Name: …… ( ) Class: ……..
Date: …….

Raffles Institution
Year 6 H2 Chemistry 2025

Set A T2W9 – Carboxylic Acid and Derivatives, and Nitrogen Compounds

☐— Pre-ChemFocus Activity —☐

- Familiarise yourself with the reactions involving carboxylic acid and its derivatives, and nitrogen compounds and its derivatives.
- To view infopack at IVY > C2025 – H2 CHEMISTRY > Pages > [ChemFocus] Y6 T2W9 Carboxylic Acid and Derivatives, and Nitrogen Compounds > **FIRST VIDEO ONLY**

Notes:

Acidity (recap):

Basicity:

Selectivity of reactions involving carboxylic acids and derivatives, and nitrogen compounds:

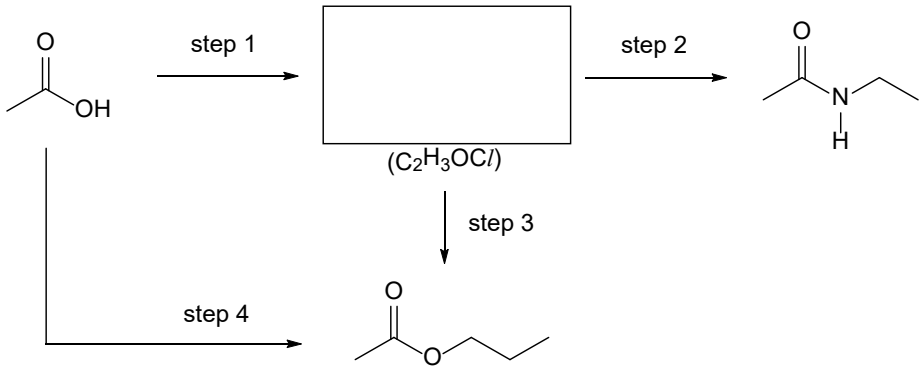
Hydrolysis of acyl chlorides, esters and amides:

Amino acids, major species present at different pH:

Self-Check Questions

Check your answers at IVY > C2025 – H2 CHEMISTRY > Pages > [ChemFocus] Y6 T2W9 Carboxylic Acid and Derivatives, and Nitrogen Compounds > Remaining videos

1 **(a)** Draw the intermediate compound and suggest reagents and conditions for the steps in the following reaction scheme.



Reagents and conditions

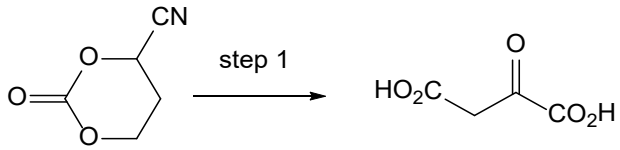
Step 1: ……

Step 2: ……

Step 3: ……

Step 4: ……

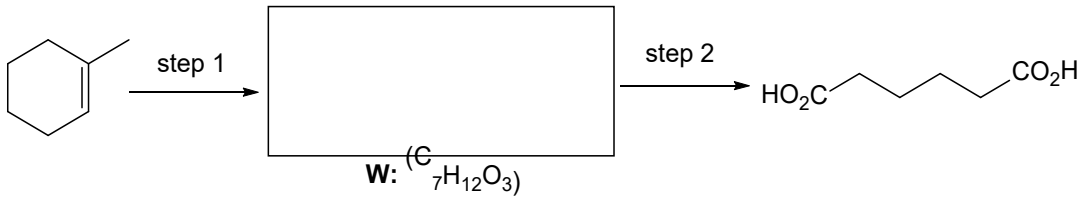
(b)



Reagents and conditions

Step 1: ……

(c)



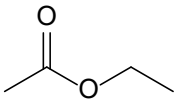
Reagents and conditions

Step 1: ……

Step 2: ……

2 Draw the products formed from the acid or base hydrolysis of the following compounds.

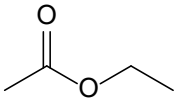
(a)



HC*l*(aq)
heat

+

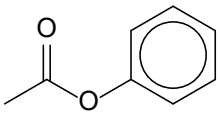
(b)



NaOH(aq)
heat

+

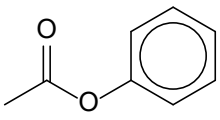
(c)



