

# 10: Organic Chemistry → the Chemistry of Carbon



a.k.a fake biology

Date

No.

## Homologous Series

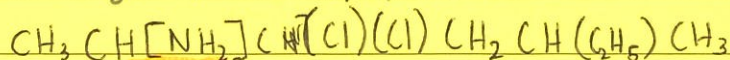
- Definition: a series of compounds of the same family, with the same general formula and differ from one another by a common structural unit.
- Varying carbon backbone lengths, from  $C_1$  to  $C_{10}$ , increasing by  $CH_2$
- similar chemical properties as same functional groups presents
- There is a gradual and progressive change in physical properties
- E.g Boiling Points → as the size of a molecule increases, the size of a random instantaneous dipole increases, hence the strength of LDFs increase as you ascend a homologous series. Therefore, more energy is required to break the stronger intermolecular force

## Identifying Compounds

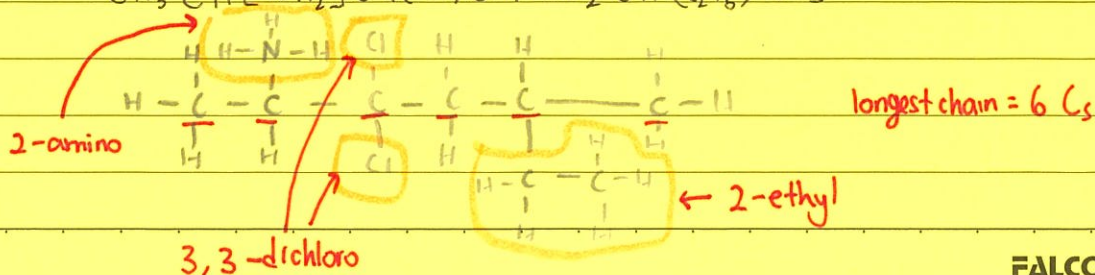
- identify longest carbon chain first [e.g  $CH_3CH(CH_3)CH_2CH_3$ , longest chain is 4 Cs and 1 methyl], ∴ it is something-butane]
  - Bonding → all single bonds → -ane, <sup>one</sup> double = -ene, one triple -yne-
  - Check functional group [see detailed list on next page]
- 1) alkene  $C=C$  → -ene
  - 2) alkane  $C-C$  → -ane
  - 3) Alcohol  $C-OH$  → -ol
  - 4) Carboxylic Acid  $C(=O)-OH$  → -oic acid
  - 5) Haloalkane  $C-C-X$  → iodo/bromo/chloro/fluoro-
  - 6) aldehyde  $C-H$  [at chain end] → -al
  - 7) ketone  $C(=O)-C$  [not at end] → -one
  - 8) Amide  $C(=O)-N-H$  → -amide [if at end]
  - 9) Amino  $-N-H$  → amino-

- Put numbers → e.g alcohols → position of OH → propan-1-ol, alkenes, position of  $C=C$ , prop-1-ene  
haloalkanes → position of halogen(s), 1-bromopropane

Example:



Let's draw it



∴

## Functional Groups

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- 1) ~~Alkane~~ Alkene  $[C=C]$  → alkenyl
- 2) Alkyne  $[C\equiv C]$  → alkynyl
- 3) Alcohol  $[C-OH]$  - hydroxyl
- 4) Ether  $[R-O-R']$  → oxy(alkane), where alkane is R' e.g. ethoxyethane
- 5) ketone  $[>C=O]$  -one
- 6) Aldehyde  $[>C=O]$  -al
- 7) carboxylic acid  $[>C(=O)OH]$
- 8) ester  $[>C(=O)O-C]$
- 9) nitrile  $[>C\equiv N]$  [alkane including last carbon - nitrile]
- 8) amine  $[>C(=O)N(H)_2]$  [alkane - an amide] e.g. propanamide
- 9) Arene  $[>C_6H_5]$  [R-benzene], e.g. methylbenzene

