction between cinnamaldehyde and HCN with trace amount of KOH.



cinnamaldehyde

[3]

(ii) The product mixture obtained at the end of the reaction was optically inactive. Explain why.

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……..[2]

3b State and explain whether phenol has a larger pK_a value than 2-nitrophenol.

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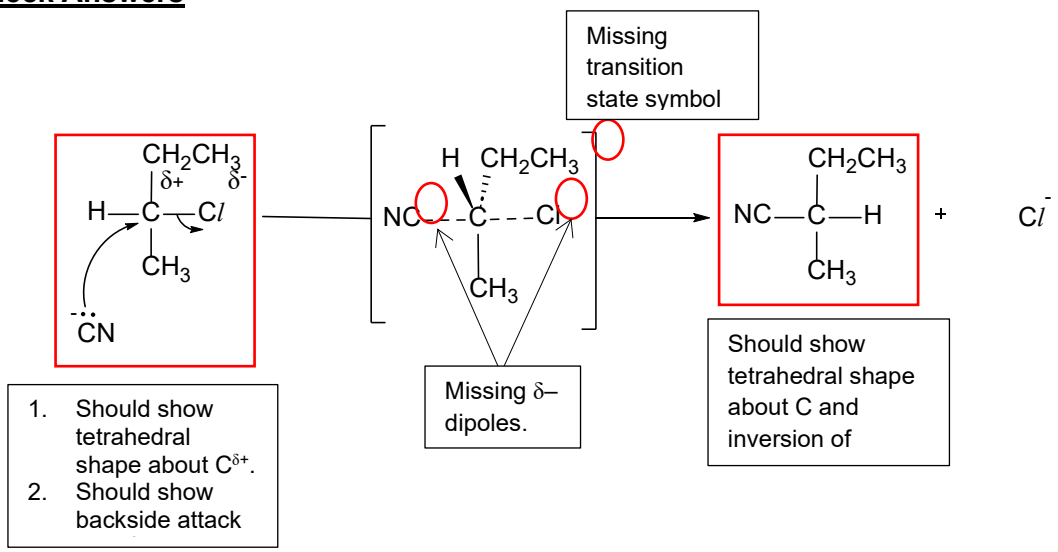
……..……..[2]

