AQA A-LEVEL CHEMISTRY · 7405

# CHEMISTRY



EXAM QUESTION PACK

## 3.3.7 OPTICAL ISOMERISM

| SCORE | PERCENTAGE |
| --- | --- |
| /160 | % |

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## Q1.

Which pair of compounds does **not** form a racemic mixture when the compounds react?

**A**  + HCl ⬭

**B**  + HCN ⬭

**C**  + HCl ⬭

**D**  + HCN ⬭

**(Total 1 mark)**

## Q2.

Which compound does **not** show stereoisomerism?

**A** 1,2-dichloropropene ⬭

**B** 1,2-dichloropropane ⬭

**C** 1,3-dichloropropene ⬭

**D** 1,3-dichloropropane ⬭

**(Total 1 mark)**

## Q3.

Which compound forms optically active compounds on reduction?

**A** $CH_3CH_2C(CH_3)=CHCH_3$ ⬭

**B** $CH_3CH_2C(CH_3)=CH_2$ ⬭

**C** $CH_3COCH_3$ ⬭

**D** $CH_3CH_2COCH_3$ ⬭

**(Total 1 mark)**

## Q4.

The aldehyde $CH_3CH_2CH_2CH_2CHO$ reacts with KCN followed by dilute acid to form a racemic mixture of the two stereoisomers of $CH_3CH_2CH_2CH_2CH(OH)CN$

(a) Give the IUPAC name of $CH_3CH_2CH_2CH_2CH(OH)CN$



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_____

**(1)**

(b) Describe how you would distinguish between separate samples of the two stereoisomers of $CH_3CH_2CH_2CH_2CH(OH)CN$

_____

_____

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**(2)**

(c) Explain why the reaction produces a racemic mixture.

_____

_____

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**(3)**

(d) An isomer of $CH_3CH_2CH_2CH_2CHO$ reacts with KCN followed by dilute acid to form a compound that does not show stereoisomerism.

Draw the structure of the compound formed and justify why it does not show stereoisomerism.

Structure

Justification

_____

_____

**(2)**

**(Total 8 marks)**

## Q5.



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This question is about isomerism.

(a) How many isomers are represented by the formula $C_5H_{12}$?

Tick (✓) **one** box.

2 ☐ 3 ☐ 4 ☐ 5 ☐

(b) Name the type of structural isomerism shown by the isomers of $C_5H_{12}$

_____

**(1)**

(c) 2-Hydroxypropanenitrile displays optical isomerism.

Draw three-dimensional representations of the two enantiomers of 2-hydroxypropanenitrile, showing how the two structures are related to each other.

**(2)**

(d) Describe how separate samples of each of these enantiomers could be distinguished.

_____

_____

_____

_____

**(2)**

(e) Butan-2-ol reacts with concentrated sulfuric acid to produce three isomeric alkenes.

Name and outline a mechanism to show how any **one** of the alkenes is formed.

Explain how this reaction can lead to the formation of each of these **three** alkenes.

Name of mechanism _____

Mechanism



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Explanation _____

_____

_____

_____

_____

_____

_____

_____

_____

**(8)**

**(Total 13 marks)**

## Q6.

Butanone is reduced in a two-step reaction using $NaBH_4$ followed by dilute hydrochloric acid.

(a) Write an overall equation for the reduction of butanone using [H] to represent the reductant.

_____

**(1)**

(b) By considering the mechanism of the reaction, explain why the product has **no** effect on plane polarised light.

_____

_____

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**(6)**

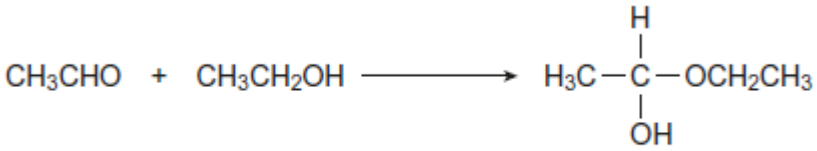
**(Total 7 marks)**



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## Q7.

Hemiacetals and acetals are compounds formed by the reaction of aldehydes with alcohols, such as the reaction of ethanal with ethanol.



a hemiacetal

(a) (i) Use your knowledge of carbonyl mechanisms to suggest the name of the mechanism of this reaction.

_____

**(1)**

(ii) Outline how an ethanol molecule reacts with an ethanal molecule in the first step of this mechanism. Include two curly arrows to show the movement of electron pairs.

**(2)**

(b) The reaction produces a racemic mixture of chiral molecules.

(i) Explain the meaning of the term racemic mixture.