Homologous series differ by a  $CH_2$

If we have a compound with 2 functional groups, example: an ethane with 2 hydroxyl groups, then it is ethane-1,2-diol. So we keep the alkane bit

# Alkanes

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- comprised purely of **C-C** and **C-H** bonds
- only react in presence of **energy source** because of **relatively high bond enthalpies**
- **Nonpolar** because of **low electronegativity difference**
- **Low reactivity** due to **inability** to attract other species, no double bonds or **-ve/+ves**
- Undergo **combustion, cracking + halogenation**

## Combustion

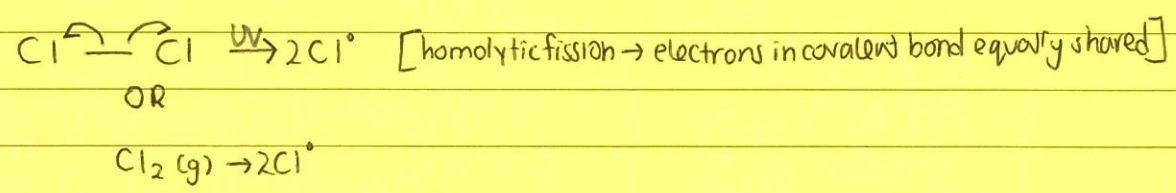
- The **C=O** bonds in **CO<sub>2</sub>** and **O-H** bonds in **H<sub>2</sub>O** are stronger than **C-H** and **C-C** bonds in alkanes, hence **-ΔH**, ∴ **exothermic** and releases energy → used as fuel source
- Complete or Incomplete [because of insufficient O<sub>2</sub>]
- CH<sub>4</sub> + 2O<sub>2</sub> → CO<sub>2</sub> + 2H<sub>2</sub>O [complete]
- CH<sub>4</sub> + 3/2 O<sub>2</sub> → **CO** + 2H<sub>2</sub>O } [incomplete]
- CH<sub>4</sub> + O<sub>2</sub> → **C** + 2H<sub>2</sub>O }  
 ← **carcinogenic**  
 binds to haemoglobin to reduce ability to absorb O<sub>2</sub>

## Halogenation

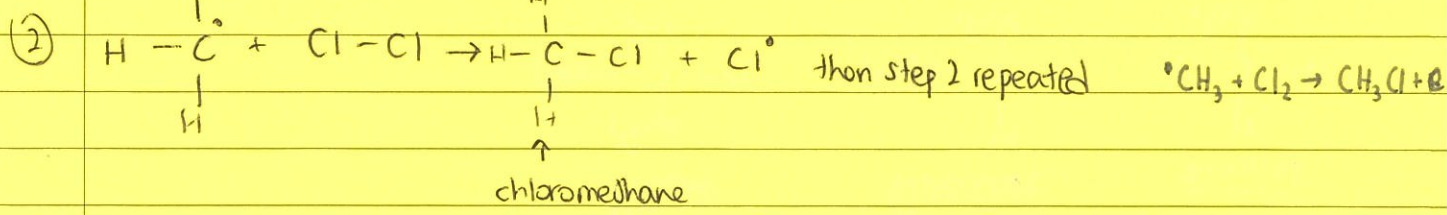
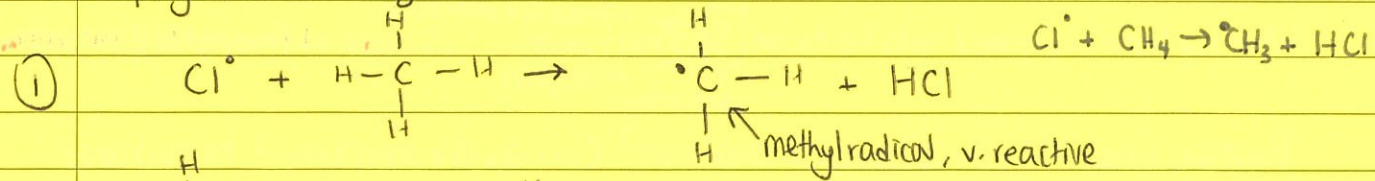
- occurs by **free radical substitution**

