1. Name the compound

   $CH_3CH_2CH(CH_3)CH=CHCH_3$

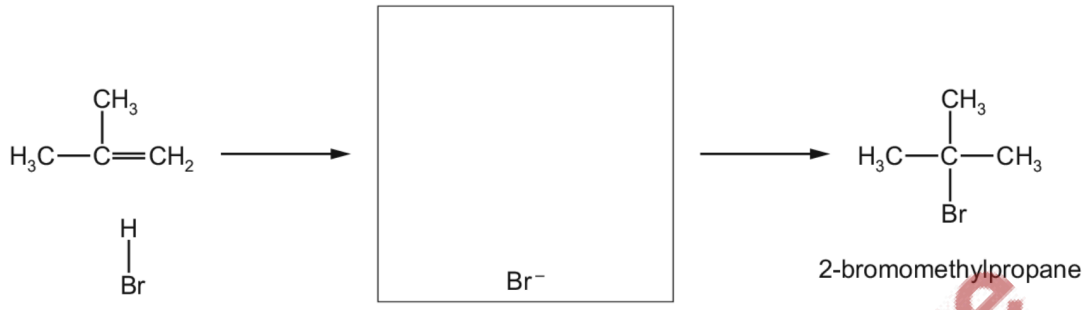
   Ans: 4-methylhex-2-ene

2. Name the compound

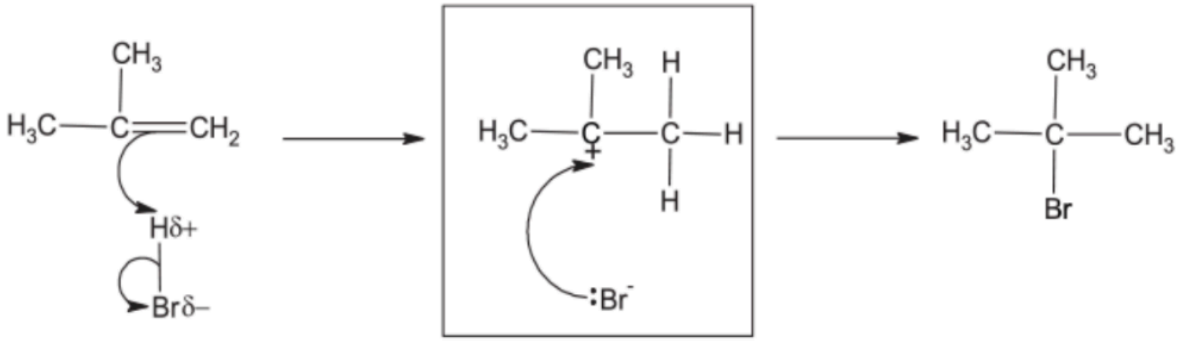
   $(CH_3)_2C=C(CH_3)_2$

   Ans: 2,3-dimethylbut-2-ene

3. **(ii)** Complete the mechanism for the reaction of this compound with hydrogen bromide. Include all necessary curly arrows, lone pairs, charges and partial charges.



[4]



4. Explain why 2-bromomethylpropane is the major product of the above reaction while only relatively small amounts of 1-bromomethylpropane are produced.
   - Tertiary carbocation with least number of hydrogen atoms bonded to it is most stable
   - Due to positive inductive effect of 3 electron donating methyl groups
   - Reducing charge density on C^+

5. Explain the meaning of the term nucleophile
   A lone pair/ electron pair donor

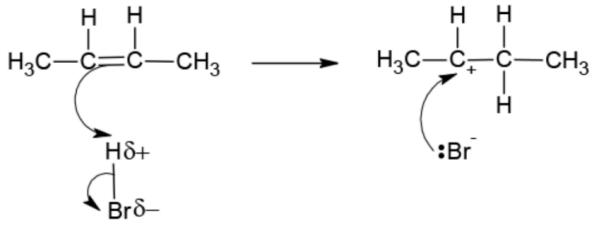
6.

Ethanal reacts with a mixture of HCN and NaCN to make 2-hydroxypropanenitrile, $CH_3CH(OH)CN$.

The reaction mechanism is nucleophilic addition.

Identify the species which acts as the nucleophile during this reaction.
Cyanide ion ($:CN^-$)

7. Draw the displayed formula of C4H8 and use it to show the mechanism of the reaction of C4H8 with HBr. include all necessary charges, dipoles, lone pairs and curly arrows.

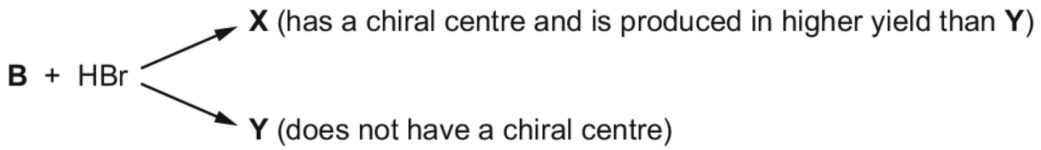


arrow from the C=C double bond drawn to the H
dipole on H–Br in correct orientation AND arrow from the H-Br bond to the $Br^{\delta-}$
correct carbocation from the structure with C=C drawn
Br^- with lone pair, negative charge AND arrow from lone pair to the positively charged carbon atom of intermediate

8. In this question, A, B and C all have the formula C4H8. They all decolourise bromine and are structural isomers of each other.

B does **not** show geometrical isomerism.

B reacts with HBr to form a mixture of two structural isomers, **X** and **Y**.

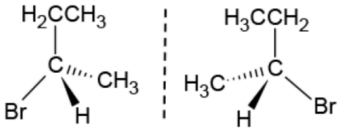


(ii) Name **B**.

But-1-ene

(iii) **X** exists as a pair of optical isomers.

Draw these isomers using the conventional three-dimensional representation.



One 3D structure of 2–bromobutane which must have 2 bonds shown the same and two different, i.e. **three** bond types altogether, e.g. two solid lines, one wedge and one dash. If two bonds are drawn in the plane of the paper, i.e. single solid lines, they must **not** be at 180 degrees to each other.

Second structure either mirror of first OR all bonds drawn the same with position of two groups swapped.

(iv) Explain why **X** is produced in higher yield than **Y**.

- Secondary carbocation from X is more stable
- Due to positive inductive effect/ electron-releasing character of 2 alkyl groups

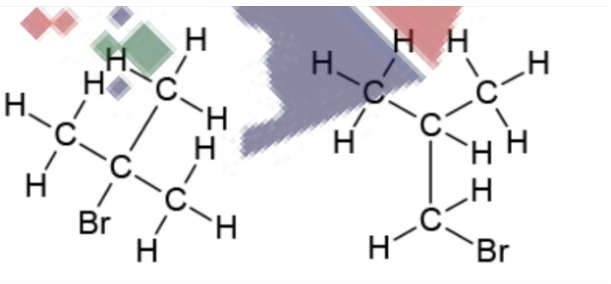
(e) **C** does **not** show geometrical isomerism.

C reacts with HBr to form a mixture of two structural isomers, neither of which has a chiral centre.

(i) Name **C**.

2-methylpropene

(ii) Draw the **displayed** formula of each of the structural isomers produced by the reaction of **C** with HBr.



9. Define addition reaction
   (a reaction where) two (or more) compounds / reagents / molecules form (only) one product

10. Define structural isomerism
    Molecules with the same molecular formula but different structural formulae.

11. Explain the meaning of the term geometrical isomerism
    Molecules with the same structural and molecular formula, but with different arrangement in space caused by C=C double bond.

12. State and explain how many stereoisomers of this structure there are

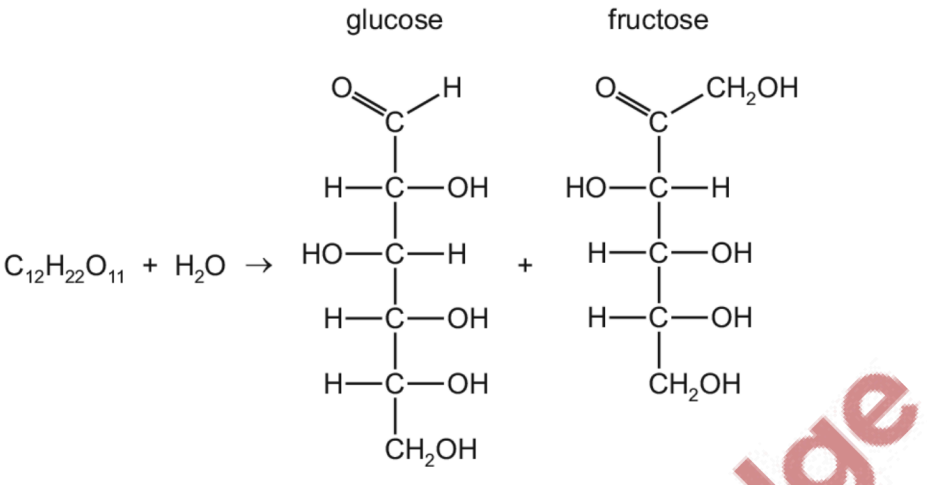
    $CH_3CH_2CH(CH_3)CH=CHCH_3$

    - 4 stereoisomers
    - Double bond/ alkene
    - 2 different bonds on each double bonded carbon
    - One chiral carbon/ chiral centre / one carbon atom has 4 different groups attached / is asymmetric / is chiral

NOTE: geometric isomers where double bond is on 3rd carbon, etc. would not be considered as that would change the structural formula – question is only about stereoisomerism.

13.

Sucrose, $C_{12}H_{22}O_{11}$, reacts with water to form glucose and fructose in reaction **A**.

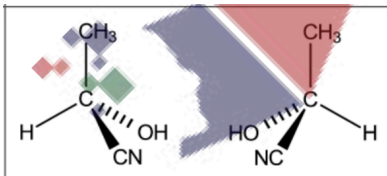


Explain in detail, why glucose and fructose are a pair of structural isomers. (your answer should refer specifically to these 2 molecules)

- Both have molecular formula $C_6H_{12}O_6$
- Both have same number and type of atoms present, but the atoms are arranged in a different order: one has a carbonyl group at the end of the chain/molecule and the other has a carbonyl group in the middle of the chain/molecule.

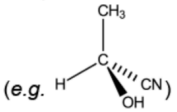
14. Explain what is meant by the term chiral centre
An atom which is bonded to four different substituents/ groups/ atoms.
A (tetrahedral) atom with 4 different substituents/ groups/ atoms attached.

15. Draw 3D diagrams of the pair of isomers of $CH_3CH(OH)CN$. Indicate with as asterisk (*) the chiral centre on one of the structures drawn.



M1 one 3-D structure of **correct** molecule shown.

M2 a mirror image of the molecule drawn in **M1 OR** same profile with two groups swapped



M3 central chiral C shown as *

16. Explain why methylpropane and butane are a pair of isomers
- Same molecular formula: C4H10

- Different structural formula (or description which does not imply stereoisomerism; eg. length of longest carbon chain is not the same).

17.

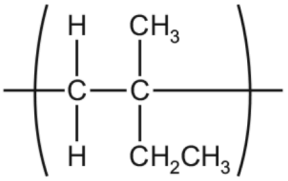
Pent-1-ene, $CH_2=CH(CH_2)_2CH_3$, does not show stereoisomerism.

(i) Give **two** reasons why pent-1-ene does **not** show stereoisomerism.

- 2 Hs on one of the C=C carbons
- No chiral carbon / no carbon with 4 different groups/atoms/chains attached

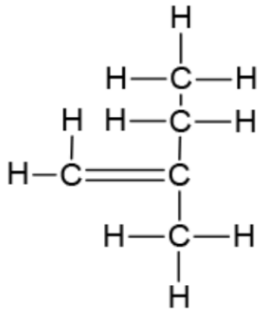
18.

(ii) A structural isomer of pent-1-ene is used as the monomer to form a polymer. The repeat unit of this polymer is shown.



Draw the **displayed** formula of the monomer used to make this polymer.

Give the name of the monomer.



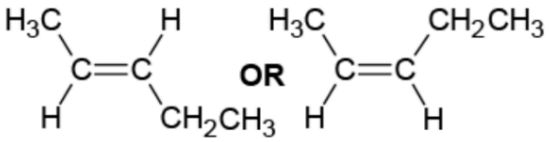
2-methylbut-1-ene

(iii) A different structural isomer of pent-1-ene shows geometrical isomerism.

Draw the structure of **one** of the two geometrical isomers with the formula C_5H_{10}.

Give the full name of this isomer.

structure



trans–pent–2–ene or or *E*–	cis–pent–2–ene or *Z*–

19.

A, **B** and **C** all have the formula C_4H_8. They all decolourise bromine and are structural isomers of each other.

(b) Draw the structures of these three **structural** isomers.

In any order
$CH_2=CHCH_2CH_3$ / $CH_2CHCH_2CH_3$ / $CH_2CHC_2H_5$
AND
$CH_3CH=CHCH_3$ / $CH_3CHCHCH_3$
AND
$(CH_3)_2C=CH_2$ / $(CH_3)_2CCH_2$

NOTE: DO NOT draw the geometric isomers of but-2-ene. Question strictly specifies structural isomers!!

20.

This question is about molecules with molecular formula C_4H_8.

(a) Give the structures of a pair of **positional** isomers with the formula C_4H_8.

[1]

(b) Give the structures of a pair of **chain** isomers with the formula C_4H_8, that do **not** exhibit stereoisomerism.

