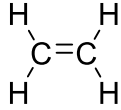
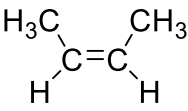
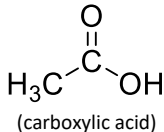
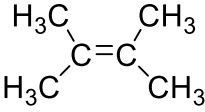
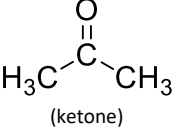
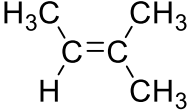
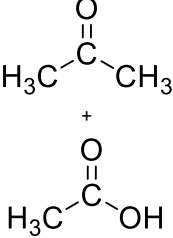

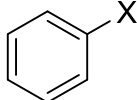
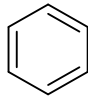
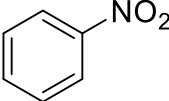
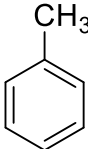
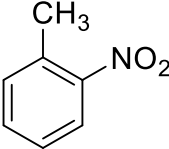
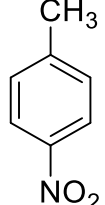
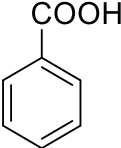
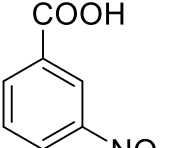


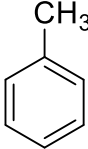
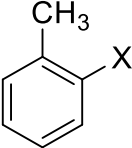
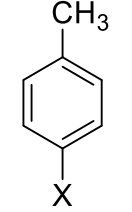
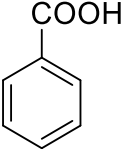
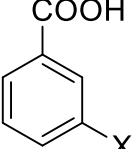
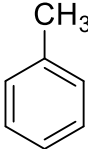
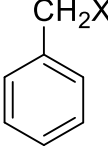
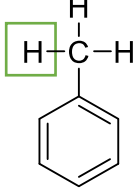
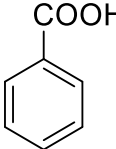
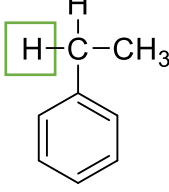
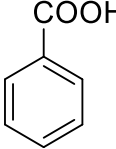
Reagents and Conditions (RnC)

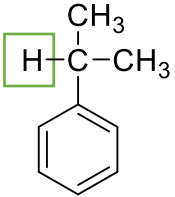
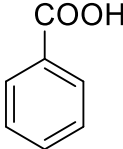
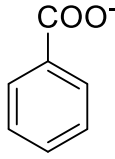
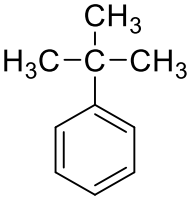

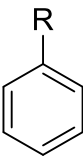

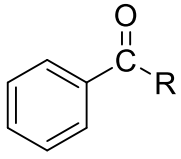
Alkanes					
N	Reactants	Reagents and Conditions	Products	Type of Reaction	Remarks
1	CH_4	Heat in Excess O_2	$\text{CO}_2 + 2\text{H}_2\text{O}$	Oxidation	<p style="text-align: center;">Combustion</p> Very exothermic but with high activation energy (requires heat/spark)
2	CH_4	X_2 , UV light/heat, X = Halogens	$\text{CH}_3\text{X} + \text{HX}$	Free Radical Substitution	Limited X_2 will cause mono-substitution. Limited CH_4 will cause multiple substitution
Alkenes					
N	Reactants	Reagents and Conditions	Products	Type of Reaction	Remarks
1	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}=\text{CH}_2 \\ \\ \text{H} \end{array}$	$\text{H}_2(\text{g})$, Ni Catalyst, heat OR $\text{H}_2(\text{g})$, Pt or Pd catalyst, room temperature	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array}$	Reduction	<p style="text-align: center;">Hydrogenation</p> Ni/Pt/Pd is acting as a heterogeneous catalyst. This is not an electrophilic addition reaction as H_2 is non-polar.
2	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}=\text{CH}_2 \\ \\ \text{H} \end{array}$	$\text{HX}(\text{g})$ room temperature. X = Cl, Br, I	$\begin{array}{c} \text{H} \quad \text{X} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array}$ (Major product) + $\begin{array}{c} \text{X} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array}$ (Minor product)	Electrophilic Addition	Apply Markonikov's rule. (More stable carbocation intermediate will be the major product) Reactivity: $\text{HI} > \text{HBr} > \text{HCl}$ HI has the highest reactivity as the H-I bond is weakest (lowest bond energy) HF is not included as the H-F bond is too strong, hence, this reaction is not feasible. One of the common mistakes is to assume that decreasing electronegativity is the main factor. $\text{HCl} > \text{HBr} > \text{HI}$ Electronegativity does affect the rate but only to a small extent.

3	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}=\text{CH}_2 \\ \\ \text{H} \end{array}$	<p>$\text{H}_2\text{O}(\text{g}), \text{H}_3\text{PO}_4(\text{aq})$ catalyst, 300°C, 60 atm</p> <p><u>OR</u></p> <p>(1) Conc. $\text{H}_2\text{SO}_4(\text{l})$, room temperature (2) $\text{H}_2\text{O}(\text{l})$ Heat</p>	$\begin{array}{c} \text{H} \quad \text{OH} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array}$ <p>(Major product)</p> <p>+</p> $\begin{array}{c} \text{OH} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array}$ <p>(Minor product)</p>	Electrophilic Addition	<p>Hydration</p> <p>Apply Markonikov's rule (More stable carbocation intermediate will be the major product) Concentrated acids such as H_2SO_4. The state symbols will be in (l)</p>
4	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}=\text{CH}_2 \\ \\ \text{H} \end{array}$	<p>X_2 (X = Cl or Br) in CCl_4, absence of UV light</p>	$\begin{array}{c} \text{X} \quad \text{X} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array}$	Electrophilic Addition	<p>Halogenation Chlorination Bromination</p> <p>Yellowish-green Cl_2 decolourise. Orange Br_2 decolourise.</p> <p>Absence of UV light is to avoid free radical substitution of the final product or the side chain alkyl.</p> <p>$\text{d}^+ \quad \text{d}^-$ $\text{I}-\text{Cl}$</p>
	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}=\text{CH}_2 \\ \\ \text{H} \end{array}$	<p>ICI in CCl_4, room temperature</p>	$\begin{array}{c} \text{I} \quad \text{Cl} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array}$	Electrophilic Addition	
5	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}=\text{CH}_2 \\ \\ \text{H} \end{array}$	<p>$\text{Br}_2(\text{aq})$, room temperature</p>	$\begin{array}{c} \text{Br} \quad \text{OH} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array}$ <p>(Major product)</p> <p>+</p> $\begin{array}{c} \text{Br} \quad \text{Br} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array}$ <p>(Minor product)</p> <p>+ HBr</p>	Electrophilic Addition	<p>Orange Br_2 decolourise. Distinguishing test for alkene.</p> <p>Major product is the one substituted with OH. H_2O although as weaker nucleophile than Br is present in large concentration hence outcompete the Br as the nucleophile. HBr is only formed when the major product is formed, when the minor product no HBr is formed.</p> <p>$\text{Cl}_2(\text{aq})$ can also react the same way as $\text{Br}_2(\text{aq})$. Yellowish-green Cl_2 decolourise.</p>
6	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}=\text{CH}_2 \\ \\ \text{H} \end{array}$	<p>Dilute $\text{KMnO}_4(\text{aq})$, $\text{NaOH}(\text{aq})$, cold</p> <p><u>OR</u></p> <p>Dilute $\text{H}_2\text{SO}_4(\text{aq})$, $\text{KMnO}_4(\text{aq})$, cold</p>	$\begin{array}{c} \text{OH} \quad \text{OH} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array}$	Oxidation	<p>Mild Oxidation</p> <p>Purple $\text{KMnO}_4(\text{aq})$ decolourise. Under alkaline condition, brown MnO_2 ppt is formed. Distinguishing test for the presence of alkene. (only alkene shows a reaction with this RnC)</p>