Note: UV needed

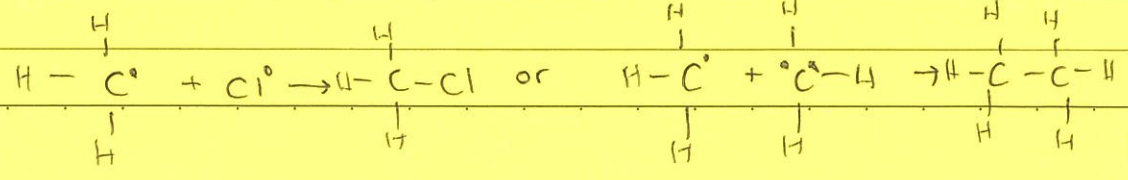
### (i) Initiation



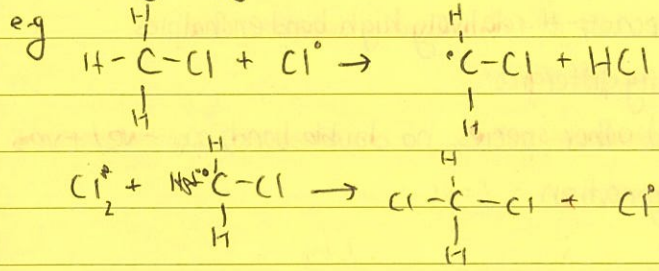
### (2) Propagation = forming more radicals



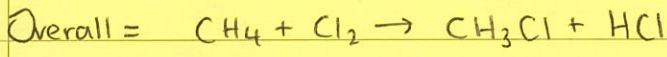
### (3) Termination → two radicals react



Theoretically, can go further.



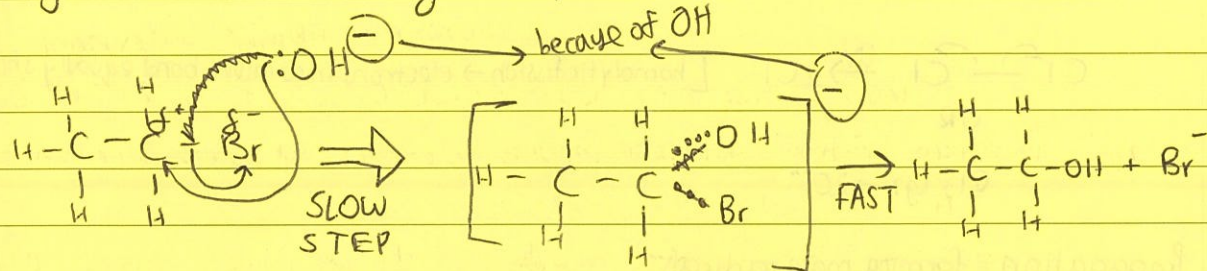
Note: The haloalkanes are more reactive than alkanes due to the polarity of the C-X bond, where X=halogen



**Nucleophilic Substitution**

- o Nucleophile = an electron rich species, such as a Lewis Base or Ligand, attracted to +ve nuclei
- o Attracted to  $\delta^+$  on a polar bond. E.g.  $\begin{matrix} \text{H} & \delta^+ & \delta^- \\ | & & | \\ \text{C} & - & \text{F} \end{matrix}$
- o Haloalkane donates a lone pair of electrons to the C-F bond, whose electrons (both) move to the  $\delta^-$  atom. This forms an intermediate in the slow step with a half-broken half formed bond to the halogen and nucleophile. A covalent bond is formed between the nucleophile and C, specifically, a dative covalent bond.

