Q1.  
(a) Write an equation for the formation of methyl propanoate, CH₃CH₂COOCH₃, from methanol and propanoic acid.

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(1)

(b) Name and outline a mechanism for the reaction between methanol and propanoyl chloride to form methyl propanoate.

_Name of mechanism_ .................................................................

_Mechanism_

(5)

(c) Propanoic anhydride could be used instead of propanoyl chloride in the preparation of methyl propanoate from methanol. Draw the structure of propanoic anhydride.

(1)

(d) (i) Give _one_ advantage of the use of propanoyl chloride instead of propanoic acid in the laboratory preparation of methyl propanoate from methanol.

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(ii) Give _one_ advantage of the use of propanoic anhydride instead of propanoyl chloride in the industrial manufacture of methyl propanoate from methanol.

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(2)
(e) An ester contains a benzene ring. The mass spectrum of this ester shows a molecular ion peak at \(m/z = 136\).

(i) Deduce the molecular formula of this ester.

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(ii) Draw two possible structures for this ester.

Q2. Consider the sequence of reactions below.

\[
\text{CH}_3\text{CH}_2\text{CHO} \xrightarrow{\text{Reaction 1}} \text{H} \quad \text{C} \quad \text{CN} \xrightarrow{\text{Reaction 2}} \text{CH}_3\text{CH}_2\text{COOH}
\]

\[
\text{P} \quad \text{Q} \quad \text{R}
\]

(a) Name and outline a mechanism for Reaction 1.

\textit{Name of mechanism} ...........................................................................................................

\textit{Mechanism}

(b) (i) Name compound Q

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(ii) The molecular formula of \(Q\) is \(C_4H_7NO\). Draw the structure of the isomer of \(Q\) which shows geometrical isomerism and is formed by the reaction of ammonia with an acyl chloride.

(c) Draw the structure of the main organic product formed in each case when \(R\) reacts separately with the following substances:

(i) methanol in the presence of a few drops of concentrated sulphuric acid;

(ii) acidified potassium dichromate(VI);

(iii) concentrated sulphuric acid in an elimination reaction.

Q3. (a) Name the compound \((CH_3)_2NH\)

.......................................................................................................................................................... (1)
(b) \((\text{CH}_3\text{)}_2\text{NH}\) can be formed by the reaction of an excess of \(\text{CH}_3\text{NH}_2\) with \(\text{CH}_3\text{Br}\). Name and outline a mechanism for this reaction.

*Name of mechanism* .................................................................

*Mechanism* 

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(c) Name the type of compound produced when a large excess of \(\text{CH}_3\text{Br}\) reacts with \(\text{CH}_3\text{NH}_2\). Give a use for this type of compound.

*Type of compound* .................................................................

*Use* .................................................................

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(d) Draw the structures of the two compounds formed in the reaction of \(\text{CH}_3\text{NH}_2\) with ethanoic anhydride.

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(Total 10 marks)
Q4. Consider the reaction sequence shown below.

\[
\text{CH}_3\text{CH}_2\text{CHO} \xrightarrow{\text{Step 1}} \text{CH}_3\text{CH}_2\text{C}^\equiv\text{H} \xrightarrow{\text{HCN}} \text{CH}_3\text{CH}_2\text{C}^\equiv\text{H} \xrightarrow{\text{Step 2}} \text{CH}_3\text{CH}_2\text{C}^\equiv\text{H} \xrightarrow{\text{OH}} \text{CH}_3\text{CH}_2\text{C}^\equiv\text{H} \xrightarrow{\text{COOH}}
\]

(a) Name and outline a mechanism for the reaction in Step 1.

Name of mechanism .................................................................

Mechanism
(b) (i) Name compound Q formed in Step 2.

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(ii) Two stereoisomers are formed by the dehydration of Q. Give the structures of these two isomers and name the type of stereoisomerism shown.

Structures of isomers

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Type of stereoisomerism .................................................................