7	 <p>(1° alkene)</p>	<p>Concentrated KMnO₄(aq) H₂SO₄(aq, heat/ HUR <u>OR</u> Concentrated KMnO₄(aq), NaOH(aq), heat/HUR</p>	$2\text{CO}_2 + 2\text{H}_2\text{O}$	<p>Oxidation</p>	<p>Strong Oxidation Oxidative Cleavage</p> <p>K₂Cr₂O₇ is not oxidising enough for this reaction. Can be used as a test for presence of alkenes, purple KMnO₄ is decolourised. Brown ppt of MnO₂ is formed in alkaline condition. For terminal alkenes, effervescence of CO₂ observed. When bubbled through limewater, forms white ppt.</p>
	 <p>(2° alkene)</p>	<p>Concentrated KMnO₄(aq) H₂SO₄(aq), heat/ HUR <u>OR</u> Concentrated KMnO₄(aq), NaOH(aq), heat/HUR</p>	 <p>(carboxylic acid)</p>	<p>Oxidation</p>	
	 <p>(3° alkene)</p>	<p>Concentrated KMnO₄(aq) H₂SO₄(aq, heat/ HUR <u>OR</u> Concentrated KMnO₄(aq), NaOH(aq), heat/HUR</p>	 <p>(ketone)</p>	<p>Oxidation</p>	
	 <p>(2° and 3° alkene)</p>	<p>Concentrated KMnO₄(aq) H₂SO₄(aq, heat/heat under reflux(HUR) <u>OR</u> Concentrated KMnO₄(aq), NaOH(aq), heat/HUR</p>		<p>Oxidation</p>	

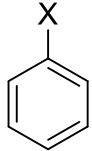
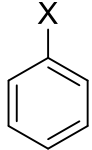
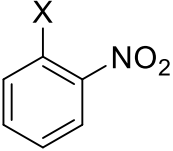
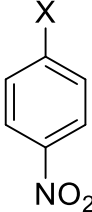
Arenes					
N	Reactants	Reagents and Conditions	Products	Type of Reaction	Remarks
1		X₂ (X = Cl or Br) Anhydrous AlX₃, FeX₃, room temperature OR Finely divided iron and Cl ₂ gas (forms FeX ₃)	 + HX	Electrophilic Substitution	Halogenation Chlorination Bromination The Lewis acid catalyst (AlX ₃ /FeX ₃) must be anhydrous as it undergoes hydrolysis when in contact with water due to the high charge density of the metal cation. (+3) The Lewis acid catalyst will cease to work.
2		Conc. H ₂ SO ₄ , Conc. HNO ₃ , 55°C $\text{HNO}_3 + 2\text{H}_2\text{SO}_4 \rightleftharpoons 2\text{HSO}_4^- + \text{NO}_2^+ + \text{H}_3\text{O}^+$	 + H₂O	Electrophilic Substitution	Nitration At a higher temperature, further substitutions may occur at 3 positions relative to the NO ₂ group due to the electron withdrawing effect of NO ₂
3	 (methyl benzene)	Conc. H ₂ SO ₄ , Conc. HNO ₃ 30°C $\text{HNO}_3 + 2\text{H}_2\text{SO}_4 \rightleftharpoons 2\text{HSO}_4^- + \text{NO}_2^+ + \text{H}_3\text{O}^+$	  + H₂O	Electrophilic Substitution	Nitration Electron donating methyl group increases electron density in the benzene (activates the ring), making methyl benzene more reactive and more susceptible to an electrophilic attack, hence lower temp is used. Substitution would be at the 2-4 position as -CH ₃ is electron donating on a benzene ring.
4	 (benzoic acid) (white ppt)	Conc. H ₂ SO ₄ , Conc. HNO ₃ 90°C $\text{HNO}_3 + 2\text{H}_2\text{SO}_4 \rightleftharpoons 2\text{HSO}_4^- + \text{NO}_2^+ + \text{H}_3\text{O}^+$	 + H₂O	Electrophilic Substitution	Nitration Carboxylic group on a benzene ring is electron withdrawing in nature hence decreases electron density (deactivates the ring) making benzoic acid less reactive and less susceptible to an electrophilic attack, hence a higher temperature (>60°C) is needed Substitution would be at the 3 positions as COOH is electron withdrawing on a benzene ring.

5		Anhydrous FeX_3 X_2 , ($\text{X}=\text{Cl}$ or Br), dark OR Finely divided iron in X_2 , room temperature, dark	  $+2 \text{HX}$	Electrophilic Substitution	Halogenation Reaction is carried out in the dark to avoid free-radical substitution from taking place on the methyl.
6		Anhydrous $\text{AlX}_3/\text{FeX}_3$, heat OR Finely divided iron in X_2 gas (forms FeX_3) heat X_2 ($\text{X} = \text{Cl}$ or Br)	 $+\text{HX}$	Electrophilic Substitution	Halogenation COOH is electron withdrawing on the benzene ring hence decreases the electron density on the benzene ring (deactivates the benzene ring), making benzoic acid less reactive and less susceptible to an electrophilic attack hence heating is required. $\text{FeBr}_3/\text{AlBr}_3$ can be used in place of $\text{AlCl}_3/\text{FeCl}_3$
7		Limited X_2 (g) ($\text{X} = \text{Cl}$ or Br) UV light/heat	 $+\text{HX}$	Free-Radical Substitution	Halogenation Limited X_2 is to prevent further substitution of the product.
8		KMnO_4 (aq), H_2SO_4 (aq) HUR OR KMnO_4 (aq), NaOH (aq), HUR	 $+\text{H}_2\text{O}$	Oxidation	Side-Chain Oxidation $\text{K}_2\text{Cr}_2\text{O}_7$ is not a strong enough oxidising agent for this reaction. Oxidation of side chain of a benzene ring only happens when the carbon directly attached to the benzene ring has at least one hydrogen atom attached to it. Purple KMnO_4 decolourises. In
		KMnO_4 (aq), H_2SO_4 (aq) HUR OR KMnO_4 (aq), NaOH (aq), HUR	 $+\text{CO}_2 + 2\text{H}_2\text{O}$	Oxidation	

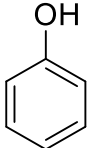
		<p>KMnO_4 (aq), H_2SO_4(aq) HUR OR KMnO_4(aq), NaOH(aq), HUR</p>	 $+2\text{CO}_2 + 3\text{H}_2\text{O}$	Oxidation	<p>alkaline condition, a brown precipitate of MnO_2 is also observed, and benzoate ion is formed instead.</p>  (benzoate) Benzoate is soluble while benzoic is a white ppt in H_2O
		<p>KMnO_4 (aq), H_2SO_4(aq) HUR OR KMnO_4(aq), NaOH(aq), HUR</p>	No reaction		
		<p>KMnO_4 (aq), H_2SO_4(aq) HUR OR KMnO_4(aq), NaOH(aq), HUR</p>		Oxidation	
9		<p>RX (X = Cl or Br), Anhydrous $\text{FeX}_3/\text{AlX}_3$, room temperature OR RX, Fe in X_2 gas (forms FeX_3), room temperature $\text{RX} + \text{FeX}_3 \rightarrow \text{R}^+ + \text{FeX}_4^-$</p>	 $+ \text{HX}$	Electrophilic Substitution	<p>Friedel Craft Alkylation</p> <p>Lewis acid catalyst is used to generate a stronger electrophile R^+</p>
		<p>$\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{X}$ (X = Cl or Br) Anhydrous FeX_3, AlX_3, room temperature OR RCOX, Fe in X_2 gas (forms FeX_3), room temperature $\text{FeX}_3 + \text{RCOX} \rightarrow \text{RCO}^+ + \text{FeX}_4^-$</p>	 $+ \text{HX}$	Electrophilic Substitution	<p>Friedel Craft Acylation</p> <p>Lewis acid catalyst is used to generate a stronger electrophile RCO^+</p>