HC*l*(aq)
heat

+

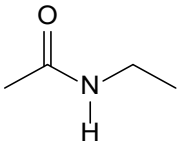
(d)



NaOH(aq)
heat

+

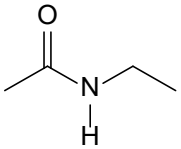
(e)



HC*l*(aq)
heat

+

(f)

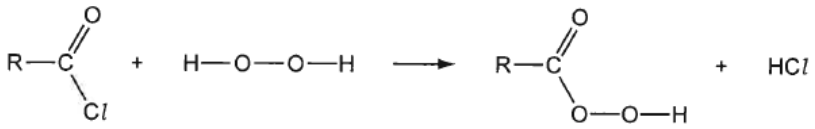


NaOH(aq)
heat

+

Tutorial Discussion Questions (to complete before Chemfocus session)

1a The reaction between acyl chlorides and hydrogen peroxide produces peroxyacids.



The pK_a values of four compounds are listed in the table below.

name	formula	pK_a
water	H_2O	14.0
hydrogen peroxide	H_2O_2	11.7
ethanoic acid	CH_3CO_2H	4.8
peroxyethanoic acid	CH_3CO_3H	8.2

Suggest an explanation for why

- the pK_a of H_2O_2 is less than that for water,
- the pK_a of CH_3CO_3H is greater than that for CH_3CO_2H

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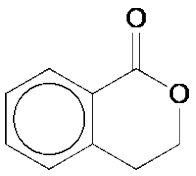
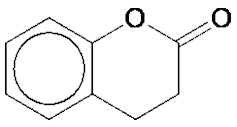
……[3]

2a Suggest a simple chemical test to distinguish between the following pair of compounds.

A: 

B: 

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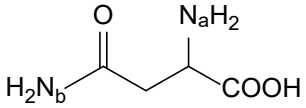
……[2]

3a There are two pK_a values associated with asparagine: α-carboxyl = 2.02 and α-amino = 8.80.



asparagine

(i) Suggest two reasons to explain why N_a is more basic than N_b.

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……

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……..[2]

(ii) Identify the species of asparagine that is present at pH 1, 7 and 10.

pH 1	**pH 7**	**pH 10**

[3]

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

1b A student is provided with the following three compounds:

A	B	C
CH_3COOH	$CH_2C\ell CO_2H$	$CH_3COC\ell$

When equal amounts of each compound were added to separate portions of water of the same volume, solutions are formed with pH values of 0.5, 2.5, and 3.0.

Suggest, with explanations, which pH value is associated with each of **A**, **B**, and **C**.

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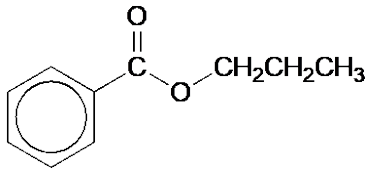
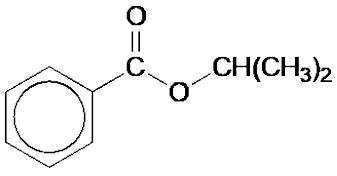
……[2]

2b Suggest a simple chemical test to distinguish between the following pair of compounds.

A: 

B: 

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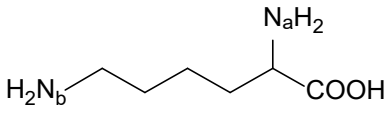
……[2]

3b There are three pK_a values associated with lysine: 2.15, 9.16 and 10.7.



lysine

(i) State and explain whether N_a or N_b is more basic.

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……

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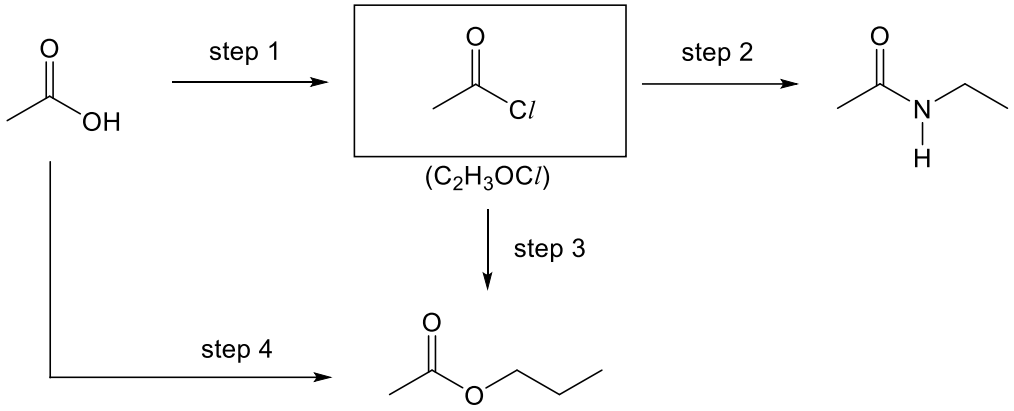
……[2]