[1]

(c) Give the structures and full names of a pair of **stereoisomers** with the formula C_4H_8.

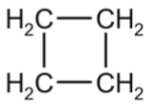
.....

.....

[2]

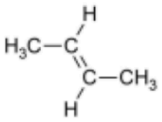
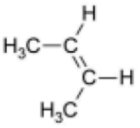
(d) The structure of a molecule, **A**, of formula C_4H_8 is shown.

Draw a functional group isomer of molecule **A** in box **B**. Explain how molecules **A** and **B** could be distinguished by a chemical test.



A

B

(a)	$CH_2=CHCH_2CH_3$ / $CH_2CHCH_2CH_3$ AND $CH_3CH=CHCH_3$ / $CH_3CHCHCH_3$	[1]
(b)	$CH_2=CHCH_2CH_3$ / $CH_2CHCH_2CH_3$ AND $(CH_3)_2C=CH_2$ / $(CH3)_2CCH_2$	[1]
(c)	  *trans*-but-2-ene (or *E*) *cis*-but-2-ene (or *Z*)	[1] [1]
(d)	**B** is $CH_2=CHCH_2CH_3$ OR $CH_3CH=CHCH_3$ OR $(CH_3)_2C=CH_2$ distinguished by addition of bromine brown/red/orange/yellow to colourless/decolourises with **B** (but not **A**)	[1] [1] [1]

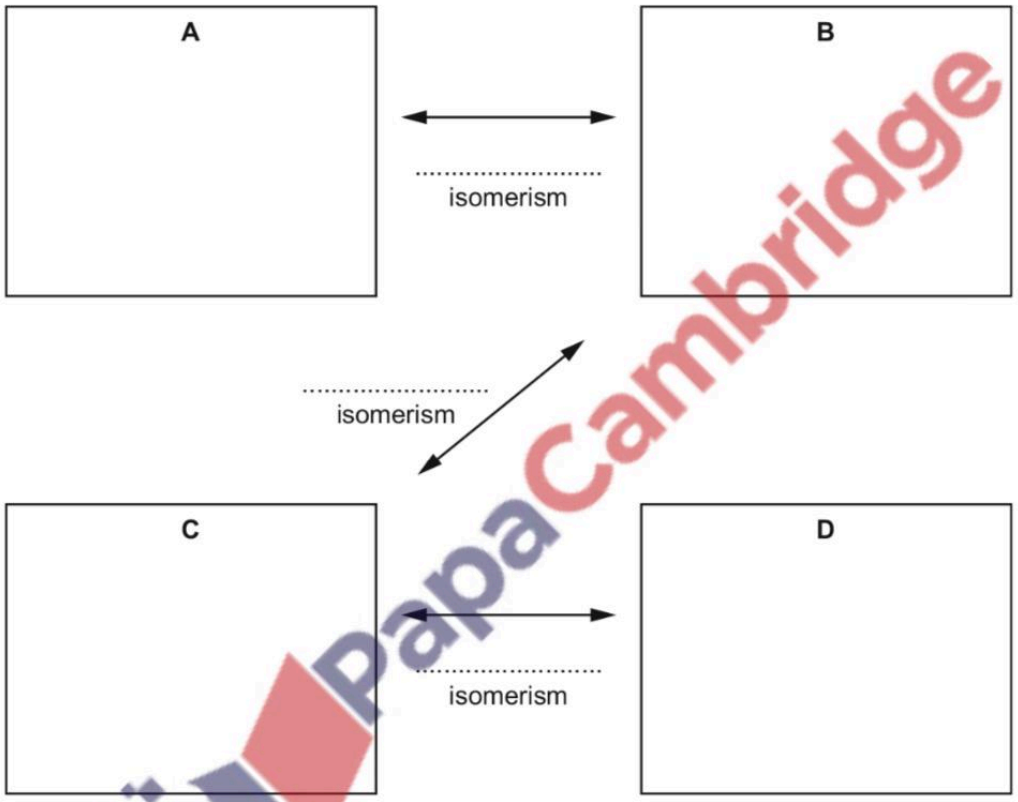
21.

There are four alcohols, **A**, **B**, **C** and **D**, which are structural isomers with the molecular formula $C_4H_{10}O$.

Alcohol **A** does not react with acidified potassium dichromate(VI) solution but **B**, **C** and **D** do.

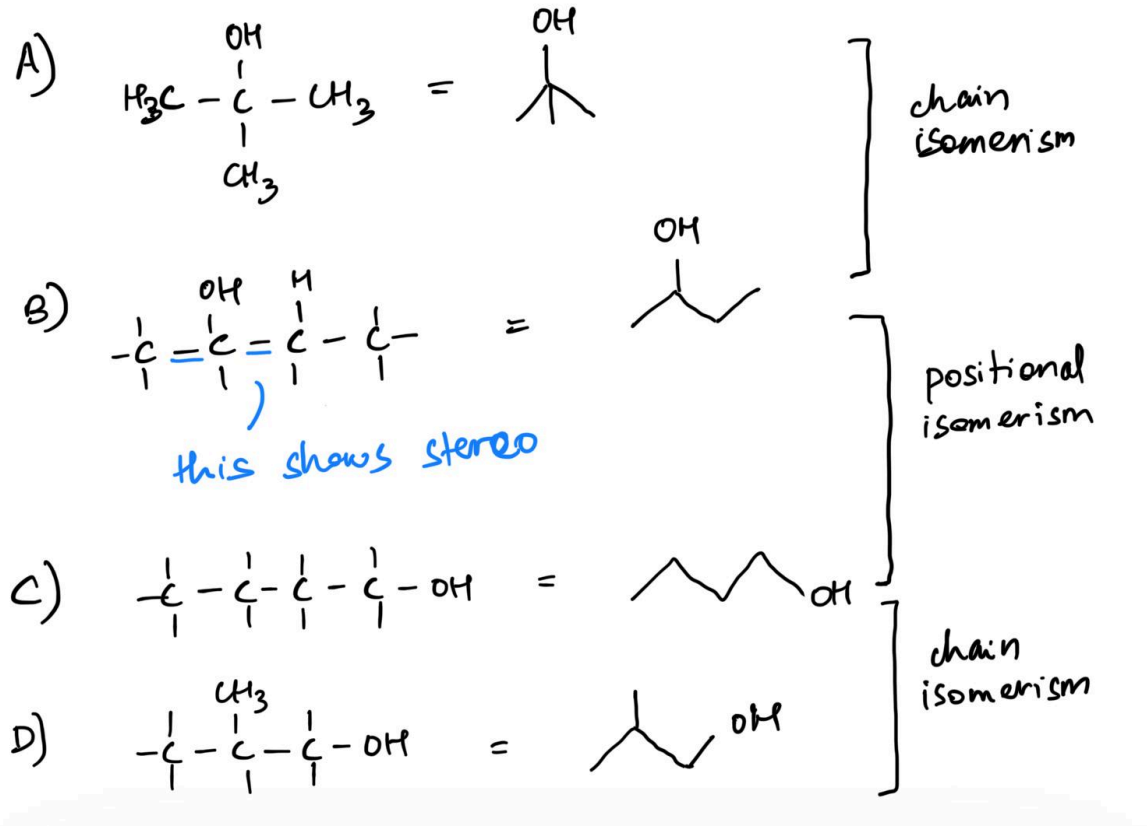
All four alcohols react with hot, concentrated sulfuric acid to form products with the molecular formula C_4H_8. **A**, **C** and **D** each give a single product in this reaction. **B** gives a mixture of two structural isomers, one of which shows stereoisomerism.

(a) Give the **skeletal** formula for each of the four alcohols and complete the diagram with the names of the types of structural isomerism shown by each linked pair of compounds.



[7]

a) A → tertiary because it's not oxidised
B, C, D → primary / secondary
Dehydration is done
A, C, D → only 1 alkene → primary
B → 2 isomers & one has stereo (cis- trans)
→ secondary



NOTE:

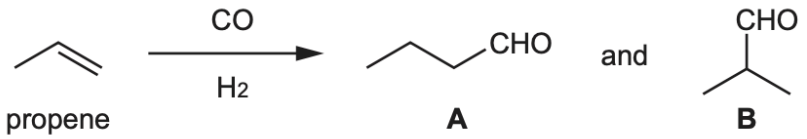
- Alcohol that does not react with $K_2Cr_2O_7$ = tertiary alcohol (not oxidised)
- Alcohol that reacts with conc. acid = dehydration = forms alkenes
- If dehydration of alcohol forms 2 structural isomers = secondary alcohol
- If dehydration of alcohol forms only 1 structural isomer = primary alcohol

22. Does but-1-ene or but-2-ene show stereoisomerism? Explain.
    - But-2-ene AND 2 different groups on each carbon of C=C
    - Double bond means no free rotation

23.

Alkenes undergo an addition reaction with a 1:1 mixture of CO and H_2 to form aldehydes.

Fig. 3.1 shows the reaction of propene with a 1:1 mixture of CO and H_2.



A. Aldehydes A and B are structural isomers. State the type of structural isomerism shown by A and B.

Positional isomerism

B.

The complete reaction of propene with a 1:1 mixture of CO and H_2 produces **A** and **B** only. The product mixture contains 96% **A** and 4% **B**.

Calculate the mass of **A** produced in this reaction when 5.00×10^3 kg of propene is used.

$$\text{mass of A} = \frac{96}{100} \times \frac{5 \times 10^3}{3 \times 12 + 6} \times (4 \times 12 + 8 + 16)$$

$$= 8230 \text{ kg}$$

C.

When propene reacts with CO and an excess of H_2, an alkane and a mixture of alcohols are formed instead. The alcohols are isomers of each other.

Suggest the molecular formulae of the alkane and the alcohols that are formed under these conditions.

molecular formula of alkane .....

molecular formula of alcohols .....

[2]

alkane	C_3H_8
alcohols	$C_4H_{10}O$

- Instead of the aldehydes with 4 carbons being formed, alcohols with 4 carbons are formed.
- The hydrogen reacts with the propene to form propane.

24. State the empirical formula of ethanedioic acid (HO_2CCO_2H)

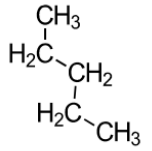
CO_2H (don't write CHO_2)

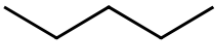
25. Name the raw material that is used to produce a sample of naphtha.
    Crude oil

26. Compound V is found in naphtha. It has a molecular formula $C_{10}H_{22}$. When V is heated at high pressure in the absence of air, an equal number of moles of ethene, propene and W are made. W is a compound made of straight chain, saturated molecules.
    A. Name the process that describes this reaction.
       Thermal cracking

    B. Deduce the structure of W. Draw its structure below.

*structure of **W***



OR $CH_3(CH_2)_3CH_3$ OR 

NOTE: Thermal cracking is a process used to break down large hydrocarbons into smaller molecules. Catalytic cracking is a process that uses a catalyst to break down large hydrocarbons into smaller molecules.

27. Propene is separated from the mixture and heated in air in the presence of a catalyst. Propene is oxidised to X, which contains two functional groups. Effervescence is seen when $Na_2CO_3(aq)$ is added to X. Identify the functional group present in X which is responsible for this observation.
    - CO_2H / carboxylic acid

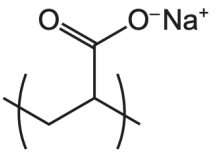
28. Identify a reagent which could be used to show that X contains a C=C. Include relevant observations.
    - add Br2(aq) / bromine water
    - solution turns from brown / orange / red to colourless / decolorises OR brown / orange / red fades

29.

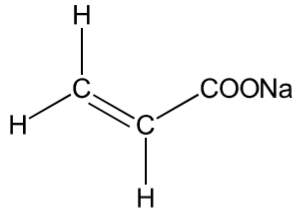
X reacts with another reagent to form **Y**.

Molecules of **Y** react together to form addition polymer **Z**. The diagram shows the repeat unit of polymer **Z**.

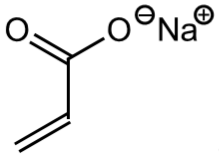
repeat unit of polymer **Z**



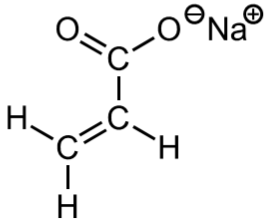
Draw the structural formula of monomer **Y**.



OR $CH_2CH(CO_2^{(-)}Na^{(+)})$
OR $CH_2{=}CH(COO^{(-)}Na^{(+)})$



OR



OR , etc.

30. Propene, C3H6, reacts with H2O in the presence of an acid catalyst to form an alcohol with molecular formula C3H8O.

A. Name this type of reaction.

Addition

B. Name the catalyst used and state conditions needed for this reaction to occur

- catalyst = sulfuric acid / phosphoric(V) acid
- conditions of reaction = steam / heat (and pressure)

31. 2-bromopropane reacts to form propene, hydrogen bromide and water under certain conditions.