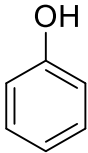
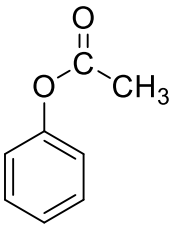
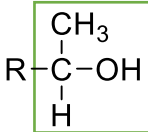
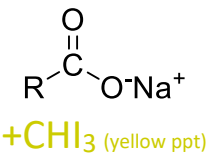
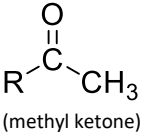
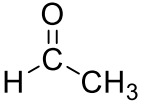
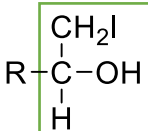
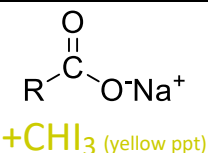
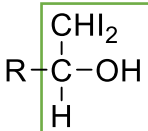
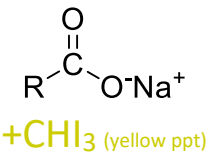
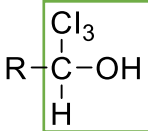
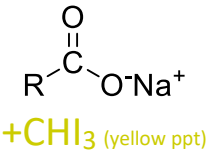
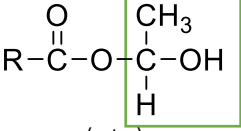
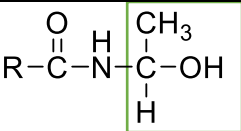
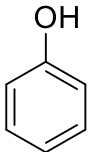
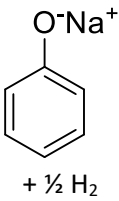
Halogen Derivatives (Alkyl halides and aryl halides)					
N	Reactants	Reagents and Conditions	Products	Type of Reaction	Remarks
1	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{Cl} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	NaOH/KOH(aq), HUR	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{OH} \\ +\text{NaCl} \end{array}$	Nucleophilic Substitution	KOH(aq) can also be used When 2 or 3 -OH groups (geminal diols) attached to the same carbon. This compound is unstable, and one molecule of water will be eliminated
	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{Cl} \\ \quad \\ \text{H} \quad \text{Cl} \end{array}$	NaOH/KOH(aq), HUR	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{OH} \\ \downarrow \\ \begin{array}{c} \text{O} \\ \\ \text{H}_3\text{C}-\text{C}-\text{H} \\ +2\text{NaCl} \end{array} \end{array}$	Nucleophilic Substitution	
	$\begin{array}{c} \text{H} \quad \text{Cl} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{Cl} \\ \quad \\ \text{H} \quad \text{Cl} \end{array}$	NaOH/KOH(aq), HUR	$\begin{array}{c} \text{H} \quad \text{OH} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{OH} \\ \downarrow \\ \begin{array}{c} \text{O} \\ \\ \text{H}_3\text{C}-\text{C}-\text{OH} \\ +3\text{NaCl} \end{array} \end{array}$	Nucleophilic Substitution	
2	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{Cl} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	Excess ethanolic NH ₃ , heat in sealed tube	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{NH}_2 \\ \quad \\ \text{H} \quad \text{H} \\ +\text{HCl} \end{array}$	Nucleophilic Substitution	Sealed tube to prevent NH ₃ (g) from escaping. When NH ₃ is in excess, there will be mono-substitution between NH ₃ and RX.

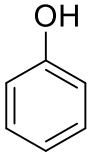
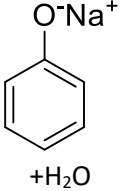
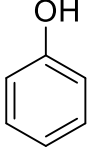
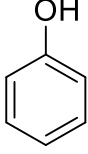
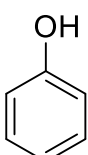
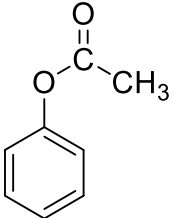
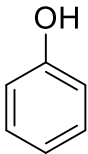
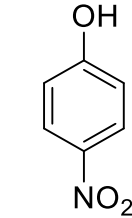
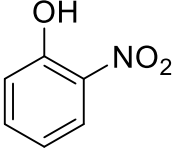
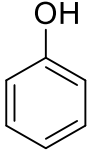
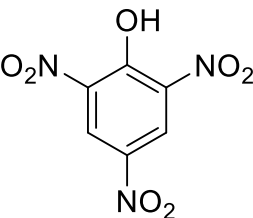
3	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{Cl} \\ \quad \\ \text{H} \quad \text{H} \\ \text{(excess)} \end{array} $	Ethanolic NH_3 , heat in sealed tube	$ \begin{array}{c} \text{CH}_2\text{CH}_3 \\ \\ \text{H}_3\text{CH}_2\text{C}-\text{N}^+-\text{CH}_2\text{CH}_3 \\ \\ \text{CH}_2\text{CH}_3 \\ \text{Cl}^- \end{array} $	Nucleophilic Substitution	Sealed tube to prevent NH_3 (g) from escaping. When RX is in excess, there will be multiple substitution between NH_3 and RX to form 2°, 3° and quaternary ammonium salts. This is because after substitution, N in RNH_2 still has a lone pair of electrons and is even more electron rich due to the extra electron donating R group. Quaternary ammonium salt is an ionic compound hence exists as a white crystalline solid with high melting and boiling point. It can give immediate white precipitation with aqueous AgNO_3 and $\text{Pb}(\text{NO}_3)_2$.
4	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{Cl} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	Ethanolic CH_3NH_2 , HUR	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{N}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \\ +\text{HCl} \end{array} $	Nucleophilic Substitution	CH_3NH_2 reacts faster than NH_3 as the nitrogen atom is more electron rich in CH_3NH_2 than the nitrogen atom in NH_3 due to the electron donating effect of $-\text{CH}_3$.
5	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{Cl} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	Ethanolic NaCN/KCN , HUR	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CN} \\ \quad \\ \text{H} \quad \text{H} \\ +\text{NaCl} \end{array} $	Nucleophilic Substitution	Addition of one carbon atom. (Step-up reaction)
6	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{CH}_3 \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \quad \\ \text{H} \quad \text{Cl} \quad \text{H} \end{array} $	Ethanolic NaOH/KOH , HUR	$ \begin{array}{c} \text{H} \quad \quad \text{CH}_3 \\ \diagdown \quad / \\ \text{C}=\text{C} \\ / \quad \diagdown \\ \text{H}_3\text{C} \quad \quad \text{CH}_3 \\ \text{(Major product)} \end{array} $ $ \begin{array}{c} \text{H} \quad \quad \text{H} \\ \diagdown \quad / \\ \text{C}=\text{C} \\ / \quad \diagdown \\ \text{H} \quad \quad \text{CH}(\text{CH}_3)_2 \\ \text{(Minor product)} \\ +2 \text{HCl} \end{array} $	Elimination	Apply Saytzeff's Rule to obtain the major product (The major product is the more substituted alkene).
7	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CN} \\ \quad \\ \text{H} \quad \text{H} \\ \text{CH}_3\text{CH}_2\text{CN} + \text{HCl} + 2\text{H}_2\text{O} \rightarrow \\ \text{CH}_3\text{CH}_2\text{COOH} + \text{NH}_4\text{Cl} \end{array} $	$\text{HCl}(\text{aq})$ OR $\text{H}_2\text{SO}_4(\text{aq})$, HUR	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{COOH} \\ \quad \\ \text{H} \quad \text{H} \\ +\text{NH}_4\text{Cl} \end{array} $	Acid Hydrolysis	NH_3 is formed from the CN group undergoing hydrolysis which reacts with acid to form NH_4^+Cl^- .

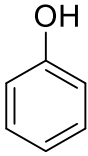
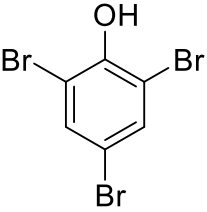
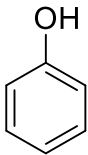
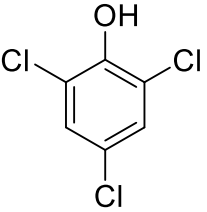
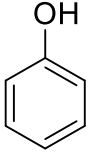
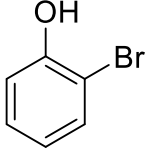
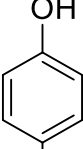
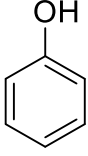
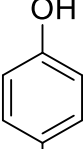
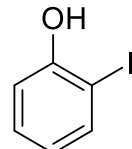
8	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CN} \\ \quad \\ \text{H} \quad \text{H} \end{array}$ $\text{CH}_3\text{CH}_2\text{CN} + \text{NaOH} + 2\text{H}_2\text{O} \rightarrow \text{CH}_3\text{CH}_2\text{COO}^- \text{Na}^+ + \text{NH}_3$	NaOH/KOH(aq), HUR	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{COO}^- \\ \quad \\ \text{H} \quad \text{H} \end{array}$ $+\text{NH}_3$	Alkaline Hydrolysis	NH ₃ is formed from the CN group undergoing hydrolysis. Pungent gas, NH ₃ is evolved. Can be used as a distinguishing test for CN.
9	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CN} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	LiAlH₄ in dry ether, room temp OR Na in ethanol, room temp OR H ₂ , Pt or Pd catalyst room temp OR H ₂ , Ni catalyst heat	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_2\text{NH}_2 \\ \quad \\ \text{H} \quad \text{H} \end{array}$	Reduction	Na in ethanol is a reducing agent that is specific to the CN group. (only for CN group) LiAlH ₄ must be in dry ether and not water as it reacts very exothermically with water (explodes)
10	 <p>X = F, Cl, Br</p>	NaOH(aq), Heat under reflux	No Reaction		The p orbital of X overlaps with the pi orbital of the benzene carbon resulting in the delocalisation of the lone pair of electrons on X into the benzene ring. This strengthens the C-X bond by forming a partial double bond character in the C-X bond. The high electron density of the benzene ring repels potential nucleophiles from attacking. Therefore, halogenoarenes (aryl halide) are resistant to nucleophilic substitution
		Excess ethanolic NH ₃ , heat in sealed tube	No Reaction		
		Ethanolic NaCN, HUR	No Reaction		
11	 <p>X = F, Cl, Br</p>	Conc. H ₂ SO ₄ , Conc. HNO ₃ , 90°C	  $+2\text{H}_2\text{O}$	Electrophilic Substitution	Nitration Electron withdrawing halogen group reduces the electron density of the benzene ring and deactivates the benzene ring; thus, higher temperature is needed. Electron-withdrawing halogen group is 2-4 directing. (Different from the rest of the electron-withdrawing groups)