(ii) With the use of an equation, explain how a solution containing lysine at pH 10.7 can maintain pH when a small amount of H^+ is added. Show the structure of lysine clearly in your answer.

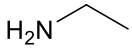
[2]

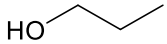
Self-Check Answers

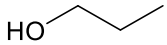
1a



Step 1: PCl_5 or PCl_3 or $SOCl_2$

Step 2: 

Step 3: 

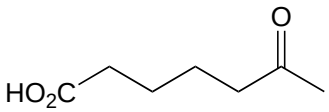
Step 4: 

, conc. H_2SO_4, heat

1b Step 1: $KMnO_4$(aq), H_2SO_4(aq), heat (under reflux)
OR $K_2Cr_2O_7$(aq) H_2SO_4(aq), heat (under reflux)

Note: acidic hydrolysis of ester and nitrile occurred, alongside oxidation of the alcohol after hydrolysis.

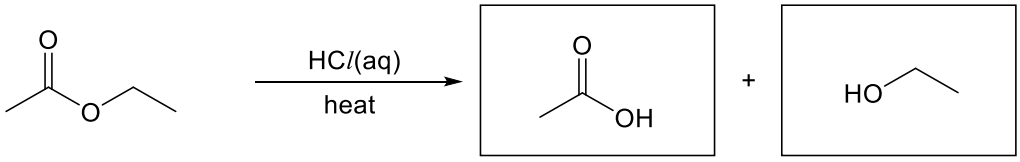
1c

W: 

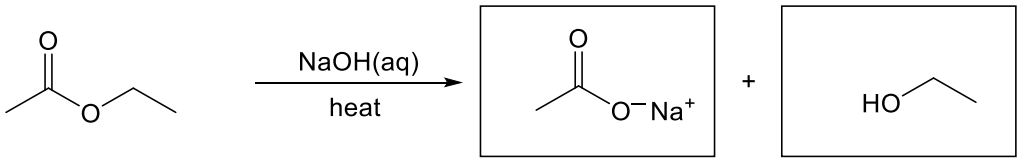
Step 1: $KMnO_4$(aq), H_2SO_4(aq), heat (under reflux)
Step 2: I_2(aq), NaOH(aq) and heat, followed by HCl(aq)/ H_2SO_4(aq)

Note: acid was added in step 2 to neutralise the $–COO^-$ to form –COOH.

2 **(a)**



(b)



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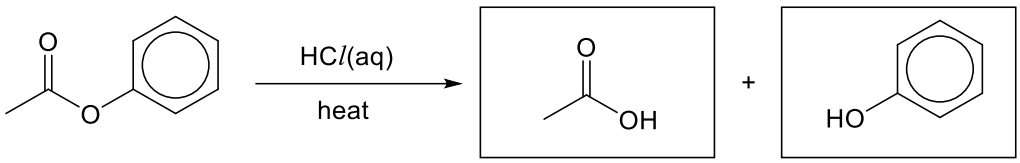
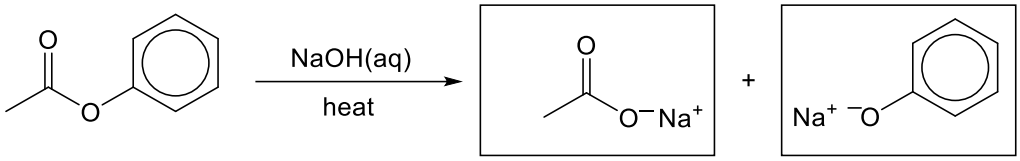
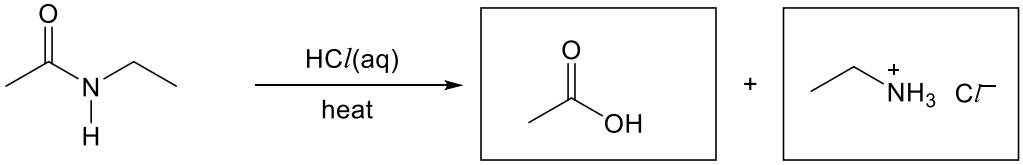