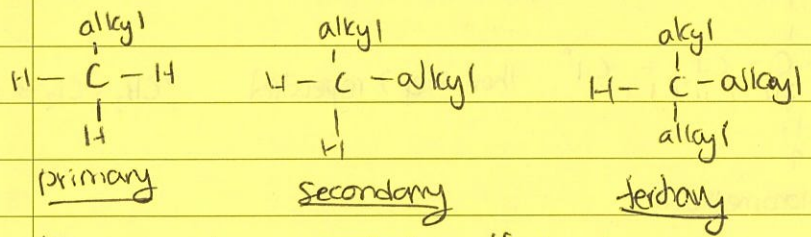
Diagram of a substitution by  $\text{OH}^-$  [ $\text{S}_\text{N}2$  Mech]



What has been explained relates to an  $\text{S}_\text{N}2$  mechanism.  $\therefore$  rate =  $k$  [nucleophile] [haloalkane]

bimolecular slow step  
nucleophilic substitution

However, what if we have loads of stabilisers? Consider the structures of haloalkanes

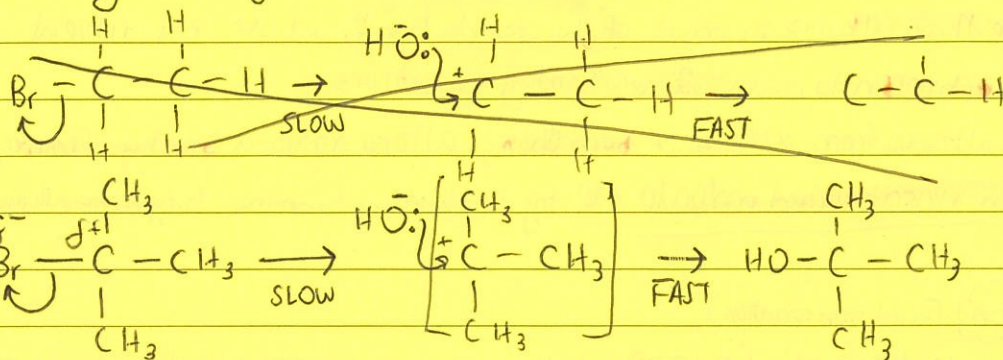


Alkyl groups have an inductive effect, whose electrons move and can stabilise any + charge

Note:  $S_N1$  faster than  $S_N2$ , needs protic solvent to stabilise carbocation

### Tertiary Structures

most likely to undergo  $S_N1$ , because more stable for  $i^+$



$\therefore \text{rate} = k[\text{haloalkane}]$

carbocation: the charge on the carbon is stabilised by the inductive effect of the methyl groups  $\rightarrow$  more likely to collide with  $OH^-$

?? ask!!

Secondary haloalkanes can undergo  $S_N1$  or 2. To determine, change [nucleophile], if rate change,  $S_N2$  used. If not;  $S_N1$ . Use aprotic solvent to favour  $S_N2$ , because it creates non-polar conditions. aprotic solvents [ethoxyethane] favours it. Protic solvents such as water or ethanol support breakdown into carbocations, dissociate into  $\delta^+$  and  $\delta^-$ , latter stabilises +ve C on carbocation.

### Rates of Reaction

The rate of reactions with haloalkanes vary with the alkane's identity. For example,  $I > Br > Cl > F$ . This is because  $C-I < C-Br < C-Cl < C-F$  in terms of bond enthalpy. A lower bond enthalpy to be broken requires less energy, not generating a relatively lower  $E_a$ ,  $\therefore$   $\uparrow$  rate of nucleophilic substitution.

The electron density of the nucleophile also affects the rate.  $\uparrow$  electron density, greater attractive force between nucleophile and  $\delta^+$  carbon,  $\therefore$   $\uparrow$  rate of reaction.  $\uparrow$  with anion, as it is a negatively charged molecule/ion. This is why  $OH^-$  is a better nucleophile than  $H_2O$ , because it has a higher electron density.

$S_N2$  is also generally slower than  $S_N1$ , because it is a bimolecular RDS, unlike  $S_N1$ .