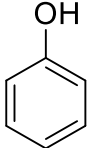
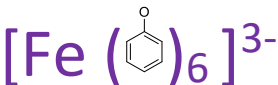
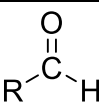
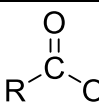
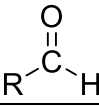
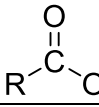
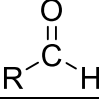
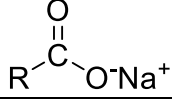
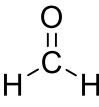
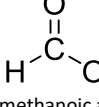
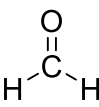
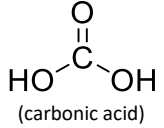

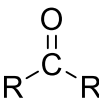
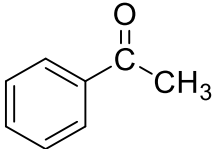
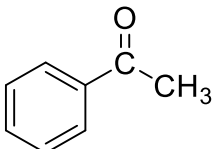
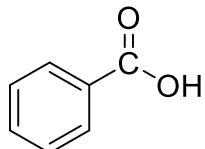
Hydroxyl Compounds (Alcohols and Phenols)					
S/N	Reactants	Reagents and Conditions	Products	Type of Reaction	Remarks
1	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	Excess O ₂	2CO ₂ + 3H ₂ O	Oxidation	Combustion
2	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	Na(s), room temperature	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{O}^-\text{Na}^+ \\ \quad \\ \text{H} \quad \text{H} \end{array}$ + ½ H ₂	Reduction/ Acid-metal	This reaction is similar to strong acid such as HCl reacting with metals. Effervescence of H ₂ gas evolved which produces a pop sound with lighted split. (test for H ₂ gas)
3	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	NaOH/KOH(aq) OR Na ₂ CO ₃ (aq) OR NaHCO ₃ (aq), room temperature		No Reaction	Alcohol is not acidic enough to react with alkali or carbonates
4	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array}$ CH ₃ CH ₂ OH + PCl ₅ → CH ₃ CH ₂ Cl + POCl ₃ + HCl CH ₃ CH ₂ OH + SOCl ₂ → CH ₃ CH ₂ Cl + SO ₂ + HCl	PCl ₅ /SOCl ₂ , room temperature OR NaCl, conc. H ₂ SO ₄ , HUR (forms HCl) OR PCl ₃ room temperature OR HCl(g), heat OR ZnCl ₂ in conc. HCl	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{Cl} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	Nucleophilic Substitution	Steamy white fumes of HCl evolved when using SOCl ₂ /PCl ₅ (not with PCl ₃). Heating NaCl with conc. H ₂ SO ₄ generates HCl which undergoes nucleophilic substitution with OH group.
5	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array}$ CH ₃ CH ₂ OH + PBr ₃ → CH ₃ CH ₂ Br + H ₃ PO ₃	PBr ₃ room temperature OR NaBr, conc. H ₂ SO ₄ , HUR (forms HBr) OR HBr(g), Heat	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{Br} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	Nucleophilic Substitution	Heating NaBr with conc. H ₂ SO ₄ generates HBr which undergoes nucleophilic substitution with OH group
6	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array}$ CH ₃ CH ₂ OH + PI ₃ → CH ₃ CH ₂ I + H ₃ PO ₃	Red phosphorus, I ₂ , heat-in-situ	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{I} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	Nucleophilic Substitution	Red phosphorus when heated in situ with I ₂ produces PI ₃ which immediately undergoes nucleophilic substitution with alcohol to form iodoalkane. PI ₃ is not used directly as PI ₃ is unstable at room temperature.
7	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array}$ (1° alcohol)	K ₂ Cr ₂ O ₇ (aq), H ₂ SO ₄ (aq) HUR OR KMnO ₄ (aq), H ₂ SO ₄ (aq) HUR	$\begin{array}{c} \text{H} \quad \text{O} \\ \quad // \\ \text{H}-\text{C}-\text{C} \\ \quad \\ \text{H} \quad \text{OH} \end{array}$ (carboxylic acid)	Oxidation	Purple KMnO ₄ decolourises. Alkaline conditions can also be used, Brown ppt of MnO ₂ will be formed.

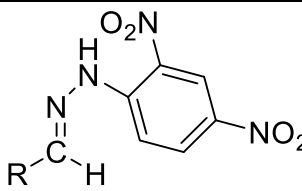
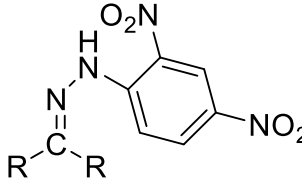
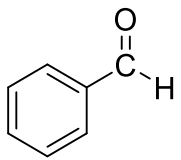
	$\begin{array}{c} \text{OH} \\ \\ \text{R}-\text{C}-\text{H} \\ \\ \text{R} \end{array}$ <p>(2° alcohol)</p>	$\text{K}_2\text{Cr}_2\text{O}_7$ (aq), H_2SO_4 (aq) HUR OR KMnO_4 (aq), H_2SO_4 (aq) HUR	$\begin{array}{c} \text{O} \\ \\ \text{R}-\text{C}-\text{R} \end{array}$ <p>(ketone)</p>	Oxidation	Orange $\text{K}_2\text{Cr}_2\text{O}_7$ turns green
8	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array}$ <p>(1° alcohol)</p>	$\text{K}_2\text{Cr}_2\text{O}_7$ (aq), H_2SO_4 (aq) Heat with immediate distillation	$\begin{array}{c} \text{H} \quad \text{O} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$ <p>(aldehyde)</p>	Oxidation	Controlled Oxidation This is the only way to produce an aldehyde in the syllabus. KMnO_4 cannot be used as it is too strong an oxidising agent which will oxidise alcohol to carboxylic acid too quickly
9	$\begin{array}{c} \text{H} \quad \text{CH}_3 \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{CH}_3 \end{array}$ <p>(3° alcohol)</p>	$\text{K}_2\text{Cr}_2\text{O}_7$ (aq), H_2SO_4 (aq), HUR OR KMnO_4 (aq), H_2SO_4 (aq) HUR	No Reaction		3° alcohol cannot be oxidised
10	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{CH}_3 \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \quad \\ \text{H} \quad \text{OH} \quad \text{H} \end{array}$	Excess concentrated H_2SO_4 , 170°C OR Al_2O_3 350°C	$\begin{array}{c} \text{H} \quad \text{CH}_3 \\ \quad \\ \text{C}=\text{C} \\ \quad \\ \text{H}_3\text{C} \quad \text{CH}_3 \end{array}$ <p>(Major product)</p> $\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{C}=\text{C} \\ \quad \\ \text{H} \quad \text{CH}(\text{CH}_3)_2 \end{array}$ <p>(Minor product)</p> <p>+2H₂O</p>	Elimination	Dehydration One H ₂ O molecule is eliminated as a by-product. The key to identifying elimination reaction is the formation of double bond (C=C in this case) Use Saytzeff's rule to determine the major product (more substituted alkene is preferred)
11	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	CH_3COOH Concentrated H_2SO_4 (catalyst), HUR	$\begin{array}{c} \text{H} \quad \text{O} \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{O}-\text{C}-\text{CH}_3 \\ \\ \text{H} \end{array}$ <p>+H₂O</p>	Condensation	Esterification Phenol is unable to undergo condensation with carboxylic acids as it is not nucleophilic enough. This is a reversible and slow reaction. H_2SO_4 acts as an acid catalyst as well as a dehydrating agent which removes H ₂ O, shifting the POE to the right and increasing the yield of the ester formed.
	 <p>(phenol)</p>	CH_3COOH Concentrated H_2SO_4 (catalyst), HUR	No Reaction	Condensation	
12	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	CH_3COCl room temperature	$\begin{array}{c} \text{H} \quad \text{O} \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{O}-\text{C}-\text{CH}_3 \\ \\ \text{H} \end{array}$ <p>+HCl</p>	Condensation	Esterification Both alcohol and phenol can react with acyl chlorides to form esters as the carbon in acyl chloride is more electron deficient in