_____

_____

**(1)**

(ii) State the relationship between two chiral molecules with the same structural formula.

_____

_____

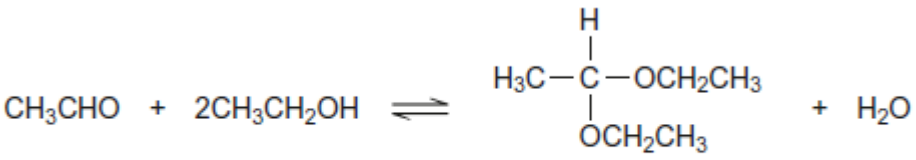
**(1)**

(c) In the presence of an acid catalyst such as dry hydrogen chloride, ethanal reacts with an excess of ethanol to form an acetal.

The overall reaction of ethanal with an excess of ethanol forms an equilibrium mixture as shown. All reactants and products are liquids.



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an acetal

A mixture of 0.75 mol of ethanal and 5.00 mol of ethanol was left to reach equilibrium in the presence of dry hydrogen chloride at a given temperature. The equilibrium mixture contained 0.42 mol of the acetal.

(i) Calculate the amount, in moles, of ethanal and of ethanol in this equilibrium mixture.

Amount of ethanal _____ mol

Amount of ethanol _____ mol

Space for working _____

_____

_____

_____

**(2)**

(ii) In a different experiment using the same reaction as in part **(c)**, an equilibrium mixture was established at a given temperature.
This mixture contained 0.58 mol of ethanal, 3.76 mol of ethanol, 0.37 mol of the acetal and 0.65 mol of water in a total volume of 310 $cm^3$.

Write an expression for the equilibrium constant $K_c$ for this reaction.
Calculate a value for $K_c$ at this temperature. Give units with your answer.

$K_c$ _____

_____

Calculation _____

_____

_____

_____

_____

_____

_____

**(4)**

(d) Draw the structure of the acetal ($C_4H_8O_2$) formed by the reaction of ethanal with ethane-1,2-diol.



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**(1)**
**(Total 12 marks)**

## Q8.

The carbonyl compound $CH_3CH_2CHO$ reacts very slowly with HCN

(a) Name and outline a mechanism for the reaction of $CH_3CH_2CHO$ with HCN

Name of mechanism _____

Mechanism

**(5)**

(b) The reaction in part (a) produces a pair of enantiomers.

(i) Draw the structure of each enantiomer to show how they are related to each other.

**(2)**

(ii) State and explain how you could distinguish between the two enantiomers.

_____

_____

_____

_____

**(2)**

(c) Give the IUPAC name of the product of the reaction in part (a).

_____



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**(1)**

(d) In practice, KCN rather than HCN is added to the carbonyl compound.

Given that $K_a$ for HCN = $4.0 \times 10^{-10}$ mol $dm^{-3}$, suggest why the reaction with HCN is very slow.

_____

_____

_____

_____

**(2)**

(e) Acrylic fibres are used as a substitute for wool. Acrylics are copolymers of acrylonitrile with other compounds.

Acrylonitrile is the common name for the following compound.

$$H_2C = CH - C \equiv N$$

(i) Acrylonitrile can be formed from propene.

Write an equation for the reaction of propene with ammonia and oxygen to form acrylonitrile and one other product.

_____

**(1)**

(ii) The term copolymer is used to describe the product obtained when two or more different monomers form a polymer.

Draw the repeating unit of the acrylic copolymer that contains 75% acrylonitrile monomer and 25% chloroethene monomer.

**(1)**

(iii) Name the type of polymerisation involved in part (ii)

_____

**(1)**

**(Total 15 marks)**

## Q9.

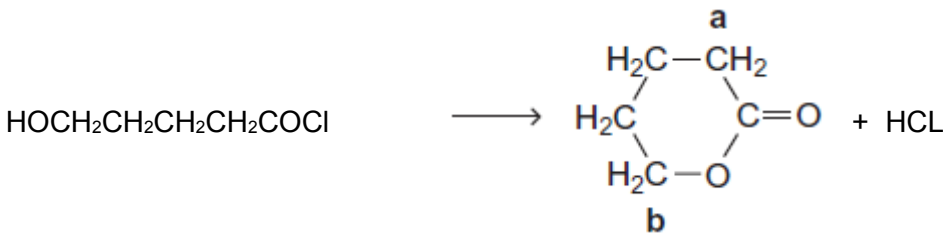
This question is about some isomers of $C_5H_8O_2$

(a) Compound **H** is a cyclic ester that can be prepared as shown.



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On the structure of **H**, two of the carbon atoms are labelled.