A. Name this type of reaction.

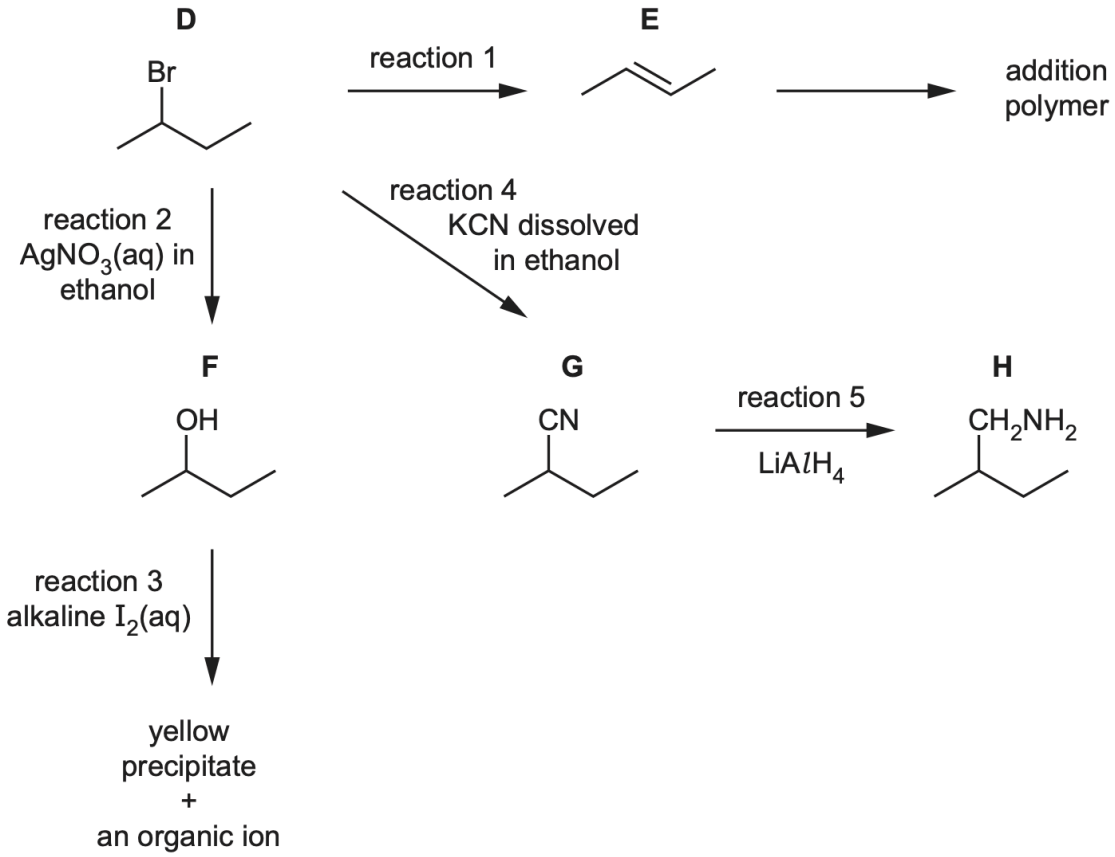
Elimination

B. Describe the reagents and conditions needed to favour this reaction.

- NaOH / KOH
- ethanolic solution / ethanol / alcohol + heat

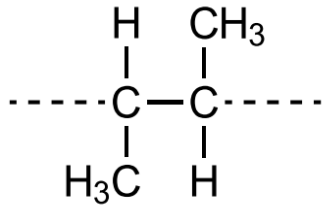
32.

Fig. 4.1 shows some reactions of compound **D**, 2-bromobutane.



a. Reagent & conditions to form E (alkene) from halogenoalkane in reaction 1
NaOH in alcohol / ethanol AND heat (under reflux)

b. Draw structure of 1 repeat unit of the addition polymer that forms from E.



NOTE: The CH3 groups are not adjacent

c. E is formed when F is heated strongly in presence of Al2O3 catalyst. Write equation for the reaction.

$$C_4H_{10}O \,/\, CH_3CH(OH)C_2H_5 \rightarrow C_4H_8 \,/\, CH_3CHCHCH_3 + H_2O$$

d. Predict what is observed when a halogenoalkane containing Br reacts with ethanolic aqueous AgNO3 to form alcohol.

- cream(-coloured) / off-white precipitate (forms)

e. Identify the yellow precipitate and the organic ion formed in reaction 3.
   - Yellow ppt = tri-iodomethane / iodoform / CHI3
   - Organic ion =

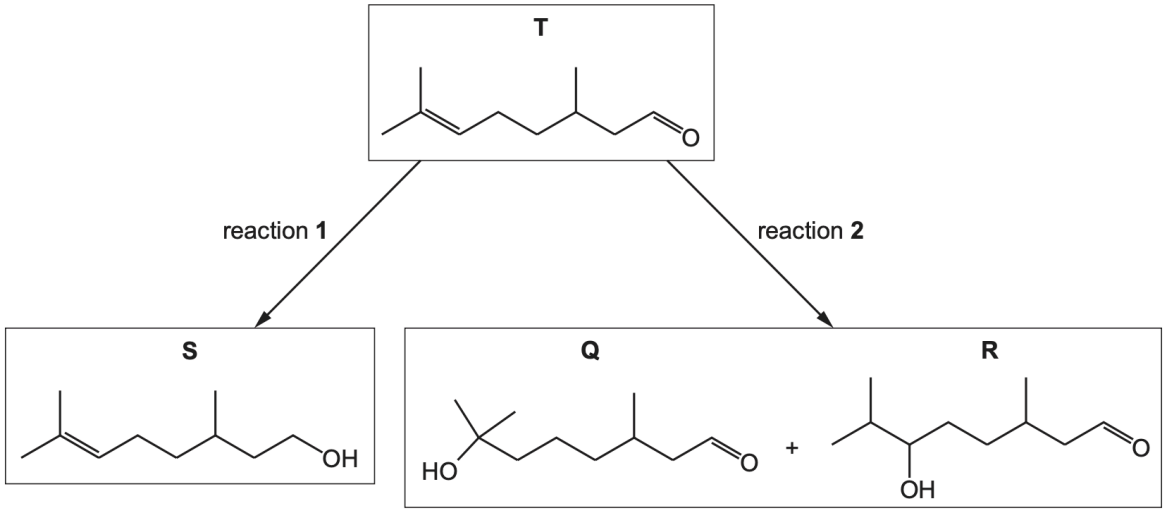
     $CH_3CH_2CO_2^-$ / propanoate

     NOTE: the salt of carboxylic acid is formed!! So there should be 2 Os.

NOTE: halogenoalkane + aq AgNO3 (ethanol) = alcohol + AgX
This reaction is used to determine which halogen is present in the halogenoalkane.
In this case, AgBr is formed, which is a cream–coloured ppt.

1. Conditions required for hydration
   - Steam
   - H3PO4 catalyst

2.



   a. Suggest which product formed in reaction 2 has a higher yield. Explain your answer.
   - intermediate/ cation is more stable
   - As the C+ has 3 more alkyl groups attached
   - So greater positive inductive effect

   b. When PCl5(s) is added to separate samples of Q and R at room temperature, both react vigorously. Suggest why samples of Q and R must be dried before PCl5 is added. Include a relevant equation to support your answer.
   - Water reacts with/ hydrolyses PCl5

$$H_2O + PCl_5 \rightarrow POCl_3 + 2HCl \quad \textbf{OR} \quad 4H_2O + PCl_5 \rightarrow H_3PO_4 + 5HCl$$

3. Describe a chemical test & observation which confirms the presence of a carboxyl functional group.
   - (add) group 1 carbonate / group 1 bicarbonate / Na2CO3 / NaHCO3 etc.
   - effervescence / fizzing / bubbling

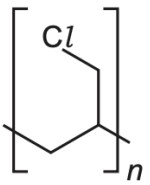
4. A 3.196g sample of Br2 reacts completely with 2.800g of V ($C_{18}H_{32}O_2$). Calculate how many alkene functional groups are present in one molecule of V. Show your working.

   3.196 g Br_2 = 3.196 / 159.8 (= 0.02 mol Br_2) **AND** 2.8(00) / 280 (= 0.01 mol **V**)
   2 alkene / 2 C=C (groups)

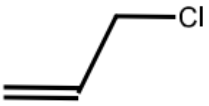
5. What is the type of structural isomerism shown by 1–bromobutane and 2–bromobutane
   - Positional isomerism!!

6. **X** is an addition polymer.

X



Draw the monomer of X.



7.

Fig. 5.1 shows three reactions of 2-bromopropane, $CH_3CH(Br)CH_3$.

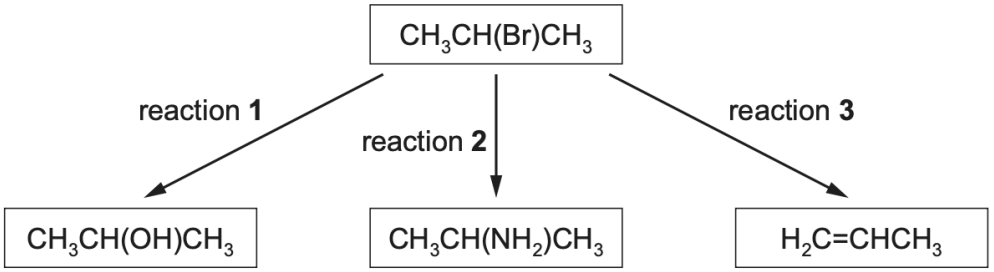


Fig. 5.1

(a) Complete Table 5.1 for each reaction, by:

- stating the reagent and conditions used
- identifying the type of reaction that occurs.

Table 5.1

reaction	reagent and conditions	type of reaction
1		
2		
3		

reaction	reagent and conditions	type of reaction
1	NaOH(aq) **[M1]**	substitution
2	NH_3 **[M2]** in ethanol **AND** heat under pressure **[M3]**	substitution
3	NaOH in ethanol **AND** heat **[M4]**	elimination

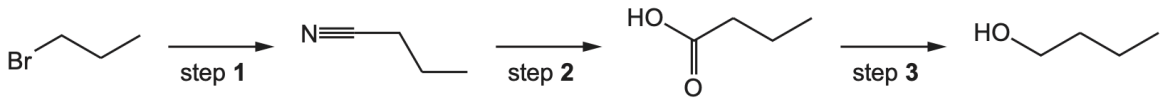
M5 and M6 types of reaction
[3 correct types = 2 marks and 2 correct types = 1 mark]

All reagents can be identified as (correct) formula or in words

8. Explain why 2-iodopropane reacts at a faster rate than 2-bromopropane.
   - C–I (covalent bond) is weaker
   - lower activation energy / lower Ea (with 2-iodopropane) OR

- low / less energy is required to make the (same)carbocation / intermediate (from 2-iodopropane) OR
- iodine / I (of C–I) has weaker attraction of nucleus to bonding / shared pair (of electrons) due to more / high shielding (of electrons from inner shells) // more / 5 electron shells in iodine // C-I greater distance from nuclei (to bonding pair of electrons)

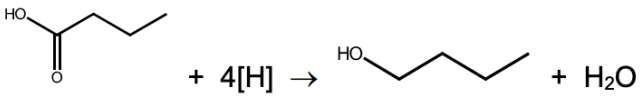
9.



Construct an equation for the reduction reaction in step 3. Use [H] to represent one atom of hydrogen from the reducing agent.

$HOOC(CH_2)_2CH_3 + 4[H] \rightarrow HO(CH_2)_3CH_3 + H_2O$

OR



NOTE: LiAlH4 is the stronger reducing agent that reduces carboxylic acid!!

10.

The functional group in **G** is an oxygen atom bonded to two carbon atoms.

G

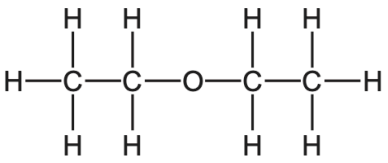


Fig. 3.3

G, **H** and **J** are structural isomers with molecular formula $C_4H_{10}O$.
H and **J** are straight chain molecules.

Table 3.3 shows the boiling points and reactions of **G**, **H** and **J** when heated under reflux with excess acidified $K_2Cr_2O_7$.

Table 3.3

	G	**H**	**J**
boiling point / °C	35	117	98
heat under reflux with excess acidified $K_2Cr_2O_7$	remains orange	orange to green	orange to green

a. Identify the type of structural isomerism shown between G and H using the information in Table 3.3.

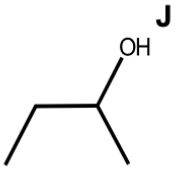
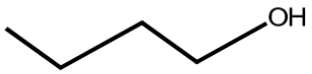
- Functional group isomerism

b. Identify the type of structural isomerism shown between H and J using the information in Table 3.3.

- Positional isomerism

(iii) Draw a possible structure for **H** and for **J**. State the systematic name for each structure.

H	J
name	name .....

J	H
 name: butan-2-ol	 name: butan-1-ol

M1 correct structures
M2 correct structures in correct boxes **H** and **J**
M3 correct corresponding name of both **H** and **J**

NOTE: H and J are straight chain molecules!! Which means it cannot branch. Length of longest carbon chain has to be 4!!

11.

Two bottles labelled **Q** and **M** each contain a straight-chain halogenoalkane with molecular formula $C_4H_9\mathbf{X}$, where **X** represents *Cl*, Br or I.
A sample from each bottle is added to separate samples of equal amounts of aqueous silver nitrate in ethanol. In each reaction, the same organic product, **T**, and a precipitate are made, as shown in Fig. 4.2.

$$\mathbf{Q} \xrightarrow{AgNO_3(aq) \text{ in ethanol}} \mathbf{T} \xleftarrow{AgNO_3(aq) \text{ in ethanol}} \mathbf{M}$$

Identify the functional group present in T and name the type of reaction that occurs using the information in Fig. 4.2 and Table 4.1.