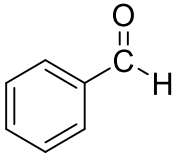
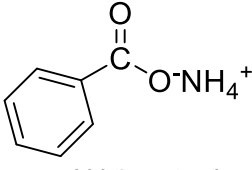
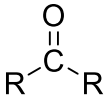
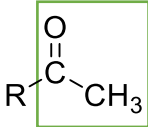
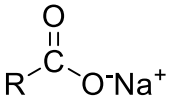
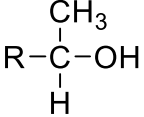
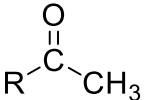
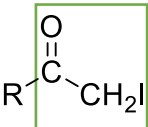
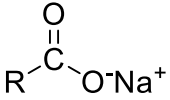
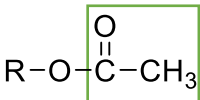
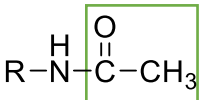
	 (phenol)	CH_3COCl room temperature		Condensation	acyl chloride than in carboxylic acid. Hence it is more susceptible to a nucleophilic attack. Condensation in this case is also known as Nucleophilic Acyl Substitution and Addition-Elimination.
13	 $\text{CH}_3\text{CH}(\text{OH})\text{R} + 4\text{I}_2 + 6\text{NaOH} \rightarrow \text{RCO}_2\text{Na}^+ + \text{CHI}_3 + 5\text{NaI} + 5\text{H}_2\text{O}$	Alkaline $\text{I}_2(\text{aq})$, warm		Oxidation	Tri-iodomethane /Iodoform test This is a distinguishing test for the methyl alcohol, methyl ketone, methyl aldehyde function groups. Yellow precipitate of CHI_3 will be observed.  (methyl ketone)  (methyl aldehyde) This is a one of the two-step-down reaction as the product has one less carbon atom. CH_2 , CH_2 and Cl_3 can all undergo the same reaction as they are all intermediates of the formation of CHI_3 Methyl alcohol attached as part of an Ester or an Amide cannot be oxidised under this reagent and condition. However, after hydrolysis, it is possible to get a positive test.
		Alkaline $\text{I}_2(\text{aq})$, warm		Oxidation	
		Alkaline $\text{I}_2(\text{aq})$, warm		Oxidation	
		Alkaline $\text{I}_2(\text{aq})$, warm		Oxidation	
	 (ester)	Alkaline $\text{I}_2(\text{aq})$, warm	No reaction		
	 (amide)	Alkaline $\text{I}_2(\text{aq})$, warm	No reaction		
14		Na(s), room temperature	 $+ \frac{1}{2} \text{H}_2$	Reduction/ Acid-Metal	

15		NaOH/KOH(aq), room temperature	 +H ₂ O	Acid-Base	Phenol is more acidic than alcohol hence will be able to react with NaOH/KOH
16		Na ₂ CO ₃ (aq), room temperature OR NaHCO ₃ (aq), room temperature	No Reaction		Unlike carboxylic acid, phenol is not acidic enough to react with carbonates.
17		CH ₃ COOH, concentrated H ₂ SO ₄ , HUR	No Reaction		The lone pair of electron on the O atom is delocalised into the benzene ring, making the oxygen atom not nucleophilic enough to attack the carbon of COOH group.
18		1. NaOH(aq) / Na(s), room temperature 2. CH ₃ COCl, room temperature		Condensation	NaOH and Na is added to react with phenol to produce phenoxide which is a stronger nucleophile which reacts more readily with acyl chloride
19		Dilute HNO ₃ , room temperature	  +2 H ₂ O	Electrophilic Substitution	Nitration The p orbital of the oxygen atom and the pi orbitals of the benzene ring overlap resulting in the lone pair of electrons on the oxygen atom to delocalise into the benzene ring. This increases the electron density of the benzene ring which activates the benzene ring making more it susceptible to electrophilic attacks. Since the benzene ring is now more susceptible, there is no need for conc. H ₂ SO ₄ to act as catalyst. In concentrated HNO ₃ or heating, multiple substitutions can occur
		Concentrated HNO ₃ , room temperature OR Dilute HNO ₃ , heat		Electrophilic Substitution	

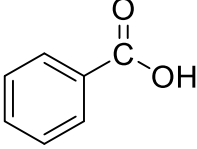
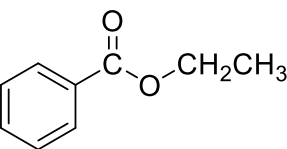
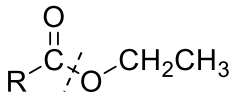
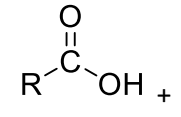
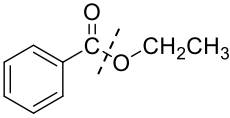
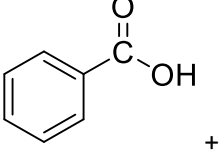
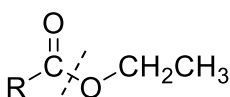
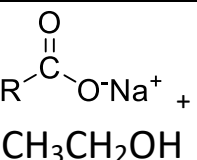
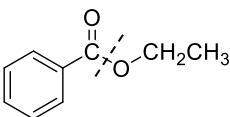
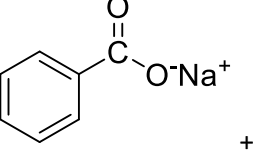
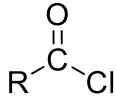
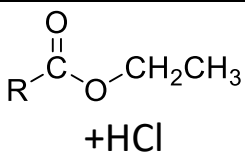
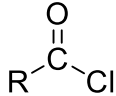

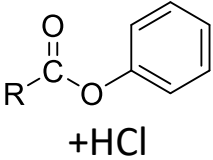
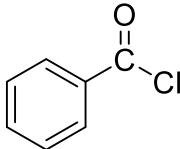
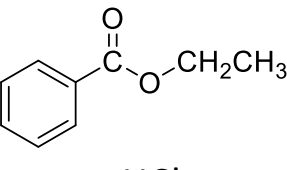
20		Br ₂ (aq), room temperature	 +3 HBr	Electrophilic Substitution	<p>Halogenation</p> <p>Distinguishing test for phenol. Reddish brown Br₂ decolourise, white fumes of HBr and white ppt of 2-4-6 tribromophenol formed.</p> <p>OH group is a very electron donating (stronger than CH₃) when attached to a benzene ring hence it increases the electron density of the benzene (activates the benzene ring) Hence no Lewis acid catalyst or heating is required and the reaction undergoes rapidly.</p> <p>OH group is electron donating hence is 2,4,6 directing in nature. However, if the 2,4,6 positions are already substituted no reaction occurs for those positions.</p>
		Cl ₂ (aq) (uncommon), room temperature	 +3 HCl		
21	2 	Br ₂ in CCl ₄ , room temperature	  + 2 HBr	Electrophilic Substitution	<p>Br₂/ICI in CCl₄ only undergoes mono-substitution with phenol.</p> <p>1 mole of Br₂ reacts with 1 mole of phenol</p> <p>This is because in Br₂, only one of the two Br can act as an electrophile to substitute the benzene ring.</p> <p>$\delta^+ \text{Br} - \text{Br} \delta^-$</p> <p>Forming Br⁺ and Br⁻. Only Br⁺ can act as electrophile.</p> <p>$\delta^+ \text{I} - \text{Cl} \delta^-$</p> <p>In ICl, it forms I⁺ and Cl⁻, I⁺ acts as the electrophile while Cl⁻ picks up the H to form HCl</p>
	2 	ICl in CCl ₄ , room temperature	  +2 HCl		

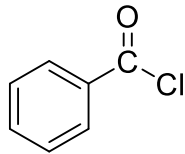

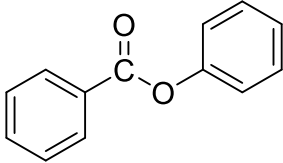
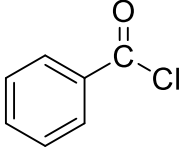
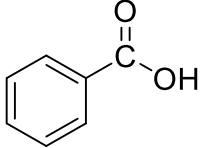
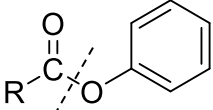
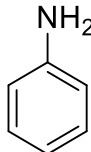