(d)

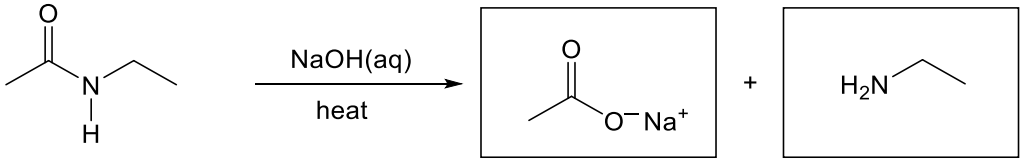


(*Note*: 2 mol of NaOH will be required for the base hydrolysis of 1 mol of this ester)

(e)



(f)



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

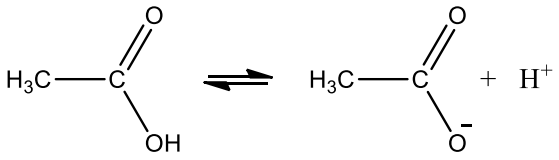
1a The more stable the conjugate base, the stronger the acid.

$$H\text{-}O\text{-}O\text{-}H \rightleftharpoons H\text{-}O\text{-}O^{-} + H^{+}$$

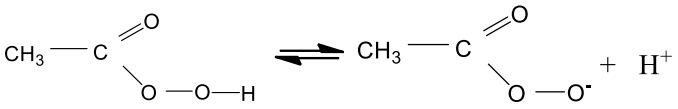
$$H\text{-}O\text{-}H \rightleftharpoons H\text{-}O^{-} + H^{+}$$

The electron withdrawing –OH group bonded to the O atom of HOO^{-} **decreases** the electron density and **disperse the negative charge** on the O atom of the HOO^{-} anion to a greater extent.

Hence, the HOO^{-} anion is more stable than HO^{-} anion and H_2O_2 is more acidic than H_2O. So H_2O_2 has a lower pK_a than water.



CH_3COO^{-} forms 2 equivalent resonance structures with delocalisation of the negative charge over 2 highly electronegative O atoms (resonance effect) and hence the conjugate base of CH_3CO_2H is resonance stabilised.



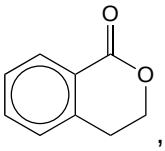
CH_3COOO^{-} is not stabilised by resonance as the negative charge on O atom cannot be delocalized over the C=O group due to the presence of the additional O atom.
Hence, it is only stabilised by a weaker electron withdrawing inductive effect of the CH_3COO- group.

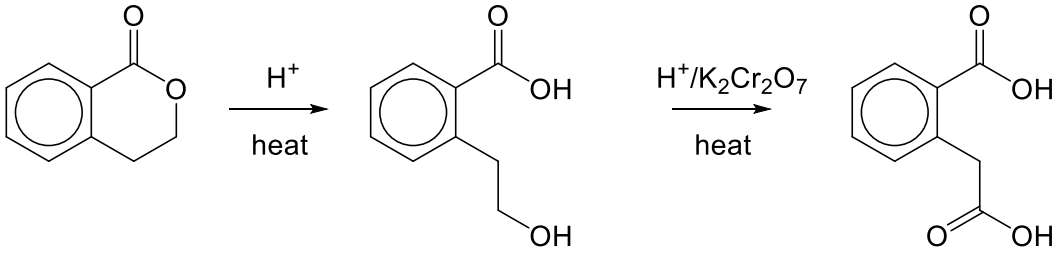
Thus, CH_3COO^{-} is more stable than CH_3COOO^{-} and CH_3CO_2H is a stronger acid than CH_3CO_3H. Thus, the pK_a of CH_3CO_3H is greater than that for CH_3CO_2H.