- Functional group in T: hydroxy(l)
- Type of reaction: substitution

When pure T is added to alkaline $I_2(aq)$, a yellow precipitate and an anion, L, are made. Identify the anion L.

$C_2H_5COO^-$ **OR** $CH_3CH_2CO_2^-$ or propanoate (an)ion

12.

But-2-ene reacts with $KMnO_4$ to form organic product, **Y**.
Y does not react with Na_2CO_3.
A gas is produced when an excess of Na is added to **Y**.

24.0 cm^3 of gas is produced when an excess of Na is added to 0.001 mol of **Y**, when measured under room conditions.
Assume that 1 mol of gas occupies 24.0 dm^3 under room conditions.

Deduce a possible structure of **Y**. Explain your answer.

M1 unbranched 4C structure **AND** any number of –OH in any position

M2 0.001 mol H_2 made from 0.001 mol **Y**
AND
R–OH + Na → RONa + ½H_2 **OR** use of 1 OH (group) → ½H_2

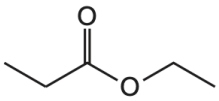
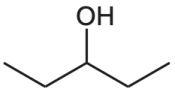
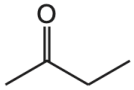
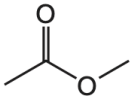
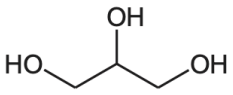
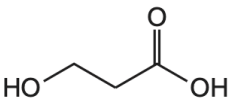
M3 $CH_3CH(OH)CH(OH)CH_3$

13. Define the term structural isomer
- (molecules / isomers with) the same molecular formula
- but different structural formulae

14.

4 Organic compounds can be distinguished using chemical tests.
Table 4.1 shows four pairs of compounds.

Table 4.1

organic compounds		reagent	positive result of chemical test on identified compound
A1 	**A2** 		
B1 	**B2** 		
C1 	**C2** 		
D1 	**D2** 		

(a) Complete Table 4.1 to:

- identify a reagent that could distinguish between the compounds in each pair
- give the **positive** result of the chemical test **and** identify which compound shows this result.

Use a different reagent for each test. [8]

$K_2Cr_2O_7$ **OR** $KMnO_4$ **OR** Na	**A2** make solution turn (orange to) green **OR** turn colourless **OR** effervescence
alkaline $I_2(aq)$ / **OR** 2,4-DNPH	**B1** gives yellow/orange ppt **OR** **B1** gives red/yellow/orange ppt
$Br_2(aq)$	**C2** turns it (orange to) colourless
Na_2CO_3 $NaHCO_3$	**D2** gives effervescence

15.

Lactones are cyclic esters. Under suitable conditions, lactones form from molecules that have both an alcohol and a carboxylic acid functional group.
Equation **1** shows an example of the formation of a lactone.

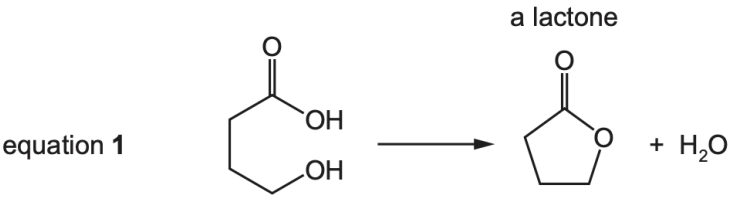
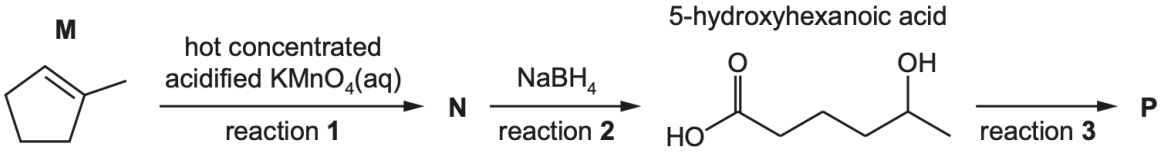


Fig. 5.1 shows the synthesis of lactone **P** from compound **M**.



Reaction 2 is a nucleophilic addition. Suggest why reaction 2 creates a mixture of two organic compounds.

- (ketone in) N is planar (so can be attacked from either side)
- different stereoisomers / optical isomers form

16.

(b) Two possible syntheses of pyruvic acid are shown in Fig. 4.3 and Fig. 4.4.

Each synthesis has a total of three steps.

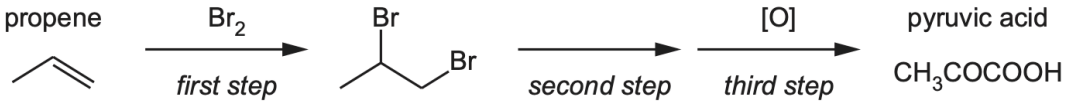


Fig. 4.3

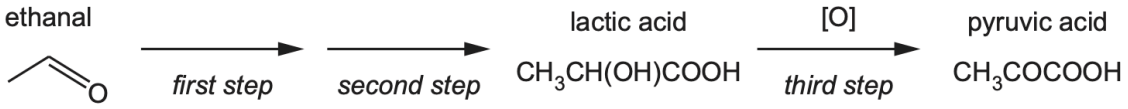


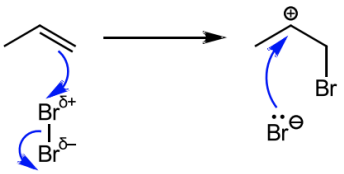
Fig. 4.4

(i) Complete the diagram in Fig. 4.5 to show the mechanism for the reaction of propene with Br_2.

Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.

Fig. 4.5

[3]



curly arrow from C=C bond to $Br^{\delta+}$ **AND** curly arrow from $Br^{\delta+}$—$Br^{\delta-}$ bond to $Br^{\delta-}$ **AND** $Br^{\delta+}$ closest to the double bond

correct intermediate

curly arrow from lone pair on Br^- to $C^{(+)}$ of the intermediate

(iii) Complete Table 4.1 to give details of the reagents and conditions used in each of the two syntheses shown in Fig. 4.3 and Fig. 4.4.

Table 4.1

		synthesis from propene (shown in Fig. 4.3)	synthesis from ethanal (shown in Fig. 4.4)
reagents and conditions used	*first step*	Br_2	
	second step		
	third step		

HCN&KCN **OR** NaCN with H_2SO_4

NaOH(aq) (1)
dilute / aq(ueous)HC*l* / H_2SO_4 (1)

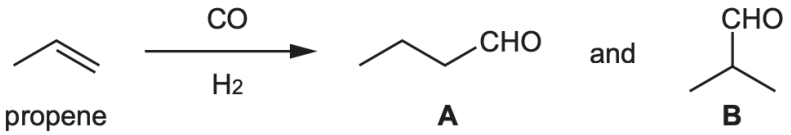
acidified $K_2Cr_2O_7$

17. Define addition reaction
- A reaction where two or more compounds / reagents / molecules form only one product

18.

Alkenes undergo an addition reaction with a 1:1 mixture of CO and H_2 to form aldehydes.

Fig. 3.1 shows the reaction of propene with a 1:1 mixture of CO and H_2.



a. State the type of structural isomerism shown by A and B
- Chain isomerism (but ms shows positional isomerism)

b. When propene reacts with CO and an excess of H2, an alkane and a mixture of alcohols are formed. The alcohols are isomers of each other. Suggest the molecular formulae of the alkane and the alcohols that are formed under these conditions.
- Molecular formula of alkane = C_3H_8
- Molecular formula of alcohols = $C_4H_{10}O$

NOTE: in first case, 1:1 mixture of CO and H2 gives 2 isomers of butanal from propene. Similarly, in the second case, you will get 2 isomers of butanol from propene. Propene will get hydrogenated to form propane. No extra carbon atom will be added to form the alkane.

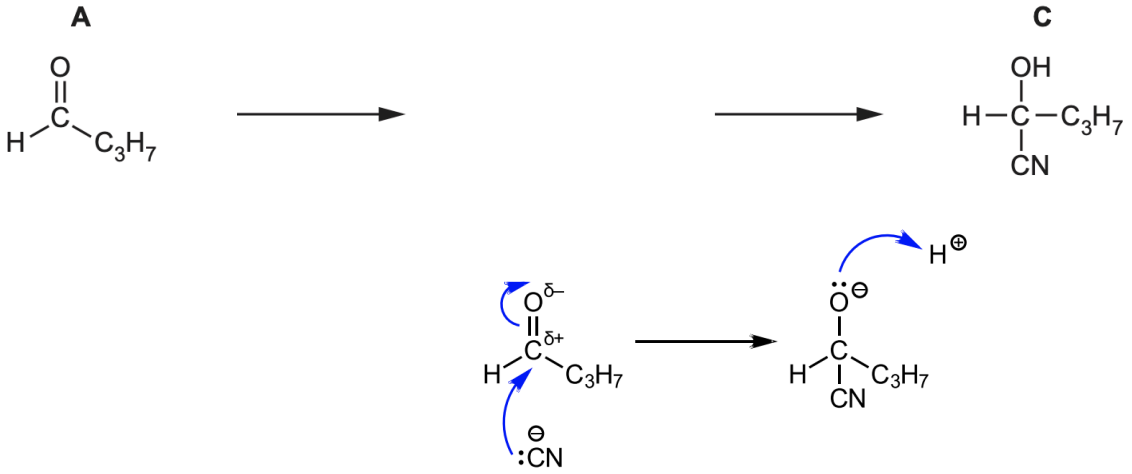
19.

(i) **A** undergoes a nucleophilic addition reaction with a mixture of HCN and KCN, forming compound **C**.

Complete the diagram to show the mechanism for this reaction.

Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.

Draw the structure of the organic intermediate.



curly arrow from lone pair on C of CN^- to $C^{(\delta+)}$

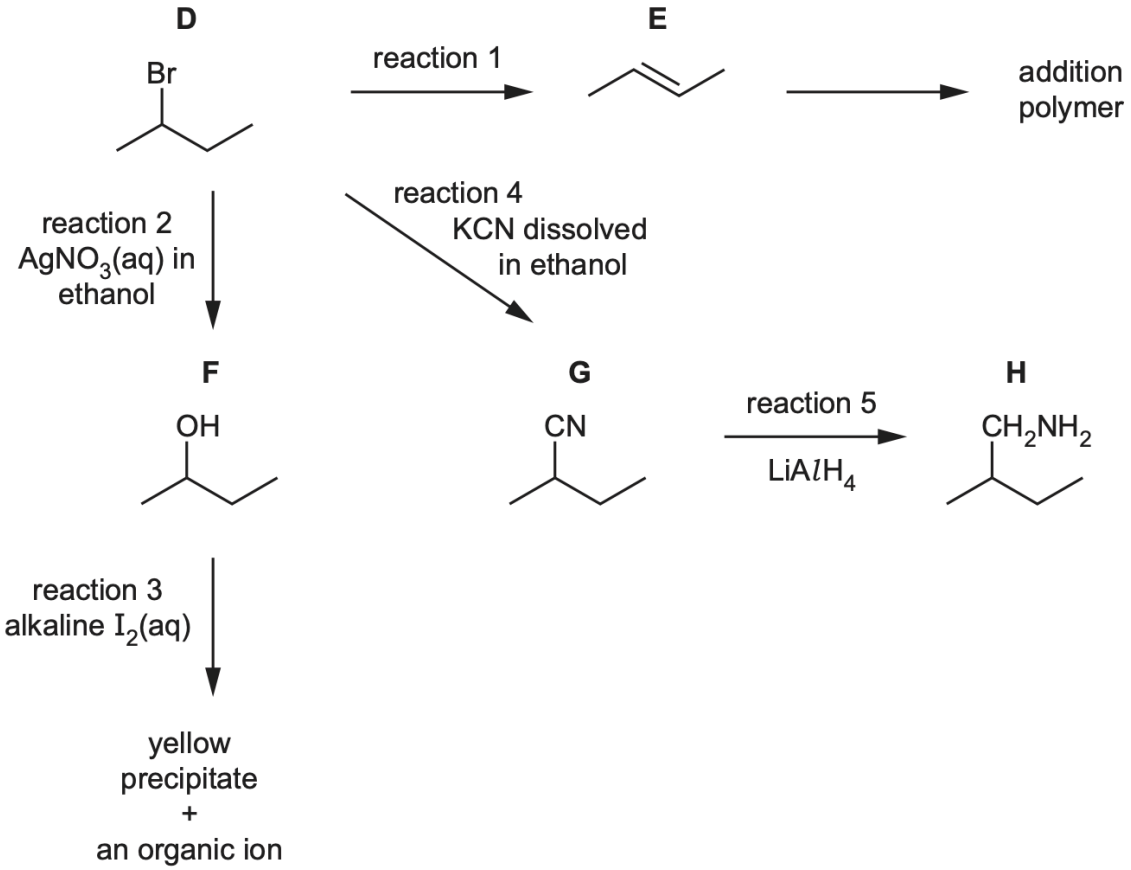
correct dipole on C=O **AND** curly arrow from C=O bond to $O^{\delta-}$

correct organic intermediate

curly arrow from lone pair on alkoxide $O^{(-)}$ to H^+ / H of HCN / H of H_2O (to reform the alcohol)

20.