22	 $6\text{C}_6\text{H}_5\text{OH} + [\text{Fe}(\text{H}_2\text{O})_6]^{3+} \rightarrow [\text{Fe}(\text{C}_6\text{H}_5\text{O})_6]^{3-} + 6\text{H}_3\text{O}^+$	Neutral $\text{FeCl}_3(\text{aq})$, room temperature	 $[\text{Fe}(\text{C}_6\text{H}_5\text{O})_6]^{3-}$	Ligand-exchange	Distinguishing test for phenol. Violet colouration observed
Carbonyl Compounds (Aldehydes and Ketones)					
S/N	Reactants	Reagents and Conditions	Products	Type of Reaction	Remarks
1		$\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$, HUR		Oxidation	Purple KMnO_4 decolourise. In alkaline condition, the carboxylate salt is formed and brown ppt of MnO_2 is observed. Orange $\text{K}_2\text{Cr}_2\text{O}_7$ turns green.
		$\text{KMnO}_4(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$ HUR		Oxidation	
		$\text{NaOH}(\text{aq})$, $\text{KMnO}_4(\text{aq})$, HUR		Oxidation	
2		$\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$, HUR	 (methanoic acid)	Oxidation	Methanal under $\text{K}_2\text{Cr}_2\text{O}_7$, is only oxidised to become methanoic acid. However, under a stronger oxidising agent, KMnO_4 , the methanoic acid is further oxidised to carbonic acid which breaks down easily at room temperature to CO_2 and H_2O
		$\text{KMnO}_4(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$ HUR	 (carbonic acid)  $\text{CO}_2 + \text{H}_2\text{O}$	Oxidation	
3		$\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$, HUR OR $\text{KMnO}_4(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$ HUR	No Reaction		Ketones cannot be oxidised except for alkyl-aryl ketones.
4	 (alkyl-aryl ketone)	$\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$, HUR	No Reaction	Oxidation	Only acidified KMnO_4 is oxidising enough to oxidise alkyl-aryl ketones.
	 (alkyl-aryl ketone)	$\text{KMnO}_4(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$ HUR	 (benzoic acid)	Oxidation	

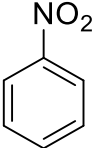
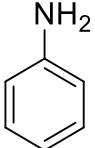
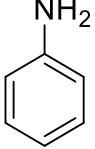
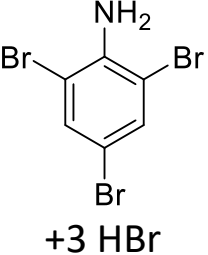
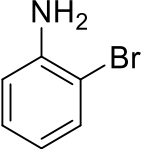
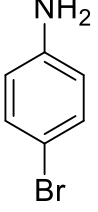
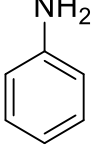
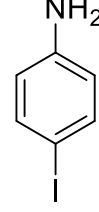
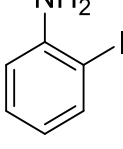
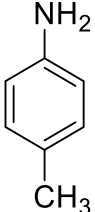
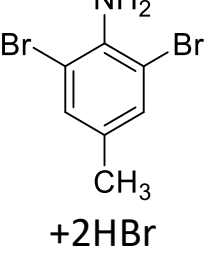
5	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{H} \\ \text{(aldehyde)} \end{array}$	LiAlH ₄ in dry ether, room temperature OR H ₂ , Ni catalyst, heat OR H ₂ , Pt/Pd catalyst, room temperature OR NaBH ₄ in methanol room temperature	$\begin{array}{c} \text{OH} \\ \\ \text{R}-\text{C}-\text{H} \\ \\ \text{R} \end{array}$	Reduction	NaBH ₄ in methanol is a specific reducing agent for aldehydes and ketones and not for any other function groups.
	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{R} \\ \text{(ketone)} \end{array}$		$\begin{array}{c} \text{OH} \\ \\ \text{R}-\text{C}-\text{H} \\ \\ \text{R} \end{array}$	Reduction	
6	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{H} \end{array}$	HCN, trace amount of NaOH/NaCN/KCN, 10-20°C	$\begin{array}{c} \text{OH} \\ \\ \text{R}-\text{C}-\text{CN} \\ \\ \text{R} \end{array}$	Nucleophilic Addition	Number of carbon atoms increases by one (Step up reaction) Reaction's temperature is at 10-20°C due to the low boiling point of HCN (26°C)
	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{R} \end{array}$		$\begin{array}{c} \text{OH} \\ \\ \text{R}-\text{C}-\text{CN} \\ \\ \text{R} \end{array}$		
7	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{H} \end{array}$	2,4-DiNitroPhenylHydrazine, room temperature		Condensation	Orange ppt observed. Distinguishing test for both aldehydes and ketones. Unable to distinguish between ketones and aldehydes. Also known as the Brady's Reagent.
	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{R} \end{array}$				
8	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{H} \end{array}$ $\text{RCHO} + 2\text{Cu}^{2+} + 5\text{OH}^- \rightarrow \text{RCO}_2^- + \text{Cu}_2\text{O} + 3\text{H}_2\text{O}$	Fehling's solution, warm	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{O}^- \\ + \text{Cu}_2\text{O} (\text{s}) \\ \text{(brick red ppt)} \end{array}$	Oxidation	Brick red ppt observed. Distinguishing test for aliphatic aldehydes. Aldehyde is oxidised to a carboxylate salt and copper(II) complex is reduced to Cu ₂ O. Carboxylate salt is obtained as Fehling's solution is basic. Fehling's solution is made up of alkaline Cu ²⁺ solution
		Fehling's solution, warm	No Reaction		
	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{R} \end{array}$	Fehling's solution, warm	No Reaction		
9	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{H} \end{array}$	Tollen's Reagent, warm	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{O}^- \text{NH}_4^+ \\ + \text{Ag}(\text{s}) \text{ (silver mirror)} \end{array}$	Oxidation	Silver mirror formed. Ag formed may sometimes precipitate out as a grey or black ppt.


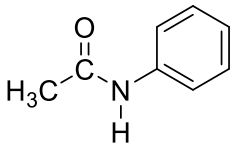
		Tollen's Reagent, warm	 + Ag(s) (silver mirror)	Oxidation	Distinguishing test for presence of all aldehydes. The aldehyde is oxidised to carboxylate salt and silver(I) diamine complex reduced to silver Ag(s). Carboxylate salt is obtained as Tollens' reagent is basic. Tollens' reagent is made up of diamine silver complex. $[\text{Ag}(\text{NH}_3)_2]^+$. Tollens' reagent is known as ammoniacal silver nitrate.
		Tollen's Reagent, warm	No Reaction		
10		Alkaline $\text{I}_2(\text{aq})$, warm	 + CHI_3 (yellow ppt)	Oxidation	Tri-iodomethane test/Iodoform test Distinguishing test for  (Methyl alcohol)  (Methyl ketone) Yellow precipitate of CHI_3 is formed. This is a step-down reaction as the product has one less carbon. RCOCH_2I , RCOCHI_2 and RCOCl_3 can all react as they are intermediates of RCOCH_3
		Alkaline $\text{I}_2(\text{aq})$, warm	 + CHI_3 (yellow ppt)	Oxidation	
		Alkaline $\text{I}_2(\text{aq})$, warm	No Reaction		
		Alkaline $\text{I}_2(\text{aq})$, warm	No Reaction		