Self-Check Answers

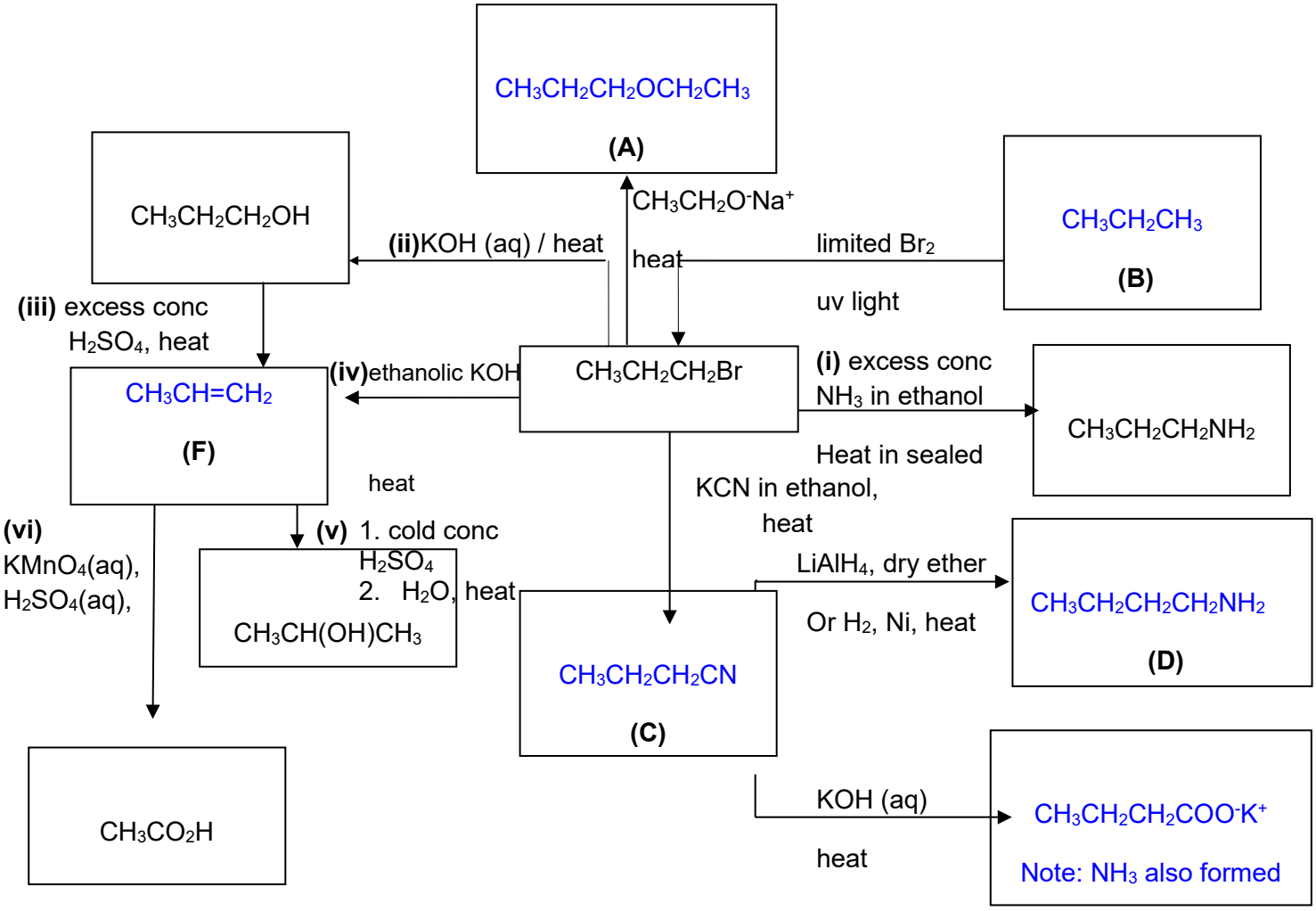
1(a)



1(b) 2-chloro-2-methylbutane forms a <u>stable carbocation</u> with <u>3 electron donating groups</u> which help to <u>disperse positive charge on C</u>. Hence, it undergoes <u>S_N1</u>.

Additionally, the <u>3 bulky</u> alkyl chains <u>hinders the approach of the nucleophile</u> for backside attack, hence, it is unable to undergo <u>S_N2</u>.

2(a)



2(b)

Reaction	Reagents and Conditions
(i)	excess conc NH_3 in ethanol, heat in sealed tube
(ii)	KOH (aq), heat
(iii)	excess conc H_2SO_4, heat
(iv)	ethanolic KOH, heat
(v)	1. cold conc. H_2SO_4 2. H_2O, heat
(vi)	$KMnO_4(aq)$, $H_2SO_4(aq)$, heat

3

✓	2,4-dinitrophenylhydrazine
✓	Fehling's solution, heat
✓	Tollens' reagent, heat
	I_2(aq), NaOH(aq), heat

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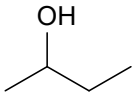
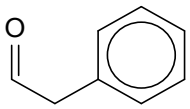
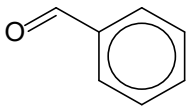


	2,4-dinitrophenylhydrazine
	Fehling's solution, heat
	Tollens' reagent, heat
✓	I_2(aq), NaOH(aq), heat



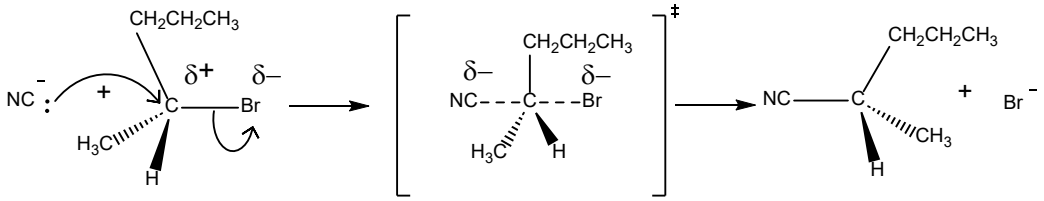
✓	2,4-dinitrophenylhydrazine
✓	Fehling's solution, heat
✓	Tollens' reagent, heat
	I_2(aq), NaOH(aq), heat