**H**

(i) Name and outline a mechanism for this reaction.

Use **Table C** on the Data Sheet to give the $^{13}C$ n.m.r. δ value for the carbon atom labelled **a** and the δ value for the carbon atom labelled **b**.

**(7)**

(ii) $HOCH_2CH_2CH_2CH_2COCl$ can also react to form a polyester in a mechanism similar to that in part (i).

Draw the repeating unit of the polyester and name the type of polymerisation involved.



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_____

_____

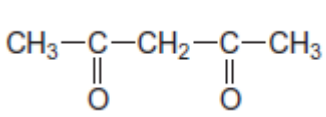
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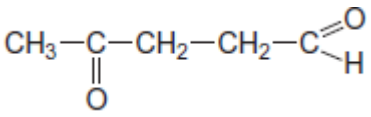
**(2)**

(b) State how you could distinguish between compounds **J** and **K** by a simple test-tube reaction.

State how you could distinguish between **J** and **K** by giving the number of peaks in the $^1H$ n.m.r. spectrum of each compound.



**J**



**K**

_____

_____

_____

_____

_____

_____

_____

_____

**(5)**

(c) Draw the structure of each of the following isomers of $C_5H_8O_2$
Label each structure you draw with the correct letter **L**, **M**, **N**, **P** or **Q**.

**L** is methyl 2-methylpropenoate.

**M** is an ester that shows E-Z stereoisomerism.

**N** is a carboxylic acid with a branched carbon chain and does **not** show stereoisomerism.

**P** is an optically active carboxylic acid.

**Q** is a cyclic compound that contains a ketone group and has only two peaks in its $^1H$ n.m.r. spectrum.

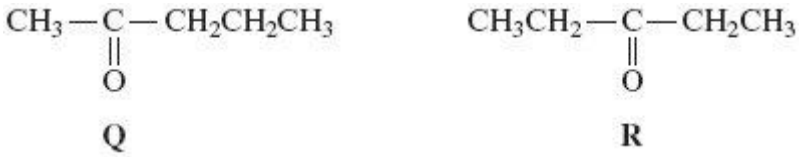


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**(5)**
**(Total 19 marks)**

## Q10.

Two isomeric ketones are shown below.



Q



R

(a) Name and outline a mechanism for the reaction of compound **Q** with HCN and name the product formed.

Name of mechanism _____

Mechanism

Name of product _____

**(6)**

(b) Some students were asked to suggest methods to distinguish between isomers **Q** and **R**.

One student suggested testing the optical activity of the products formed when **Q** and **R** were reacted separately with HCN.

By considering the optical activity of these products formed from **Q** and **R**, explain why this method would **not** distinguish between **Q** and **R**.

_____

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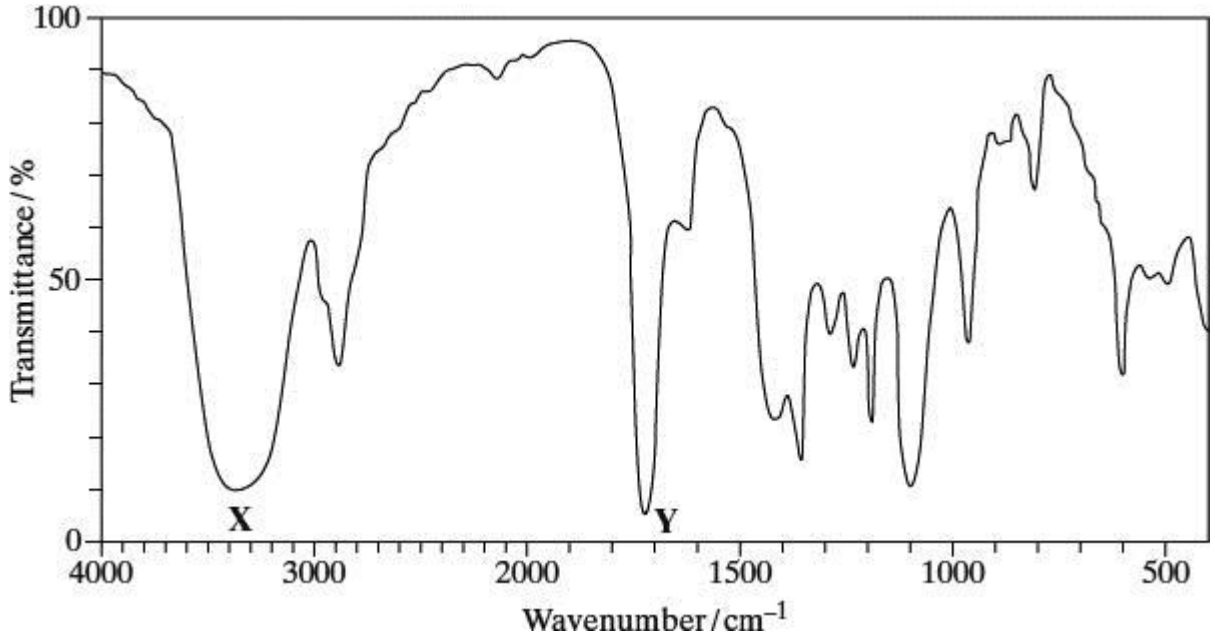
**(3)**
**(Total 9 marks)**