Carboxylic Acids and Derivatives					
N	Reactants	Reagents and Conditions	Products	Type of Reactions	Remarks
1	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} \end{array}$	Na(s), room temperature	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{O}^-\text{Na}^+ \end{array} + \frac{1}{2} \text{H}_2$	Reduction/ Acid-Metal	Effervescence of H_2 gas evolved, test with lighted splint, produces pop sound.
2	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} \end{array}$	NaOH(aq), room temperature	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{O}^-\text{Na}^+ \end{array} + \text{H}_2\text{O}$	Acid-Base	Carboxylate salt is formed.
3	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} \end{array}$	$\text{Na}_2\text{CO}_3(\text{aq})$ OR $\text{NaHCO}_3(\text{aq})$, room temperature	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{O}^-\text{Na}^+ \end{array} + \text{CO}_2 + \text{H}_2\text{O}$	Acid-Base	Carboxylate salt is formed. Effervescence of CO_2 is produced when passed through limewater, produces white precipitate. Distinguishing test for carboxylic acids.
4	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} \end{array}$	$\text{PCl}_5(\text{s})$ or $\text{SOCl}_2(\text{l})$, room temperature OR $\text{PCl}_3(\text{l})$ room temperature	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{Cl} \end{array}$	Nucleophilic Substitution	$\text{HCl}(\text{g})$ generated from $\text{NaCl} + \text{conc. H}_2\text{SO}_4$ is no longer able to undergo substitution of the $-\text{OH}$.
5	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} \end{array}$	LiAlH_4 in dry ether, room temperature	$\begin{array}{c} \text{H} \\ \\ \text{R}-\text{C}-\text{OH} \\ \\ \text{H} \end{array}$ (1° alcohol)	Reduction	LiAlH_4 is the only reducing agent that can reduce carboxylic acid in the syllabus
6	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} \end{array}$	$\text{KMnO}_4(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$ HUR	No Reaction		All Carboxylic acid is unable to further oxidise except methanoic acid, carbonic acid and ethanedioic acid.
7	$\begin{array}{c} \text{O} \\ \parallel \\ \text{H}-\text{C}-\text{OH} \end{array}$ (methanoic acid)	$\text{KMnO}_4(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$ HUR	$\begin{array}{c} \text{O} \\ \parallel \\ \text{HO}-\text{C}-\text{OH} \end{array}$ (carbonic acid) \downarrow $+\text{CO}_2 + \text{H}_2\text{O}$	Oxidation	Methanoic, Ethanedioic and Carbonic acid are the only carboxylic acids that can be oxidised to form CO_2 and H_2O . Acidified $\text{K}_2\text{Cr}_2\text{O}_7$ is unable to oxidise them as $\text{K}_2\text{Cr}_2\text{O}_7$ is not oxidising enough for this reaction. The chemical formula of ethanedioic acid is $\text{C}_2\text{H}_2\text{O}_4$ has only one way of drawing the compound. Whenever the formula $\text{C}_2\text{H}_2\text{O}_4$ is shown, think of ethanedioic acid.
	$\begin{array}{c} \text{O} \\ \parallel \\ \text{HO}-\text{C}-\text{OH} \end{array}$ (carbonic acid)	$\text{KMnO}_4(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$ HUR	$\text{CO}_2 + \text{H}_2\text{O}$	Oxidation	
	$\begin{array}{c} \text{O} \quad \text{O} \\ \diagdown \quad / \\ \text{C} - \text{C} \\ / \quad \diagdown \\ \text{HO} \quad \text{OH} \end{array}$ (ethanedioic acid)	$\text{KMnO}_4(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$ HUR	$2\text{CO}_2 + \text{H}_2\text{O}$	Oxidation	
8	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} \end{array}$	$\text{CH}_3\text{CH}_2\text{OH}$, Conc. H_2SO_4 (catalyst) HUR	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{O}-\text{CH}_2\text{CH}_3 \end{array}$	Condensation (Addition-Elimination)	Ester bond/Ester linkage is formed. Phenol do not undergo condensation with carboxylic acid.

		CH ₃ CH ₂ OH Conc. H ₂ SO ₄ (catalyst) HUR		Condensation (Addition- Elimination)	This is a reversible and slow reaction. Conc. H ₂ SO ₄ is used as a catalyst as well as a dehydrating agent to remove H ₂ O on the right-hand side of the equation to shift the POE to the right and yield more of the products.
9		HCl(aq) or H ₂ SO ₄ (aq) HUR		Acid Hydrolysis	The first reaction is a reversible reaction as the alcohol produced can react with carboxylic acid to form back ester, while the second reaction is irreversible as phenol is unable to react with carboxylic acid to form back an ester.
		HCl(aq) or H ₂ SO ₄ (aq) HUR			
10		NaOH(aq) HUR		Alkaline Hydrolysis	Carboxylate and Phenoxide anions are formed due to basic conditions. The carboxylic acid and phenol formed will undergo neutralisation with NaOH to give carboxylate and phenoxide. Carboxylate is unable to react with both phenoxide and alcohol to produce an ester hence both reactions here are irreversible.
		NaOH(aq) HUR		Alkaline Hydrolysis	
11		CH ₃ CH ₂ OH, room temperature		Condensation (Addition- Elimination)	Ester bond is formed. NaOH/Na is added to phenol to produce phenoxide, which is a stronger nucleophile to react with the acyl chloride 1 mol of HCl is eliminated in the reaction. The way to identify condensation reaction is similar to identifying elimination reaction, through the double bond.
		 in NaOH(aq) room temperature			
		CH ₃ CH ₂ OH, room temperature			

		 in NaOH(aq) room temperature	 +HCl	Condensation (Addition-Elimination)	
12	$\text{R}-\text{C}(=\text{O})-\text{Cl}$	H_2O room temperature	$\text{R}-\text{C}(=\text{O})-\text{OH}$ +HCl	Hydrolysis	A highly acidic solution of HCl(aq) is formed. Ph of final solution is very low due to the HCl(aq). Acyl chloride is more acidic than carboxylic acid.
		H_2O room temperature	 +HCl		
13	$\text{R}_1-\text{C}(=\text{O})-\text{O}-\text{R}_2$	LiAlH_4 in dry ether, room temperature	$\begin{array}{c} \text{H} \\ \\ \text{R}_1-\text{C}-\text{OH} \\ \\ \text{H} \\ + \\ \text{H} \\ \\ \text{R}_2-\text{C}-\text{OH} \\ \\ \text{H} \end{array}$	Reduction	Ester bond is broken, and carboxylic acid is reduced to a 2° alcohol.
		LiAlH_4 in dry ether, room temperature	$\begin{array}{c} \text{H} \\ \\ \text{R}-\text{C}-\text{OH} \\ \\ \text{H} \\ + \\ \text{OH} \\ \\ \text{C}_6\text{H}_5 \end{array}$	Reduction	
Nitrogen Compounds					
N	Reactants	Reagents and Conditions	Products	Type of Reaction	Remarks:
1	$\text{R}-\text{NH}_2$	HCl(aq) OR $\text{H}_2\text{SO}_4(\text{aq})$, room temperature	$\text{R}-\text{NH}_3^+\text{Cl}^-$	Acid-Base	1°,2°,3° amines and phenyl amines undergo this reaction
			NH_3^+Cl^- 		

2		1. Sn in conc. HCl, HUR 2. NaOH (aq) room temp		Reduction	Only method to produce phenylamine in the syllabus
3		Br ₂ (aq), room temperature	 +3 HBr	Electrophilic Substitution	Orange Br ₂ decolourises, effervescence, steamy white fumes of HBr evolved and white ppt of 2-4-6 tribromophenylamine formed. (like -OH, NH ₂ is electron donating) No Lewis Acid catalyst or heating is required as the -NH ₂ is like -OH, an electron donating group, activates the ring due to the increase in electron density and hence makes it more susceptible to electrophilic attacks. Chlorine will react the same way as Bromine, Br ₂ in CCl ₄ only undergoes mono-substitution as Br ₂ in CCl ₄ only produces one Br ⁺ , the electrophile needed for the reaction, hence only mono-substitution happens.
		Br ₂ in CCl ₄ , room temperature	  + 2HBr		
		ICl in CCl ₄ , room temperature	  +2HCl	Electrophilic Substitution	
4		Br ₂ (aq), room temperature	 +2HBr	Electrophilic Substitution	-NH ₂ is a strong electron donating group than -CH ₃ , hence the effect on the position of substitution by NH ₂ should take precedence over CH ₃ as it causes a stronger electron donating effect. -CH ₃ is blocking the 4-position hence no substitution occurs at the 4-position.