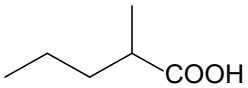


✓	2,4-dinitrophenylhydrazine
	Fehling's solution, heat
✓	Tollens' reagent, heat
	I_2(aq), NaOH(aq), heat

Set A Tutorial Discussion Questions (to complete before Chemfocus session)

1a (i) Nucleophilic substitution S_N2

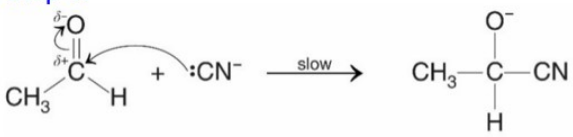


(ii) $CH_3(CH_2)_2CH(CH_3)COOH$ or 

2a (i)

Nucleophilic addition
$NaCN(aq) \longrightarrow Na^+(aq) + CN^-(aq)$
[1] for type of rxn and generation of nucleophile

Step 1:

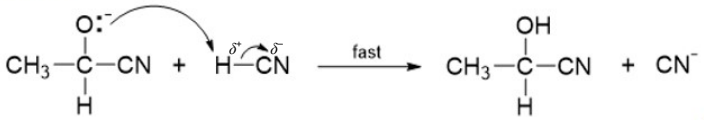


[1]

Checklist for nucleophilic addition mechanism:

- ☐ Name of mechanism
- ☐ Dipoles and relevant charges
  - δ+ on C, δ– on O of C=O
  - δ+ on H, δ– on C of HCN
- ☐ Curly arrows to show flow of e^-
  - Lone pair on Nu to δ+ C
  - C=C bond to δ– O
  - Lone pair on O^- to H (of HCN)
  - H–C bond to C
- ☐ Label slow/fast steps

Step 2:



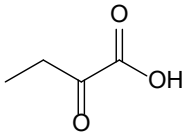
[1]

(ii) Test

Add $Na_2CO_3(aq)$ separately to each compound in separate test tube.

Observation

does not produce effervescence of CO_2, while

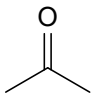


produces effervescence of CO_2 which forms a white ppt in limewater.

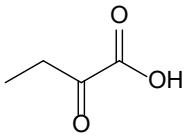
Alternatives:

Test
Add Na(s) separately to each compound in separate test tube.

Observation



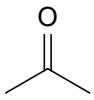
does not produce effervescence of H_2, while



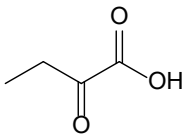
produces effervescence of H_2 which extinguishes lighted splint with a 'pop' sound.

Test
Add PCl_5(s) separately to each compound in separate test tube.

Observation



does not produce white fumes of HCl, while

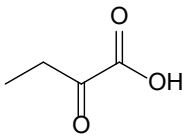


produces white fumes of HCl.

Test
Add I_2(aq), NaOH(aq), separately to each compound in separate test tube. Heat in a hot water bath.

Observation

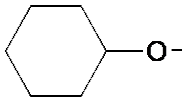
gives a yellow ppt of CHI_3, while



does not give a yellow ppt of CHI_3.

3a (The larger the K_a, the stronger the acid. The strength of an acid is dependent on the stability of the conjugate base. The more stable the conjugate base, the stronger the acid.)

The negative charge of the anion formed by the dissociation of cyclohexanol is further intensified by the electron-donating cyclohexyl group.