Fig. 4.1 shows some reactions of compound **D**, 2-bromobutane.



State the reagent and conditions used to form E in reaction 1

- NaOH in alcohol / ethanol AND heat (under reflux)

NOTE: don't forget to state heat!!

21.

Write an equation for the reaction of C_2H_5OH with PCl_5 to form C_2H_5Cl.

$$C_2H_5OH + PCl_5 \rightarrow C_2H_5Cl + POCl_3 + HCl$$

22.

Halogenoalkanes can also be prepared by reacting alcohols with hydrogen halides, such as HCl and HI.

- HCl is prepared using $NaCl$ and concentrated H_2SO_4.
- HI is prepared by reacting NaI with concentrated H_3PO_4.

Suggest why HI is **not** prepared by the reaction of NaI with concentrated H_2SO_4.

EITHER

- HI / I– is a strong(er) reducing agent (than HCl / Cl –)
- HI / I– is oxidised to iodine but the chloride is not

OR

- H2SO4 is a (strong enough) oxidising agent (to react with HI / I–)
- HI / I– forms iodine

OR

- phosphoric acid is a weak / not an oxidising agent
- so does not react with iodide (where M2 is dependent on M1 here

23. The rate of the hydrolysis reaction of halogenoalkanes with NaOH(aq) is dependent on the halogen that is bonded to carbon. State and explain the order of reactivity when NaOH(aq) reacts separately with C_2H_5Cl, C_2H_5Br and C_2H_5I.

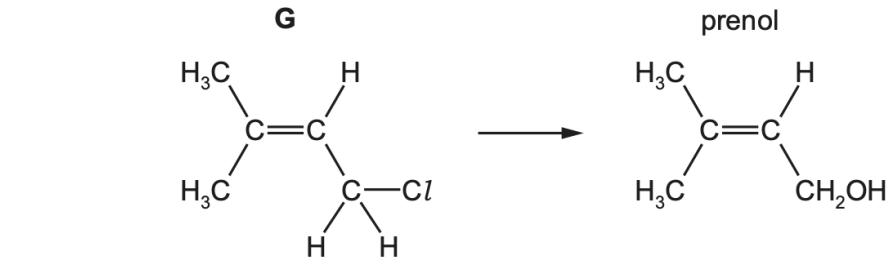
- C_2H_5I reacts fastest <u>AND</u> C_2H_5Cl reacts slowest <u>OR</u> $C_2H_5Cl < C_2H_5Br < C_2H_5I$
- C—I bond is the weak(est) <u>AND</u> C—Cl bond strong(est)

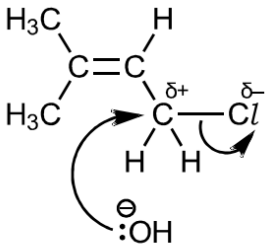
24.

Prenol can be formed by the reaction of **G** with NaOH(aq).

Complete the diagram to show the mechanism of the reaction between **G** and NaOH(aq) to form prenol.

Include all relevant charges, partial charges, lone pairs and curly arrows.





M1: curly arrow from lone pair on O of OH^- to C of C—Cl

M2: correct dipole on C—Cl **AND** curly arrow from C—Cl bond to $Cl^{\delta-}$

25.

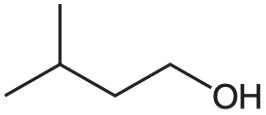
Give the balanced equation to represent the reaction of **K**, $C_5H_{12}O_2$, with acidified potassium dichromate(VI) to form **M**, $C_5H_8O_3$.

Use [O] to represent an atom of oxygen provided by the oxidising agent.

$C_5H_{12}O_2 + 3[O] \rightarrow C_5H_8O_3 + 2H_2O$

NOTE: don't forget the H2O!!

26. Name this compound:



- 3-methylbutan-1-ol
  DON'T forget the 1!!

27. Suggest the commercial use of an ester
- solvents / perfumes / flavourings

28. State the conditions required for chlorine to react with methane.
- Ultraviolet light

29.

(ii) One of the products of the reaction is CH_2Cl_2 which reacts further to produce $CHCl_3$.

Complete Table 3.2 to show details of the mechanism that forms $CHCl_3$ from CH_2Cl_2.

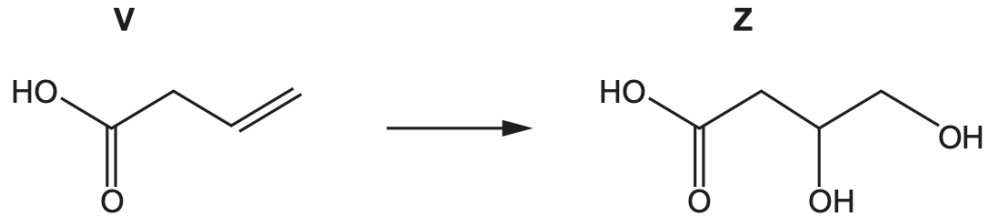
Table 3.2

name of step	equation
initiation	.....
propagation	$CH_2Cl_2 + Cl\bullet \rightarrow$ .....
termination	..... $\rightarrow CHCl_3$

name of stage	equation	
initiation	$Cl_2 \rightarrow 2Cl\bullet$	[1]
propagation	$CH_2Cl2 + Cl\bullet \rightarrow CHCl_2\bullet + HCl$	[1]
termination	$CHCl_2\bullet + Cl\bullet \rightarrow CHCl_3$	[1]

30.

V reacts to form **Z** in a single reaction, as shown in Fig. 4.2.



Suggest the reagent and conditions needed to form Z from V.

- Cold dilute acidified KMnO4

REMEMBER all 3 conditions!

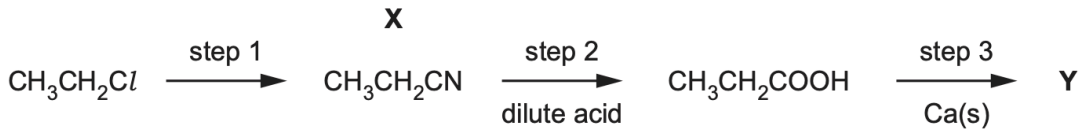
31. A saturated non-cyclic hydrocarbon undergoes complete combustion. Describe how the composition of products differs when incomplete combustion of this product occurs instead.
    - CO, C, unburnt hydrocarbons
    - less/no CO2

NOTE:

- Reagent & conditions for esterification: concentrated acid AND heat
- Reagent & conditions for hydrolysis: dilute acid / dilute alkali AND heat

32.

Fig. 3.1 describes a sequence of reactions that can be used to produce a food additive, compound **Y**, from CH_3CH_2Cl.



a. State the reagent and conditions for step 1

- KCN in ethanol AND heat

b. Identify type of reaction that occurs when dilute acid is added to X in step 2.

- Acid hydrolysis

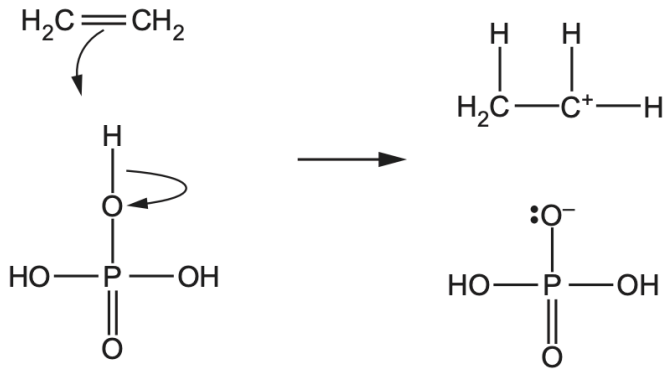
33. CH3CH2COOH can be formed from propan-1-ol and potassium dichromate(VI). State the conditions required.

- Acidic conditions AND heat under reflux

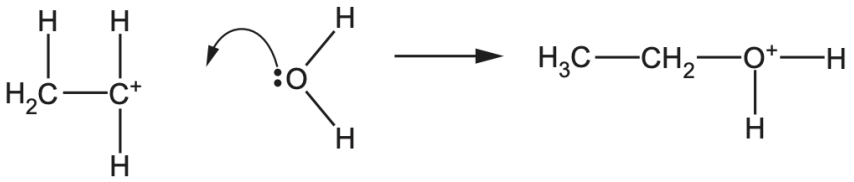
34.

The mechanism for reaction 1 can be described in three steps. Steps 1 and 2 for reaction 1 are shown in Fig. 4.1.

step 1



step 2



a. Describe the behaviour of H3PO4 in step 1 in Fig. 4.1. Explain your answer.

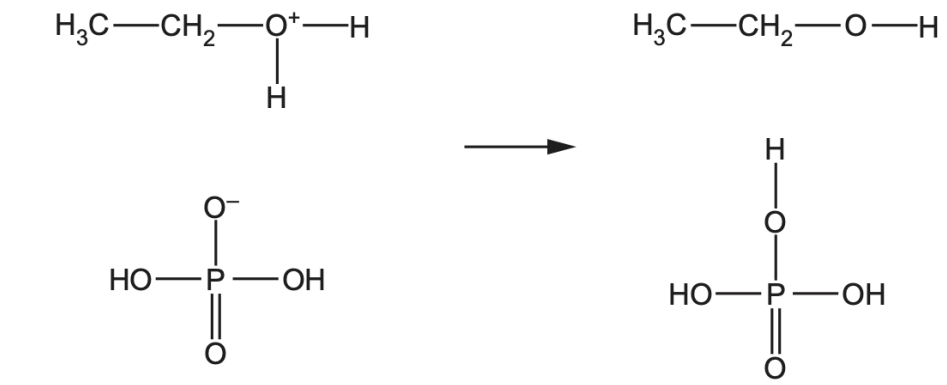
- acid AND it donates a proton/H+

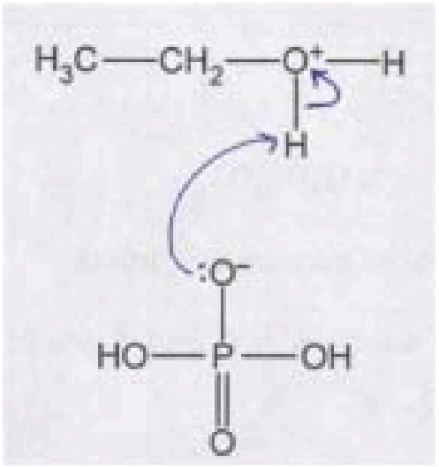
b. Identify the species that behaves as an electrophile in step 2 in Fig. 4.1. Explain your answer.

- (CH3CH2)+ AND because it accepts a pair of electrons

c.

Complete Fig. 4.2 to show the mechanism for step 3 of reaction 1. Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.





M1 arrow from bond of one of the O-H to O of the cation
M2 arrow from lone pair on O of the anion to between H of H-O

d. Use Fig. 4.1 and Fig. 4.2 to justify why H3PO4 is described as a catalyst in reaction 1.

- It is regenerated/ reformed

35.

(d) Describe the covalent bonds present between the carbon atoms in an ethene molecule by completing Table 4.2.

Table 4.2

	sigma (σ)	pi (π)
type of orbitals involved in bond		
how the orbitals overlap		

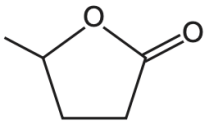
	sigma	pi
type of orbitals involved in bond	sp^2(-sp^2)	(2)p(-(2)p)
how the orbitals overlap	direct	sideways

36.

D reacts in the presence of a sulfuric acid catalyst to form **E** and water.

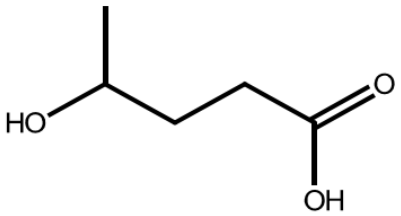
The structure of **E** is shown in Fig. 5.1.

E



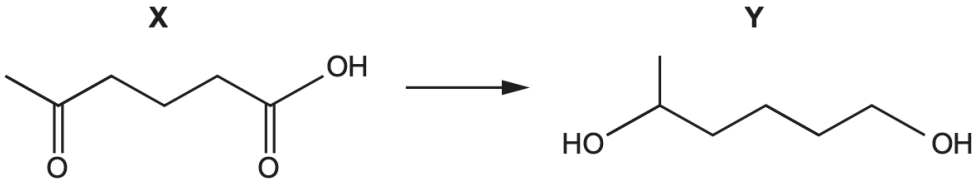
Draw the structure of **D** in the box.

D



37.

Y is formed from **X** in a single-step reaction, as shown in Fig. 5.1.



The formation of Y from X requires the addition of a suitable reducing agent. Construct an equation using molecular formulae and [H] for the reaction. Use [H] to represent one atom of hydrogen from the reducing agent.

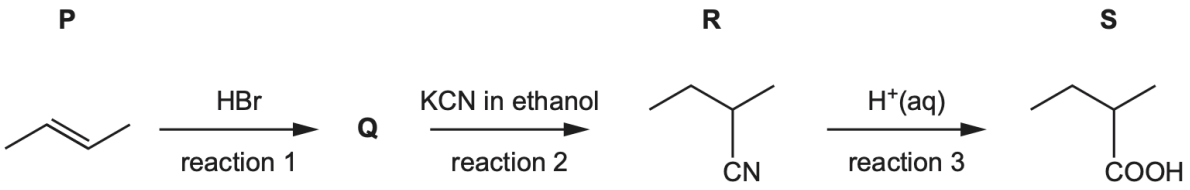
$$C_6H_{10}O_3 + [6H] \rightarrow C_6H_{14}O_2 + H_2O$$

NOTE:
2,4-DNPH = orange ppt
Fehlings' reagent = red ppt

38. Define stereoisomerism
    - molecules / compounds with the same structural formula and same molecular formula with different arrangement of atoms / groups in space.