5	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} \end{array}$	RNH ₂ , room temperature	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{O}^- + \text{R}-\text{NH}_3^+ \end{array}$	Acid-Base	Amide cannot be formed from carboxylic acid and amine as they undergo acid-base reaction instead. The only way to form an amide in the syllabus is through acyl chloride and amines
6	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{Cl} \\ \text{(acyl chloride)} \end{array}$	NH ₃ , room temperature	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{NH}_2 + \text{HCl} \end{array}$	Condensation (Addition-Elimination)	This is the only method in the syllabus to form an amide bond through acyl chloride and amine or ammonia. Amide bond and peptide bond is the same, however when discussing normal organic chemistry, we use amide bonds/amide linkage to describe the bond while for proteins and amino acids we use peptide bonds. For the 3° amine, they are unable to react as the C-R Bond is much stronger and harder to break than the C-H Bond.
		RNH ₂ (1° amine) room temperature	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{NH}-\text{R}_1 + \text{HCl} \end{array}$		
		R ₁ R ₂ NH (2° amine) room temperature	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{N} \begin{array}{l} \nearrow \text{R}_1 \\ \searrow \text{R}_2 \end{array} + \text{HCl} \end{array}$		
		R ₁ R ₂ R ₃ N (3° amine) room temperature	No reaction		
	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{Cl} \\ \text{(acyl chloride)} \end{array}$	 , room temperature	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{N} \begin{array}{l} \nearrow \text{C}_6\text{H}_5 \\ \searrow \text{H} \end{array} + \text{HCl} \end{array}$	Condensation	
7	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{NH}_2 \end{array}$	HCl(aq), HUR OR H ₂ SO ₄ (aq), HUR	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} + \text{NH}_3^+\text{Cl}^- \end{array}$	Acid Hydrolysis	Under acidic condition, carboxylic acid and ammonium salt is formed. Ammonium salt is formed from the neutralisation of amine/ammonia and the acid.
	$\begin{array}{c} \text{O} \quad \text{H} \\ \parallel \quad \\ \text{R}-\text{C}-\text{N}-\text{R} \end{array}$		$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} + \text{NRH}_2^+\text{Cl}^- \end{array}$		
			$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OH} + \text{C}_6\text{H}_5\text{NH}_3^+\text{Cl}^- \end{array}$		
8	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{NH}_2 \\ \text{(1° amide)} \end{array}$	NaOH(aq), HUR	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{O}^- \text{Na}^+ + \text{NH}_3 \end{array}$	Alkaline Hydrolysis	Under alkaline conditions, a carboxylate salt and ammonia or amine is formed.
	$\begin{array}{c} \text{O} \quad \text{H} \\ \parallel \quad \\ \text{R}-\text{C}-\text{N}-\text{R} \\ \text{(2° amide)} \end{array}$	NaOH(aq), HUR	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{O}^- \text{Na}^+ + \text{RNH}_2 \end{array}$	Alkaline Hydrolysis	When ammonia is formed, a pungent gas will be detected. It can

		NaOH(aq), HUR	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{O}^-\text{Na}^+ \\ + \\ \text{C}_6\text{H}_5\text{NH}_2 \end{array}$	Alkaline Hydrolysis	be used as a distinguishing test for primary amide. Only ammonia is a pungent gas, not the other amines.
9	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{NH}_2 \end{array}$	LiAlH ₄ in dry ether, room temperature	$\begin{array}{c} \text{H} \\ \\ \text{R}-\text{C}-\text{NH}_2 \\ \\ \text{H} \\ +\text{H}_2\text{O} \end{array}$	Reduction	Reduction of an amide produces an amine. Unlike esters, which breaks the ester linkage and reduces the carboxylic acid into an alcohol, only the C=O bond of an amide is reduced to a CH ₂ group.
	$\begin{array}{c} \text{O} \quad \text{H} \\ \parallel \quad \\ \text{R}-\text{C}-\text{N}-\text{R} \end{array}$		$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{R}-\text{C}-\text{N}-\text{R} \\ \\ \text{H} \\ +\text{H}_2\text{O} \end{array}$		
			$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{R}-\text{C}-\text{N}-\text{C}_6\text{H}_5 \\ \\ \text{H} \\ +\text{H}_2\text{O} \end{array}$		
10	$\begin{array}{c} \text{R} \\ \\ ^+\text{H}_3\text{N}-\text{C}-\text{COO}^- \\ \\ \text{H} \\ \text{(zwitterion)} \end{array}$	HCl(aq) <u>OR</u> H ₂ SO ₄ (aq), room temperature	$\left[\begin{array}{c} \text{R} \\ \\ ^+\text{H}_3\text{N}-\text{C}-\text{COOH} \\ \\ \text{H} \end{array} \right] \text{Cl}^-$	Acid-Base	Zwitterions can react with both acid and bases hence they can be used as a buffer. Zwitterions are amphoteric
	$\begin{array}{c} \text{R} \\ \\ ^+\text{H}_3\text{N}-\text{C}-\text{COO}^- \\ \\ \text{H} \\ \text{(zwitterion)} \end{array}$	NaOH(aq), room temperature	$\begin{array}{c} \text{R} \\ \\ \text{H}_2\text{N}-\text{C}-\text{COO}^-\text{Na}^+ \\ \\ \text{H} \end{array}$	Acid-Base	

11	$ \begin{array}{c} \text{R}_1 \\ \\ \text{H}_2\text{N}-\text{C}-\text{COOH} \\ \\ \text{H} \end{array} + \begin{array}{c} \text{R}_2 \\ \\ \text{H}_2\text{N}-\text{C}-\text{COOH} \\ \\ \text{H} \end{array} + \begin{array}{c} \text{R}_3 \\ \\ \text{H}_2\text{N}-\text{C}-\text{COOH} \\ \\ \text{H} \end{array} $ $ + \dots + \begin{array}{c} \text{R}_n \\ \\ \text{H}_2\text{N}-\text{C}-\text{COOH} \\ \\ \text{H} \end{array} $ $ \begin{array}{c} \text{R}_1 \quad \text{O} \quad \text{H} \quad \text{R}_2 \quad \text{O} \quad \text{H} \quad \text{R}_3 \quad \text{O} \\ \quad \quad \quad \quad \quad \quad \quad \\ \text{H}_2\text{N}-\text{C}-\text{C}-\text{N}-\text{C}-\text{C}-\text{N}-\text{C}-\text{C} \sim \text{N}-\text{C}-\text{COOH} \\ \quad \quad \quad \quad \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array} $ $+ (n-1) \text{H}_2\text{O}$			<p>Condensation (Addition-Elimination)</p>	<p>The formation of polypeptides/proteins take place in the presence of enzyme catalyst. Hence, COOH and NH₃ can react directly (not usually the case in the syllabus) to give the peptide bond. Usually, COOH and NH₃ only undergo acid-base reaction and not condensation.</p> <p>By convention, when drawing amino-acids and proteins, the N-terminal is always drawn on the left and the C-terminal is always drawn on the right.</p> <p>Amide bonds/linkages and peptide bond is the same thing, peptide bond is used when discussing amino acids and proteins while amide linkages/bonds are used during general organic chemistry.</p>
12	$ \begin{array}{c} \text{H} \quad \text{R}_1 \quad \text{O} \quad \text{R}_2 \quad \text{O} \\ \quad \quad \quad \quad \quad \\ \sim\text{N}-\text{C}-\text{C}-\text{N}-\text{C}-\text{C}\sim \\ \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array} $	<p>HCl(aq) <u>OR</u> H₂SO₄(aq), HUR for several hours</p>	$ \begin{array}{c} \text{H} \quad \text{R}_1 \quad \text{O} \\ \quad \quad \\ \sim\text{N}-\text{C}-\text{C}-\text{OH} \\ \\ \text{H} \end{array} + \begin{array}{c} \text{R}_2 \quad \text{O} \\ \quad \\ ^-\text{Cl}^+\text{H}_3\text{N}-\text{C}-\text{C}\sim \\ \\ \text{H} \end{array} $	<p>Acid Hydrolysis</p>	<p>Heating under reflux for several hours is only for proteins/poly peptides to ensure the complete hydrolysis as multiple peptide bonds are not so easy to break</p> <p>If polypeptide/protein is not mentioned, HUR would suffice.</p>
13	$ \begin{array}{c} \text{H} \quad \text{R}_1 \quad \text{O} \quad \text{R}_2 \quad \text{O} \\ \quad \quad \quad \quad \quad \\ \sim\text{N}-\text{C}-\text{C}-\text{N}-\text{C}-\text{C}\sim \\ \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array} $	<p>NaOH (aq), HUR for several hours</p>	$ \begin{array}{c} \text{H} \quad \text{R}_1 \quad \text{O} \\ \quad \quad \\ \sim\text{N}-\text{C}-\text{C}-\text{O}^-\text{Na}^+ \\ \\ \text{H} \end{array} + \begin{array}{c} \text{R}_2 \quad \text{O} \\ \quad \\ \text{H}_2\text{N}-\text{C}-\text{C}\sim \\ \\ \text{H} \end{array} $	<p>Alkaline Hydrolysis</p>	<p>Heating under reflux for several hours is only for proteins/poly peptides to ensure the complete hydrolysis as multiple peptide bonds are not so easy to break</p> <p>If polypeptide/protein is not mentioned, HUR would suffice.</p>