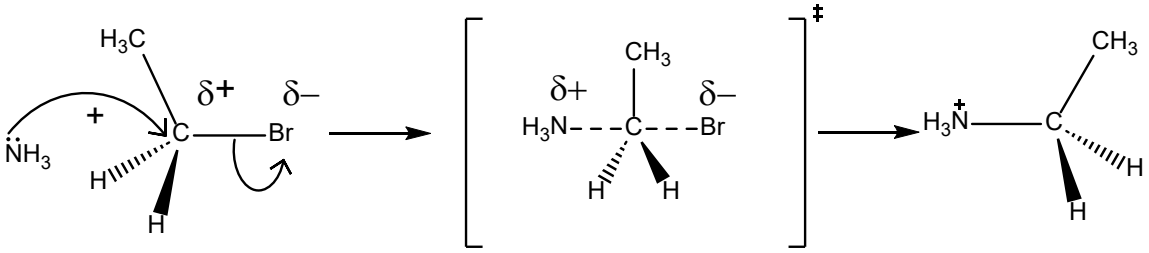


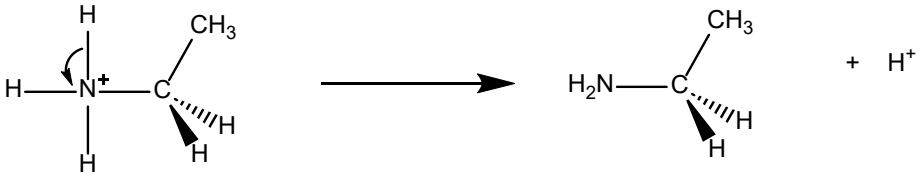
The p-orbital containing the lone pair of electrons on the oxygen atom of the phenoxide ion overlaps with the π electron cloud of the benzene ring and the lone pair of electrons is delocalised into the ring. This results in the delocalisation of negative charge on oxygen into the ring, i.e., dispersal of the negative charge over the ring. Thus, the phenoxide ion is resonance stablised and more stable than the anion of cyclohexanol. Therefore phenol will dissociate to a larger extent as compared to cyclohexanol.

So phenol is more acidic than cyclohexanol and thus have a larger K_a value.

Set A Tutorial Practice Questions (to be attempted **IN CLASS**)

1b Mechanism: Nucleophilic substitution S_N2

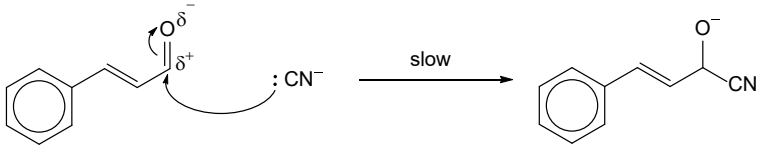




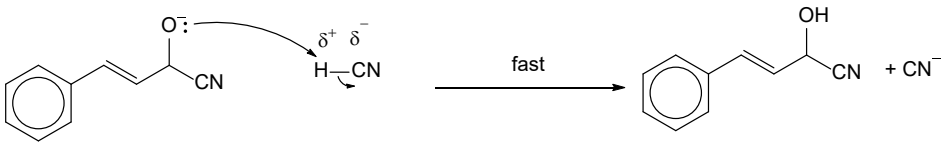
2b (i) Name of mechanism: Nucleophilic Addition

Generation of nucleophile: $HCN + OH^- \longrightarrow CN^- + H_2O$

Step 1:

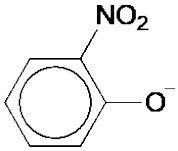
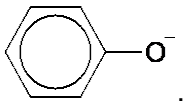


Step 2:



(ii) Since the geometry around the *sp*^{2} hybridised carbonyl carbon atom is trigonal planar, the nucleophile can attack the carbonyl carbon from either side of the plane with equal chance to form a racemic mixture (or racemate) containing equal proportions of the two enantiomers.

3b (The smaller the pK_a, the stronger the acid. The strength of an acid is dependent on the stability of the conjugate base. The more stable the conjugate base, the stronger the acid.)

2-nitrophenol is more acidic than phenol due to the presence of <u>electron-withdrawing group</u>, $-NO_2$, on the benzene ring which <u>disperses the negative charge on the oxygen</u> atom. Thus  is more stable than  .

Therefore, phenol has a <u>larger pK_a value</u> than 2-nitrophenol.