39. Describe 2 essential features of an alkene molecule that cause it to show geometrical stereoisomerism
    - Restriction rotation of C=C bond
    - Each C of the double bond has two different groups attached

40.



Complete the equation for reaction 3. R is represented as C4H9CN.

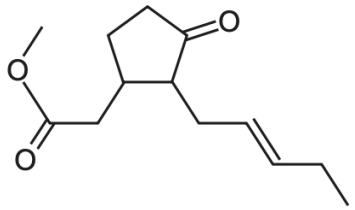
$$C_4H_9CN + 2H_2O + H^+ \rightarrow C_4H_9COOH + NH_4^+$$

41. In electrophilic reactions involving alkenes the π bond of C=C is broken. Suggest one difference between σ and π bonds that explains why the π bond is broken in electrophilic addition reactions involving alkenes.
    - pair of electrons in π bond are further away from the nuclei so weaker attraction OR pair of electrons in σ bond are closer to the two nuclei so stronger attraction

42.

V shows stereoisomerism.

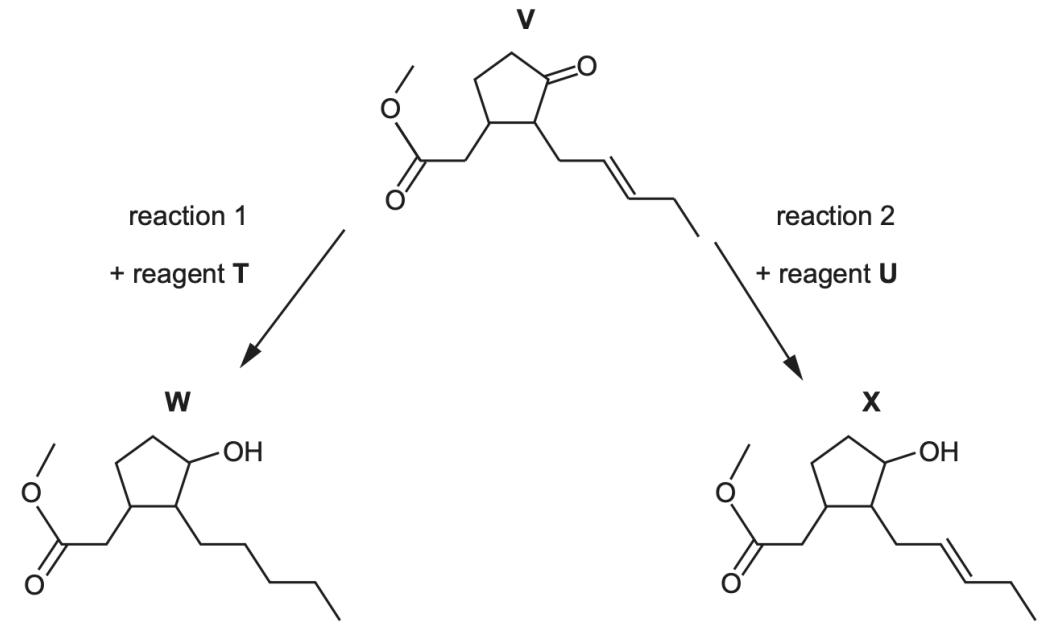
V



Deduce the number of stereoisomers of V. Explain your reasoning.
- number of stereoisomers = 8
- reasoning: 2 chiral centres AND 1 C=C producing a cis-and trans or geometrical pair

43.

(b) Fig. 6.2 shows two reactions involving **V**.



Identify the role of reagent T for each functional group that reacts in reaction 1.

- Reducing agent for C=O and C=C

44. Under certain conditions, 0.0020mol of an organic compound reacts with an excess of sodium to produce a total of 44.8cm3 of gas at s.t.p. Calculate the number of hydroxyl groups present in the molecule. Show your working.

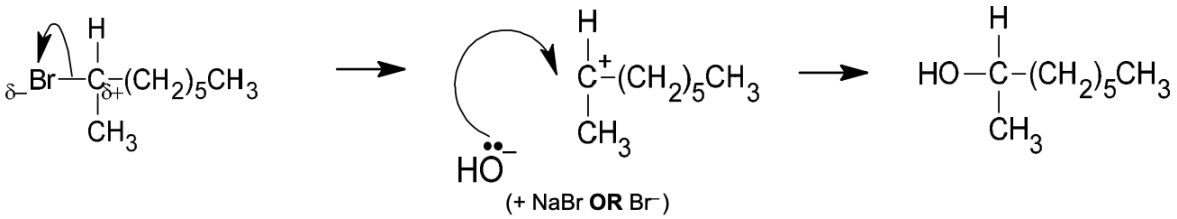
$ROH + Na \rightarrow RONa + 1/2H_2$
(0.002 mol **Q** produced 0.002 mol H_2 gas so) 2 OH groups
M1 *answer indicates that OH group(s) in* ***Q*** *react with Na to produce the* H_2 *in the ratio 1 mol OH : ½ mol* H_2
M2 *uses data to show 2OH groups*

45.

(b) A sample of $CH_3(CH_2)_5CHBrCH_3$ reacts with NaOH to make $CH_3(CH_2)_5CH(OH)CH_3$ in an S_N1 mechanism.

Complete Fig. 4.1 to show the mechanism for the reaction of $CH_3(CH_2)_5CHBrCH_3$ and NaOH.

Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.



M1 correct dipole ($^{\delta+}$C—Br$^{\delta-}$) **AND** curly arrow from bond of C—Br to Br (or just beyond)
M2 correct intermediate **ALLOW** R for $-(CH_2)_5CH_3$
M3 curly arrow from lone pair on OH^- to the C of intermediate (or suitable position where C–OH bond is made)

If SN_2 mechanism shown:
Apply SN_2 mechanism mark scheme **only** if mechanism shows OH / NaOH species attacking the reactant and no OH
M1 correct dipole ($^{\delta+}$C—Br$^{\delta-}$) AND curly arrow from bond of C—Br to Br of reactant (or just beyond)
NOT M2
M3 curly arrow from lone pair on $:OH^-$ to the appropriate C of the reactant

46.

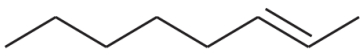
(c) Separate samples of $CH_3(CH_2)_5CHBrCH_3$, $CH_3(CH_2)_5CH(OH)CH_3$ and $CH_3(CH_2)_5CHCH_2$ are tested with different reagents.

Complete Table 4.1. If no reaction occurs, write × in the relevant box.

Table 4.1

reagent added	observation with $CH_3(CH_2)_5CHBrCH_3$	observation with $CH_3(CH_2)_5CH(OH)CH_3$	observation with $CH_3(CH_2)_5CHCH_2$
Br_2(l) in the dark			
PCl_5(s)			
$AgNO_3$(aq)			

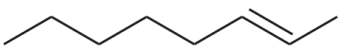
Chemical test	observation with 2-bromooctane	observation with octan-2-ol	observation with $CH_3(CH_2)_5CHCH_2$
Br_2 in the dark	×		orange / brown to colourless
PCl_5		steamy fumes	×
$AgNO_3$(aq)	cream precipitate **OR** off white precipitate	×	

47. 

(e) (i) Both σ and π bonds are present in a molecule of **E** as a result of different types of hybridisation in the carbon atoms.

Complete Table 4.2 to show the number of carbon atoms with each type of hybridisation in a molecule of **E**.

Table 4.2

	number of carbon atoms		
	sp hybridised	sp^2 hybridised	sp^3 hybridised
E 			

	0	2	6

REMEMBER: sp = triple bond; sp3 = single bond!!

48. Describe the essential feature of an unbranched hydrocarbon that causes its molecules to show stereoisomerism. Explain how this feature leads to stereoisomerism.
    - presence of a π bond
    - limited rotation of C=C bond
    - two different groups on each / both double bonded carbon atoms OR one H / atom and one alkyl group on each / both double bonded carbon atom

49. Substitution reactions of NH3 and OH– with halogenoalkanes both involve a lone pair of electrons. Name the role of NH3 and OH– in these reactions.
    - Nucleophile

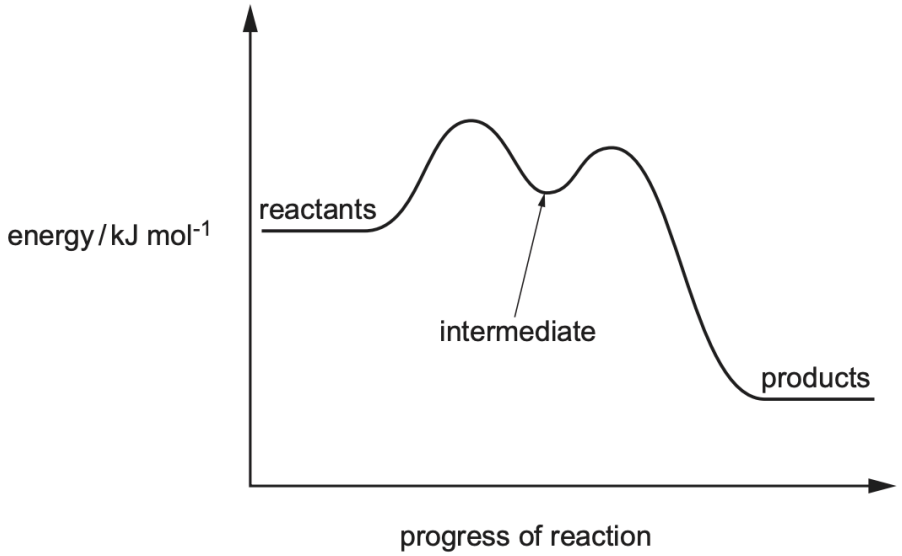
    Suggest which species, NH3 or OH–, is more reactive during these reactions. Explain your answer.
    - OH– because negatively charged species is more attracted to with $C^{\delta+}$ / intermediate / C^{+}

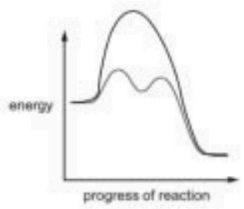
50.

When 2-bromo-2-methylpropane reacts with OH^-, two mechanisms, S_N1 and S_N2, both occur. The S_N2 mechanism has a slower rate.

Fig. 4.1 shows the reaction pathway diagram for the S_N1 mechanism.

Sketch a graph on Fig. 4.1 to show the reaction pathway for the S_N2 mechanism.

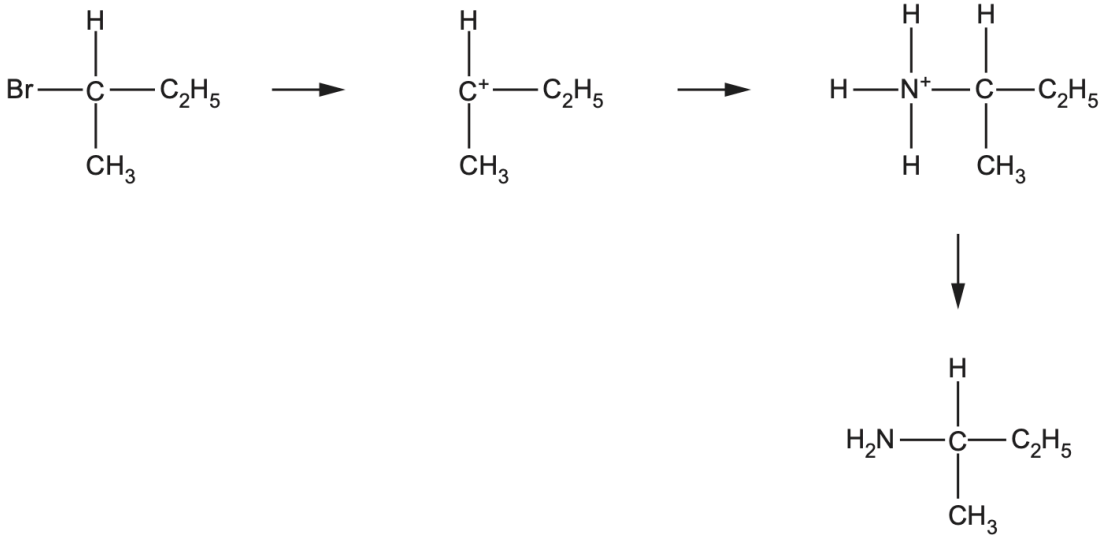




M1 same start energy and finishing energy **AND** single hump
M2 transition state / activation energy shown in answer is higher than both transition state energies shown in reaction profile (as the reaction is slower)

51.