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## Q11.

(a) The infra-red spectrum of compound **A**, $C_3H_6O_2$, is shown below.




Identify the functional groups which cause the absorptions labelled **X** and **Y**.

Using this information draw the structures of the three possible structural isomers for **A**.

Label as **A** the structure which represents a pair of optical isomers.

**(6)**

(b) Draw the structures of the three **branched-chain** alkenes with molecular formula $C_5H_{10}$



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Draw the structures of the three dibromoalkanes, $C_5H_{10}Br_2$, formed when these three alkenes react with bromine.

One of these dibromoalkanes has only three peaks in its proton n.m.r. spectrum. Deduce the integration ratio and the splitting patterns of these three peaks.

**(10)**

**(Total 16 marks)**

## Q12.

Which one of the following can exhibit both geometrical and optical isomerism?

**A** $(CH_3)_2C=CHCH(CH_3)CH_2CH_3$

**B** $CH_3CH_2CH=CHCH(CH_3)CH_2CH_3$

**C** $(CH_3)_2C=C(CH_2CH_3)_2$



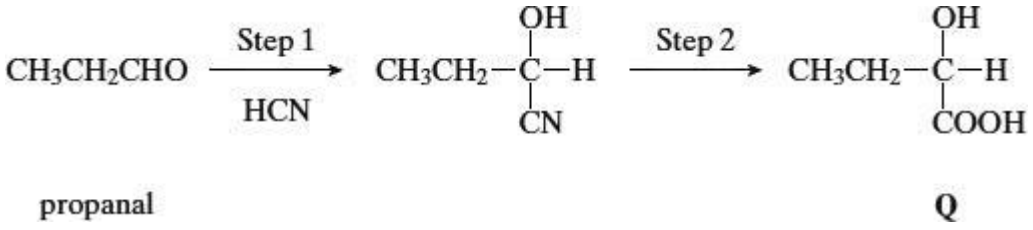
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**D** $CH_3CH_2CH(CH_3)CH(CH_3)C=CH_2$

**(Total 1 mark)**

## Q13.

Consider the reaction sequence shown below.




propanal Q

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

*Name of mechanism* _____

Mechanism

**(5)**

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

_____

(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*

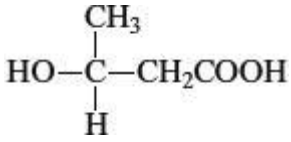


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*Type of stereoisomerism* _____

**(4)**

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



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

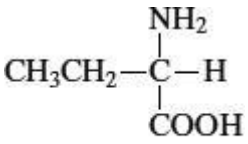
(ii) Suggest a reason why the polymer is biodegradeable.

_____

_____

**(2)**

(d) The amino acid **R** is shown below.



**R**

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



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(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).

_____

**(3)**

**(Total 14 marks)**

## Q14.

Which one of the following reactions will produce an organic compound that has optical isomers?

**A** dehydration of butan-2-ol by heating with concentrated sulphuric acid

**B** reduction of pentan-3-one by warming with $NaBH_4$

**C** addition of $Br_2$ to 3-bromopropene

**D** reduction of 2,3-dimethylpent-2-ene with $H_2$ in the presence of a nickel catalyst

**(Total 1 mark)**

## Q15.

Each of the parts (a) to (e) below concerns a different pair of isomers.

Draw one possible structure for each of the species **A** to **J**, using Table 2 on the Data Sheet where appropriate.

(a) Compounds **A** and **B** have the molecular formula $C_5H_{10}$
**A** decolourises bromine water but **B** does not.

**A** **B**

**(2)**



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(b) Compounds **C** and **D** have the molecular formula $C_2H_4O_2$

Each has an absorption in its infra-red spectrum at about 1700 $cm^{-1}$ but only **D** has a broad absorption at 3350 $cm^{-1}$

**C** **D**

**(2)**

(c) Compounds **E** and **F** are esters with the molecular formula $C_5H_{10}O_2$

The proton n.m.r. spectrum of **E** consists of two singlets only whereas that of **F** consists of two quartets and two triplets.