(4)

(c) An isomer of Q which has the structure shown below is polymerised to form the biodegradeable polymer known as PHB.

\[
\text{CH}_3
\]

\[
\text{HO} - \text{C} - \text{CH}_2\text{COOH}
\]

\[
\text{H}
\]

(i) Draw the repeating unit of the polymer PHB.

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(ii) Suggest a reason why the polymer is biodegradeable.

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(d) The amino acid R is shown below.

(i) Draw the structure of the zwitterion formed by R.

(ii) Draw the structure of the major organic product formed when an excess of R is reacted with bromomethane.

(iii) Name the mechanism of the reaction which results in the formation of the product given in part (ii).

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(3)

(Total 14 marks)
Q5. (a) Name and outline a mechanism for the formation of butylamine, \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2 \), by the reaction of ammonia with 1-bromobutane, \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} \).

**Name of mechanism** .................................................................................................................................

**Mechanism**

(b) Butylamine can also be prepared in a two-step synthesis starting from 1-bromopropane, \( \text{CH}_3\text{CH}_2\text{CH}_2\text{Br} \). Write an equation for each of the two steps in this synthesis.

**Step 1**

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**Step 2**

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(c) (i) Explain why butylamine is a stronger base than ammonia.

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(ii) Identify a substance that could be added to aqueous butylamine to produce a basic buffer solution.

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(d) Draw the structure of a tertiary amine which is an isomer of butylamine.

Q6. (a) P, Q and R have the molecular formula C₆H₁₂

All three are branched-chain molecules and none is cyclic.
P can represent a pair of optical isomers.
Q can represent a pair of geometrical isomers.
R can represent another pair of geometrical isomers different from Q.

Draw one possible structure for one of the isomers of each of P, Q and R.

Structure of P

Structure of Q

Structure of R

(b) Butanone reacts with reagent S to form compound T which exists as a racemic mixture. Dehydration of T forms U, C₅H₇N, which can represent a pair of geometrical isomers.

(i) State the meaning of the term racemic mixture and suggest why such a mixture is formed in this reaction.

Racemic mixture .......................................................... .......................................................... ..........................................................

Explanation ..................................................................................................................................

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(ii) Identify reagent $S$, and draw a structural formula for each of $T$ and $U$.

_**Reagent S**_ .................................................................

_**Compound T**_ .................................................................

_**Compound U**_ .................................................................

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**Q7.** Hydrogen and carbon monoxide were mixed in a 2:1 mole ratio. The mixture was allowed to reach equilibrium according to the following equation at a fixed temperature and a total pressure of $1.75 \times 10^4$ kPa.

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$$

(a) The equilibrium mixture contained 0.430 mol of carbon monoxide and 0.0850 mol of methanol.

(i) Calculate the number of moles of hydrogen present in the equilibrium mixture.

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(ii) Hence calculate the mole fraction of hydrogen in the equilibrium mixture.

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(iii) Calculate the partial pressure of hydrogen in the equilibrium mixture.

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(b) In a different mixture of the three gases at equilibrium, the partial pressure of carbon monoxide was 7550 kPa, the partial pressure of hydrogen was 12300 kPa and the partial pressure of methanol was 2710 kPa.

(i) Write an expression for the equilibrium constant, $K_p$, for this reaction.

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(ii) Calculate the value of the equilibrium constant, $K_p$, for the reaction under these conditions and state its units.

\[ K_p \] ................................................................. ................................................................. ................................................................. .................................................................

\[ Units \] ............................................................................................................

(3)

c) Two isomeric esters \textbf{E} and \textbf{F} formed from methanol have the molecular formula $\text{C}_6\text{H}_{12}\text{O}_2$.

Isomer \textbf{E} has only 2 singlet peaks in its proton n.m.r. spectrum.

Isomer \textbf{F} is optically active.

Draw the structures of these two isomers.

\textit{Isomer E}

\textit{Isomer F}

(2)

(Total 10 marks)