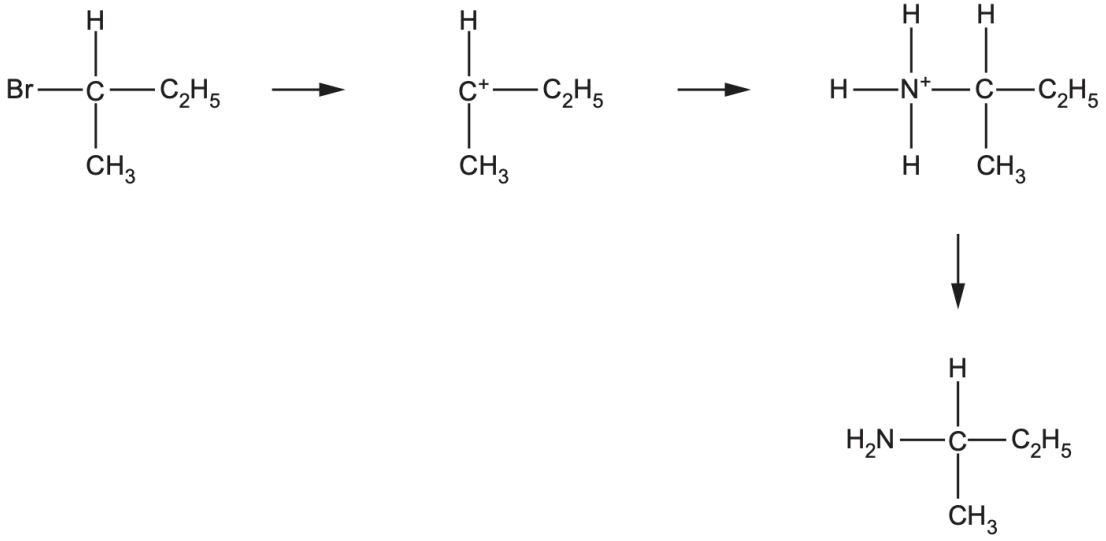
(e) (i) Complete Fig. 4.2 to show the mechanism for the S_N1 reaction that occurs when $CH_3CHBrC_2H_5$ reacts with NH_3 to produce $CH_3CH(NH_2)C_2H_5$.
Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.



- dipole and correct arrow on C—Br of 2-bromobutane
- lone pair on NH3 attacking C(+) of the intermediate drawn
- curly arrow showing bond between N—H breaking and pointing towards the N+

52.

(e) (i) Complete Fig. 4.2 to show the mechanism for the S_N1 reaction that occurs when $CH_3CHBrC_2H_5$ reacts with NH_3 to produce $CH_3CH(NH_2)C_2H_5$.
Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.



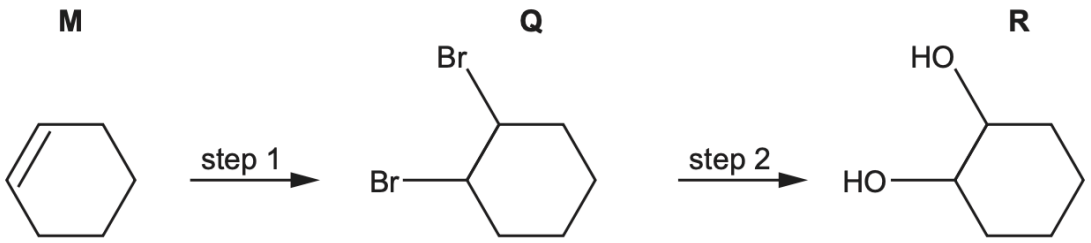
Identify the inorganic product that forms in the reaction in Fig. 4.2.

- Ammonium bromide (NH4Br)

NOTE:
Halogenoalkane + ammonia = primary amine + ammonium halide

53. Give the systematic name for CH3CH(NH2)C2H5.
    - Butan–2–amine

54.



Identify the reagent and conditions for step 1
- Br2 in the dark

NOTE:
- Acid hydrolysis of nitrile = carboxylic acid + ammonium salt
- Alkali hydrolysis of nitrile = salt of carboxylic acid + ammonia

55.

Dichloromethane, CH_2Cl_2, is widely used as an organic solvent.

CH_2Cl_2 can be prepared by reacting CH_3Cl and Cl_2 at room temperature.

The reaction proceeds via several steps, as shown.

$$Cl_2 \xrightarrow{\text{initiation}} 2Cl^{\bullet}$$

$$Cl^{\bullet} + CH_3Cl \xrightarrow{\text{propagation 1}} HCl + {}^{\bullet}CH_2Cl$$

$$Cl_2 + {}^{\bullet}CH_2Cl \xrightarrow{\text{propagation 2}} \text{products}$$

$$Cl^{\bullet} + {}^{\bullet}CH_2Cl \xrightarrow{\text{final step}} CH_2Cl_2$$

Identify the products of the step labelled propagation 2.

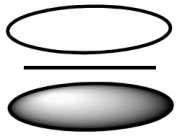
$Cl^{\bullet}$ **AND** CH_2Cl_2

Suggest the identity of another organic molecule that is a product of the reaction of CH3Cl and Cl2 under the same conditions.

$CHCl_3$ **OR** $(CH_2Cl)_2$

56. Ethyne, HCN and Q all contain triple bonds between two atoms. A triple bond consists of one sigma (σ) and two pi (π) bonds. Draw a labelled diagram to show the formation of one pi (π) bond.

M1: overlap of two p orbitals side-on / above and below the plane
M2:



pi (π) orbital

57. Name this compound: $CH_3CH_2CH_2NH_2$
    - Propan–1–amine

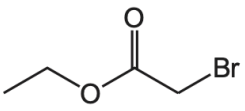
REMEMBER to put the 1!!

58. Hydroxyethanal is converted to ethanedioic acid when it reacts with excess acidified dichromate(VI) ions. State and explain any other necessary conditions for this reaction to be successful.
    - heat under reflux
    - to allow full oxidation of alcohol and aldehyde groups

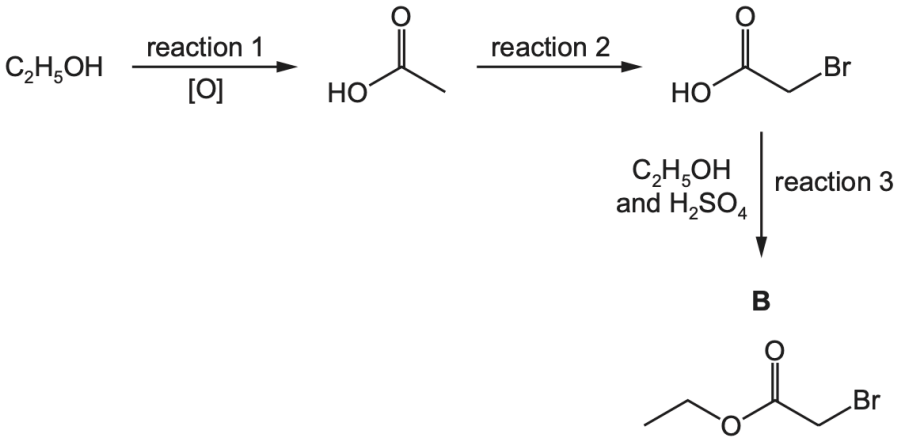
59.

Compound **B** is a liquid with a fruity smell.

B



The reaction scheme shows how **B** can be made from ethanol, C_2H_5OH.

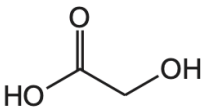


Reaction 1 is an oxidation reaction. Give the reagent(s) and conditions required for reaction 1.

- reagent(s): potassium/sodium dichromate [(VI)] / K2Cr2O7 / Na2Cr2O7
- conditions: acidified AND (heat) under reflux

Reaction 2 needs to take place in the absence of water to prevent formation of compound **C**.

C



If **C** is present in the reaction mixture of reaction 3, a different compound, compound **D**, will also form. Compound **D** has two identical functional groups.

The infrared spectrum of **D** shows strong absorptions at 1100 cm^{-1} and 1720 cm^{-1}, but no absorption due to O–H bonds.

Use the *Data Booklet* to identify the functional group present in **D**.

Explain your answer as fully as you can.

- ester
- 1100 cm−1 linked to C—O AND 1720 cm−1 linked to C=O
- No COOH and No OH in D (but present in C) OR COOH and OH reacted (in C to form D)

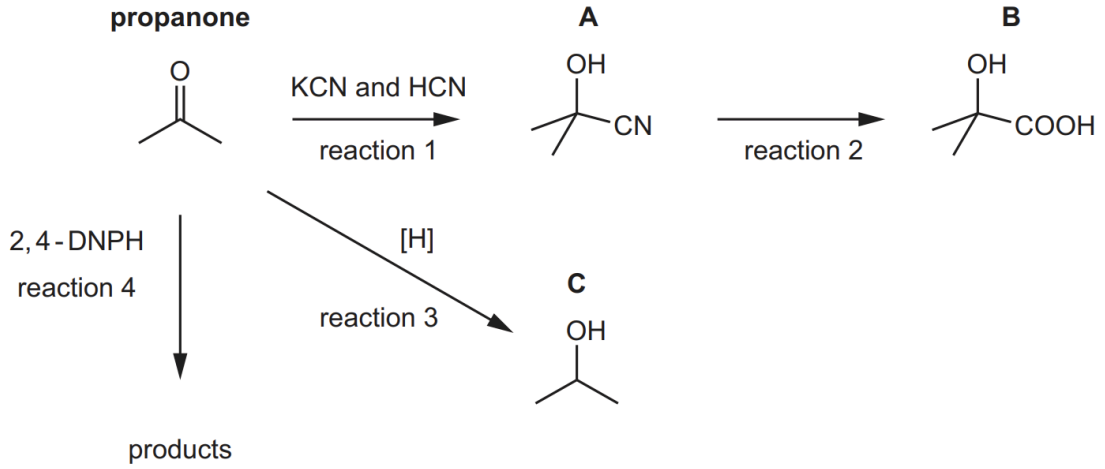
60. Construct an equation for the reaction of (CH2OH)2 with SOCl2 to form (CH2Cl)2.

$$(CH_2OH)_2 + SOCl_2 \rightarrow (CH_2Cl)_2 + SO_2 + H_2O$$

61. Aqueous AgNO3 dissolved in ethanol reacts with an aqueous solution of CHCl3 . State what is observed in this reaction. Explain your answer.
    - White precipitate forms
    - CHCl3 is hydrolysed / chloride ions are released OR Cl– ions which are released react with Ag+ OR silver chloride / AgCl is formed

62.

Propanone, CH_3COCH_3, is an important organic reagent. Fig. 4.1 shows some reactions of propanone and its derivatives.



Suggest the reagents and conditions for reaction 2.

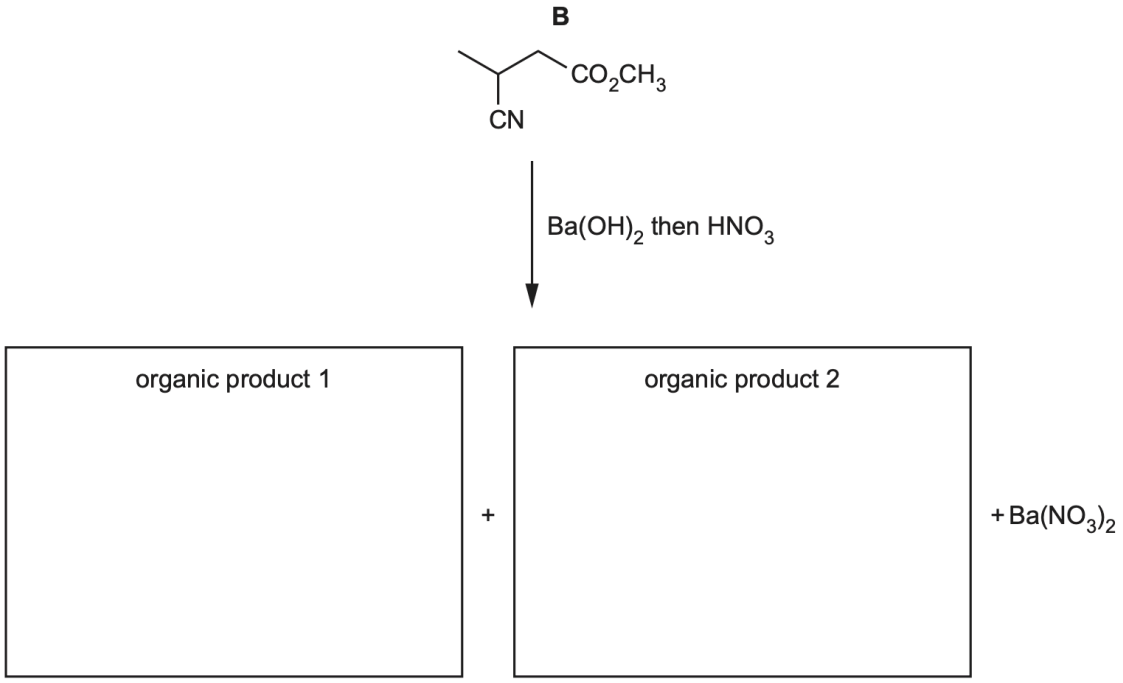
- H2SO4(aq) or HCl(aq)

63.

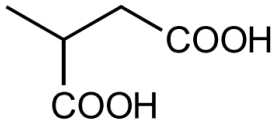
(c) $Ba(OH)_2$ is used to hydrolyse organic compounds.

Fig. 2.2 shows the reaction of **B** with $Ba(OH)_2$, followed by acidification.

Draw the structures of the organic products of the process shown in Fig. 2.2.