**E** **F**

**(2)**

(d) Compounds **G** and **H** have the molecular formula $C_3H_6Cl_2$ **G** shows optical activity but **H** does not.

**G** **H**

**(2)**

(e) Compounds **I** and **J** have the molecular formula $C_6H_{12}$

Each has an absorption in its infra-red spectrum at about 1650 $cm^{-1}$ and neither shows geometrical isomerism. The proton n.m.r. spectrum of **I** consists of a singlet only whereas that of **J** consists of a singlet, a triplet and a quartet.

**I** **J**

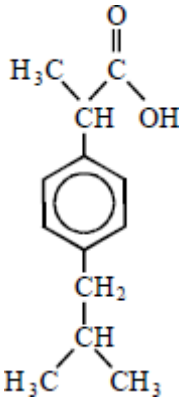


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**(2)**
**(Total 10 marks)**

## Q16.

Ibuprofen is a drug used as an alternative to aspirin for the relief of pain, fever and inflammation. The structure of ibuprofen is shown below.



Which one of the following statements is **not** correct?

**A** It has optical isomers.

**B** It liberates carbon dioxide with sodium carbonate solution.

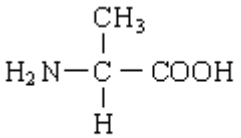
**C** It undergoes esterification with ethanol.

**D** It undergoes oxidation with acidified potassium dichromate(VI).

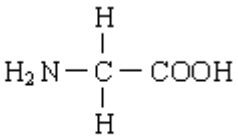
**(Total 1 mark)**

## Q17.

The structures of the amino acids *alanine* and *glycine* are shown below.



*alanine*



*glycine*

(a) Give the systematic name for *alanine.*

_____

**(1)**

(b) *Alanine* exists as a pair of stereoisomers.

(i) Explain the meaning of the term *stereoisomers.*

_____



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_____

_____

(ii) State how you could distinguish between the stereoisomers.

_____

_____

_____

**(4)**

(c) Give the structural formula of the species formed by *glycine* at pH 14.

**(1)**

(d) When two amino acids react together, a dipeptide is formed. Give the structural formulae of the **two** dipeptides which are formed when *alanine* and *glycine* react together.

*Dipeptide 1*

*Dipeptide 2*

**(2)**



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(e) Give the structural formula of the organic compound formed when *glycine* reacts with methanol in the presence of a small amount of concentrated sulphuric acid.

**(1)**

**(Total 9 marks)**

## Q18.

Which one of the following statements about but-2-enal, $CH_3CH=CHCHO$, is **not** true?

**A** It has stereoisomers.

**B** It shows a strong absorption in the infra-red at about 1700 $cm^{-1}$.

**C** It will turn an acidified solution of potassium dichromate(VI) green.

**D** It can be dehydrated by concentrated sulphuric acid.

**(Total 1 mark)**

## Q19.

(a) **P**, **Q** and **R** have the molecular formula $C_6H_{12}$

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***



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**(3)**

(b) Butanone reacts with reagent **S** to form compound **T** which exists as a racemic mixture. Dehydration of **T** forms **U**, $C_5H_7N$, 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* _____

_____

_____

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

*Reagent **S*** _____

*Compound **T***

*Compound **U***

**(6)**
**(Total 9 marks)**

## Q20.

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.

_____

(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.

_____

_____

_____

**(5)**

(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.

_____

(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 **E** and **F** formed from methanol have the molecular formula $C_6H_{12}O_2$

Isomer **E** has only 2 singlet peaks in its proton n.m.r. spectrum.

Isomer **F** is optically active.

Draw the structures of these two isomers.

*Isomer **E***

*Isomer **F***



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**(2)**

**(Total 10 marks)**

## Q21.

On reduction, a racemate can be formed by

**A** $CH_3CH_2CH_2CH_2CHO$

**B** $CH_3CH_2CH_2COCH_3$

**C** $CH_3CH_2COCH_2CH_3$

**D** $CH_3CH{=}CHCH_2CHO$

**(Total 1 mark)**

## Q22.

Which one of the following reaction mixtures would give a product capable of exhibiting optical isomerism?

**A** $CH_3CH{=}CH_2$ + HBr

**B** $CH_3CH_2CH_2Br$ + NaOH

**C** $CH_3CH_2CH_2OH$ + $H_2SO_4$

**D** $CH_3CH_2$ CHO + HCN

**(Total 1 mark)**



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