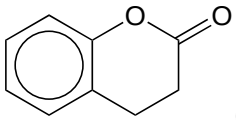
2a Test

Add two drops of $K_2Cr_2O_7$(aq), acidified with dilute H_2SO_4(aq) to each sample in a test-tube, and heat each mixture in a hot water bath. (Note: DO NOT heat under reflux)

Observation:

For  , orange acidified $K_2Cr_2O_7$(aq) turns green



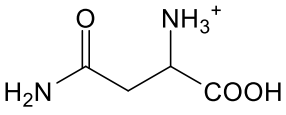


does not turn orange dichromate solution green

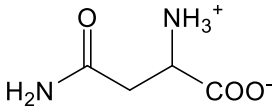
3ai N_a is basic as it has an electron donating group, which increases the electron density about N_a, causing the lone pair of electrons to be more available for dative bonding with H^+.

The orbital containing lone pair of electrons on N_b overlaps with the π-electron cloud of the C=O double bond, causing the lone pair of electrons to delocalise into the C=O. The lone pair of electrons on N_b is not available for dative bonding with H^+.

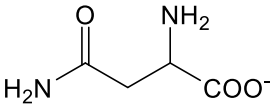
3aii



pH 1



pH 7



pH 10

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

1b

	A	B	C
	CH_3COOH	CH_2ClCO_2H	CH_3COCl
pH	3.0	2.5	0.5

For compound A: The negative charge of the conjugate base CH_3COO^- is dispersed by the delocalisation of the negative charge over 2 highly electronegative O atoms.

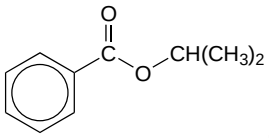
For compound B: The presence of an extra electronegative Cl atom further disperses the negative charge on the CH_2ClCOO^-, which favours the dissociation of the acid, this results in more H^+ dissociated, hence a lower pH value.

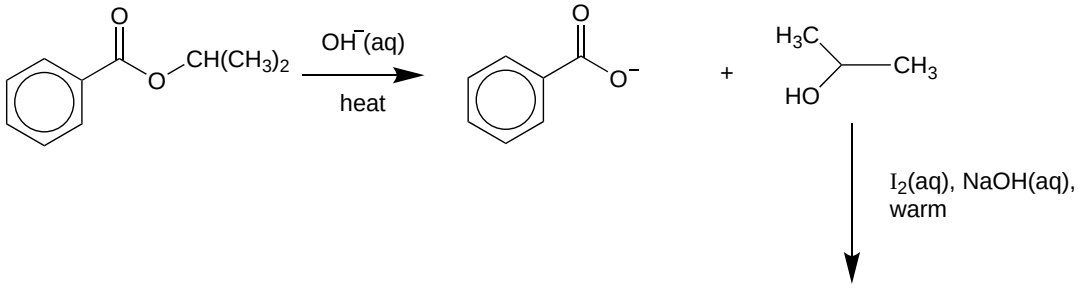
For compound C: CH_3COCl readily hydrolyses in water to produce CH_3COOH and HCl. HCl is a strong acid, which dissociates fully in water to produce H^+ ions, hence it will have the lowest pH value

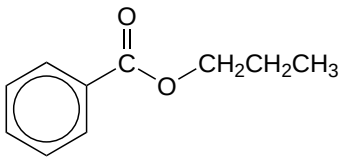
2b Test

Add I_2(aq), followed by NaOH(aq) to each sample in a test-tube and heat each mixture in a hot water bath. (Note: DO NOT heat under reflux)

Observation:

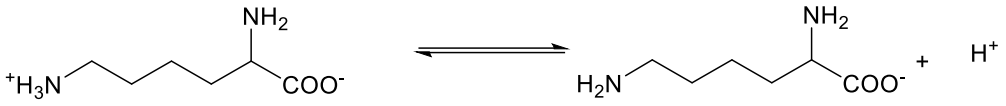
For  , yellow ppt of CHI_3 is formed.



No yellow ppt observed for 

3bi N_a is less basic as the electron withdrawing –COOH is of closer proximity to N_a than N_b. Hence, the electron withdrawing effect is greater on N_a than N_b, causing the lone pair of electrons on N_a to be less available for dative bonding with H^+.

3bii



When small amounts of H^+ is added, $[H^+]$ increases. This causes the backward reaction is favoured to partially offset the increase in $[H^+]$, causing position of equilibrium to shift to the left. This results in a small derease in pH.