CH_3OH



one COOH group **AND** correct carbon framework (5C's)
(each C has the correct valency)

---

both COOH groups

64.

C can be used to form **H**.

H

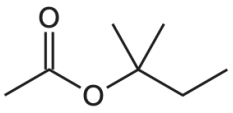
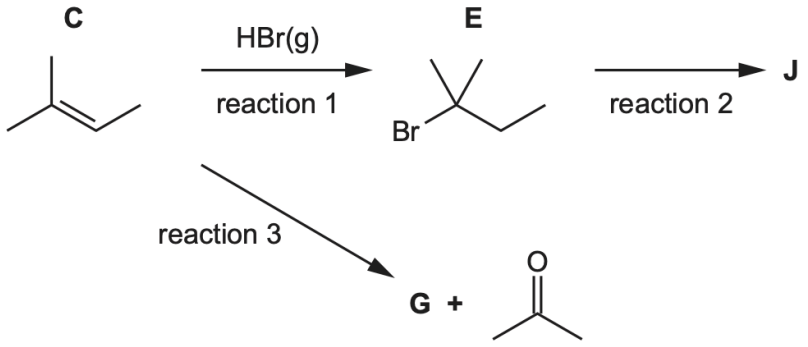
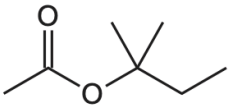


Fig. 4.4

One possible synthesis of **H** is shown in Fig. 4.5. Different portions of **C** are used in reactions 1 and 3. Some of the products are then combined to produce **H**.

Fig. 4.5 does not show any of the inorganic products of the reactions.



then: **J + G** → reaction 4 → 

Complete Table 4.1 with the reagents and conditions required for each of the reactions shown in Fig. 4.5.

Table 4.1

	reagent and conditions
reaction 1 **C** → **E**	HBr(g)
reaction 2 **E** → **J**	
reaction 3 **C** → **G** + 	
reaction 4 **J** + **G** → **H**	

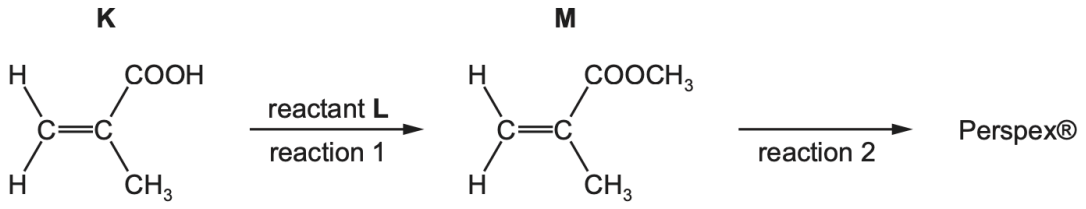
(reaction 2) NaOH**(aq)**

(reaction 3) hot **acidified <u>concentrated</u>** $KMnO_4$

(reaction 4) <u>conc</u> H_2SO_4 catalyst

65.

(b) **K** is used to make the addition polymer Perspex®. A synthesis of Perspex® is shown in Fig. 4.2.



Identify L. State the conditions required for reaction 1.

- L: CH3OH
- Conditions: acidic / H+ / H2SO4 AND (heat under) reflux

Use information from Table 4.2 to suggest how the infrared spectra of M and Perspex® would differ. Explain your answer.

- Perspex® would not have absorption 1500 –1680 cm–1 AND Perspex® does not have C=C

66.

(iv) **K** can be made from propanone in the three-step synthesis shown in Fig. 4.3.

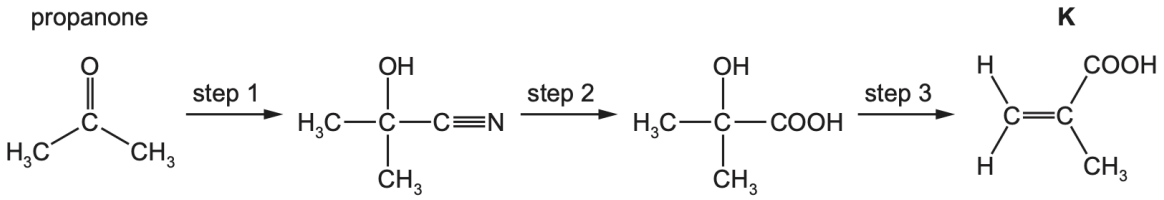


Fig. 4.3

Complete Table 4.3 to identify the reagent(s) used and the type of reaction in each step.

Table 4.3

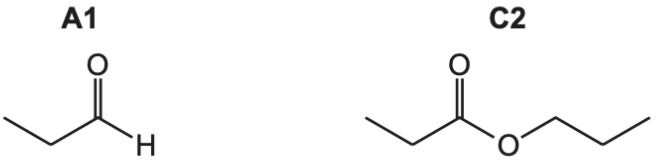
step	reagent(s)	type of reaction
1		
2		
3	Al_2O_3	

step 1 KCN / HCN **OR** NaCN / H_2SO_4 [1] addition [1]
step 2 H^+ / H_2SO_4(aq) [1] hydrolysis / substitution [1]
step 3 elimination / dehydration [1]

67. Define tertiary bromoalkane.
- The C—Br carbon is bonded to three other carbon atoms

68.

C2 can be synthesised using **A1** as a single organic reactant.



Devise a multi-step synthetic route to form **C2** from **A1**.
Identify relevant reagents and conditions, and state the organic products of each step.

- first portion of A1: add NaBH4 to form propan-1-ol / CH3(CH2)2OH
- second portion of A1: add acidified K2Cr2O7 to form propanoic acid / C2H5CO2H
- to the 2 products, add conc. H2SO4 (catalyst)

69. A sample of propan-1-ol reacts with concentrated sulfuric acid to form propene.
Identify the role of concentrated sulfuric acid in this reaction.

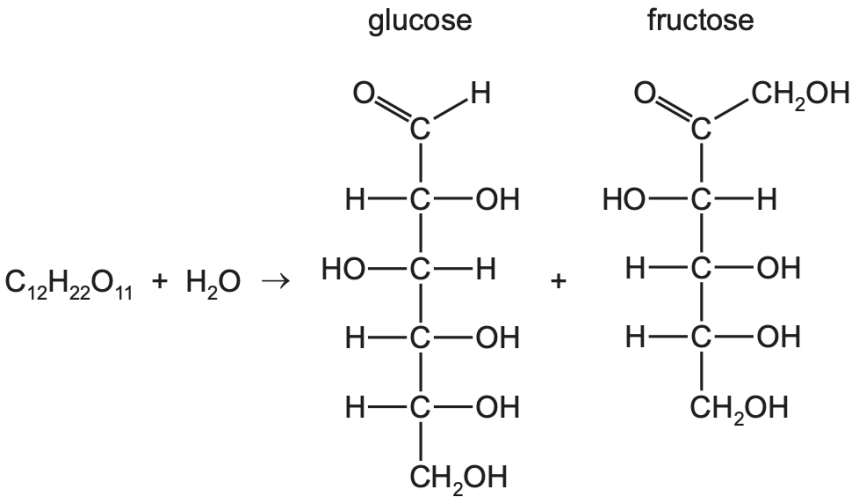
- Dehydrating agent

NOTE:
- Acid hydrolysis of nitrile = ammonium ion
- Alkali hydrolysis of nitrile = ammonia

NOTE:
- Type of reaction = substitution
- Mechanism of reaction = nucleophilic substitution

70.

Sucrose, $C_{12}H_{22}O_{11}$, reacts with water to form glucose and fructose in reaction **A**.



Suggest a name for this type of reaction
- Hydrolysis

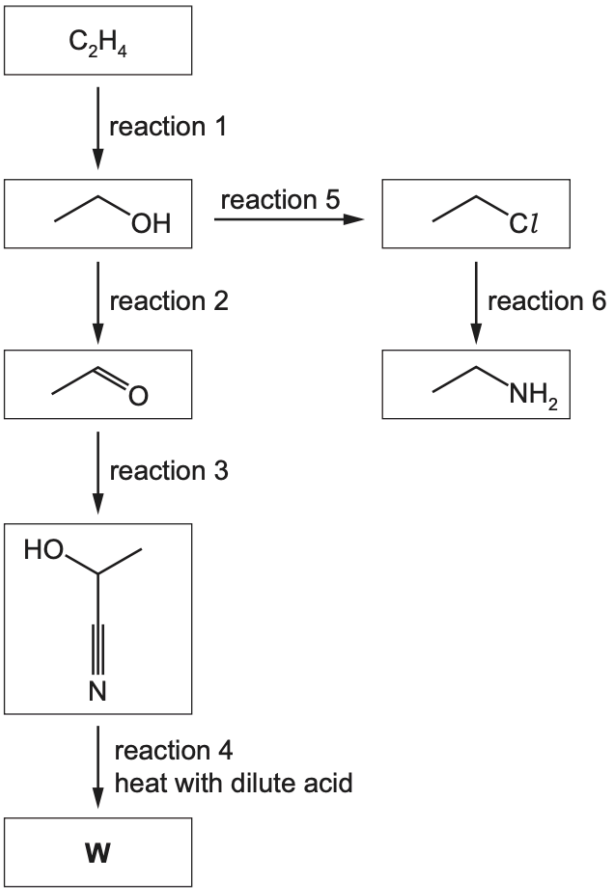
71. Explain why the reaction of a primary halogenoalkane tends to proceed via an SN2 mechanism rather than an SN1 mechanism.
    - Primary carbocation formed is not very stable
    - as only one alkyl group exerting an inductive effect OR only one alkyl group so the charge is (more) localised on the C+

72. A halogenoalkane with molecular formula C4H9Cl is dissolved in ethanol and heated under reflux with sodium hydroxide. Write an equation, using molecular formulae, to represent the reaction occurring.

$$C_4H_9Cl + NaOH \rightarrow C_4H_8 + NaCl + H_2O$$

73.

The reaction sequence shows how ethene, C_2H_4, can be converted into other organic molecules.



(a) Complete the table to give

- the name of the reaction mechanisms of reactions 1 and 6
- the reagents and conditions required for reactions 1, 2 and 6.

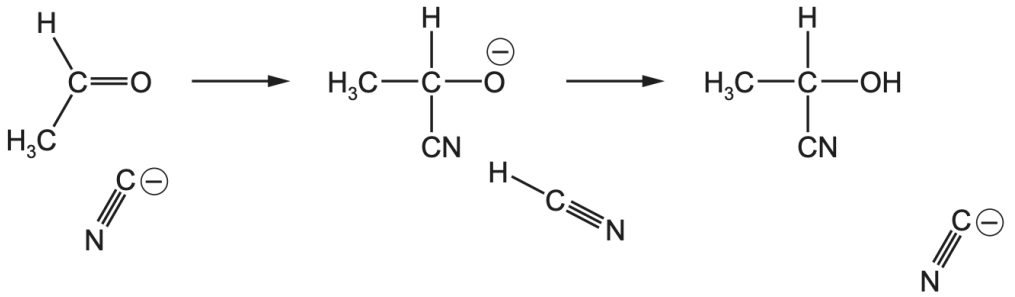
reaction	name of mechanism	**name** of reagents and conditions
1		
2		
6		

Rxn.	name of mechanism	**Name** of reagents and conditions
1	**M1** electrophilic addition	**M2** steam **AND** concentrated phosphoric acid (catalyst)
2		***M3*** **&** ***M4*** *Two marks for name of reagent and both conditions.* *One mark for name of reagent and one conditions* acidified potassium dichromate ((VI)) *condition 1* warm *condition 2* distil NOT reflux
6	**M5** nucleophilic substitution	**M6** ammonia (alcoholic) AND heat in a sealed tube / heat under pressure

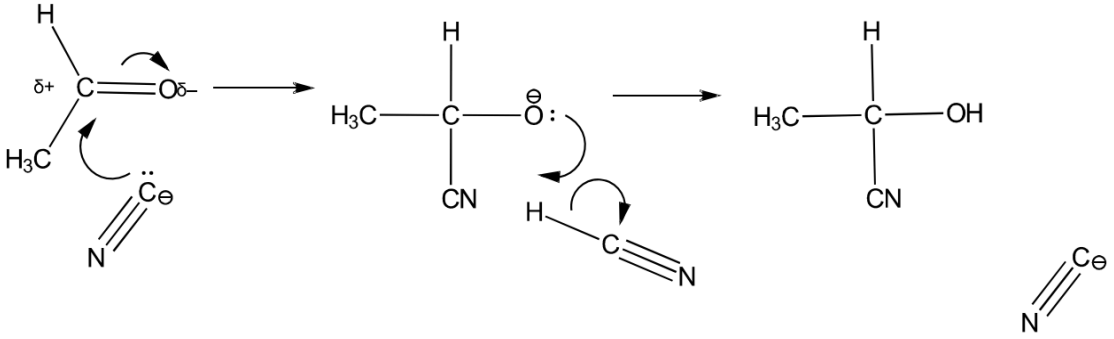
74.

In reaction 3 the organic molecule reacts with HCN and a KCN catalyst.

(i) Complete the diagram to show the mechanism of the reaction occurring.
Include all relevant dipoles, lone pairs and curly arrows in your answer.



mechanism for ethanal and HCN using CN^- (from KCN) as the catalyst



DRAW the lone pairs!!

- Lone pair on C
- Lone pair on O

NOTE: when question asks for functional group, write secondary alcohol or tertiary alcohol as functional group.