### Protic vs Aprotic

Aprotic for  $S_N2 \rightarrow$  this is because protic solvents i.e. polar solvents will solvate the nucleophile, rendering it unable to attack the species. Also, because protic, no  $\delta^-$  or  $\delta^+$  to stabilise charge on carbocation,  $\therefore$  unlikely to move through  $S_N1$ ,  $\therefore$   $S_N2$ . Aprotic solvate metal cation,  $\uparrow$   $\therefore$  nucleophile is unsolvated, increasing rate.

# Alkenes

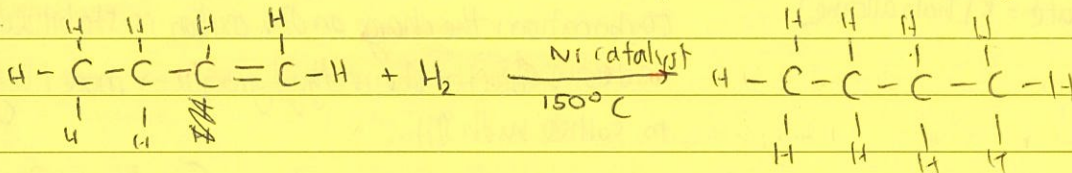
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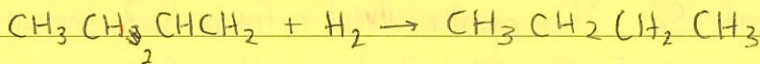
- unsaturated hydrocarbons containing a C=C bond
- $C \overset{sp^2}{=} C$ , each C is  $sp^2$  hybridised
- More reactive than alkanes because of the double bond, whose constituent  $\sigma$  bond can easily be broken to create 2 new bonding positions
- Distinguishing alkanes from alkenes  $\rightarrow$  burn them, alkene produces a smoky flame, indicates an unsaturated molecule OR try decolourising bromine, happens for alkenes, not alkanes

## Hydrogenation [Addition reaction]

- alkenes react with  $H_2$  (g) at  $T \uparrow 150^\circ C$  in the presence of a nickel catalyst to form alkanes



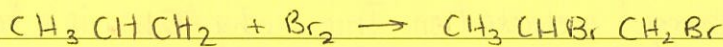
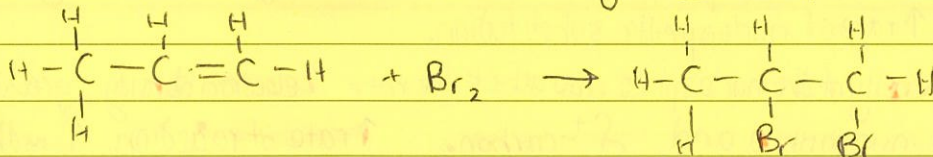
but (1)ene + hydrogen gas  $\rightarrow$  butane



- used to break down oils containing many unsaturated hydrocarbons into saturated compounds with higher b.p and m.p. Allows for margarine to be solid at room temperature

## Halogenation [Addition reaction]

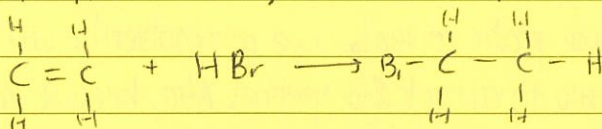
- react with diatomic halogens to produce dihalogeno compounds
- occur at r. temperature, decolourises one halogen: tests for presence of C=C



prop(1)ene + bromine  $\rightarrow$  1,2 dibromopropane

## Addition Reactions with Hydrogen Halides [Hydrohalogenation]

- react to form haloalkanes, at room temperature

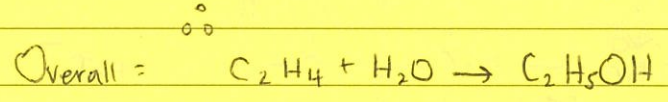
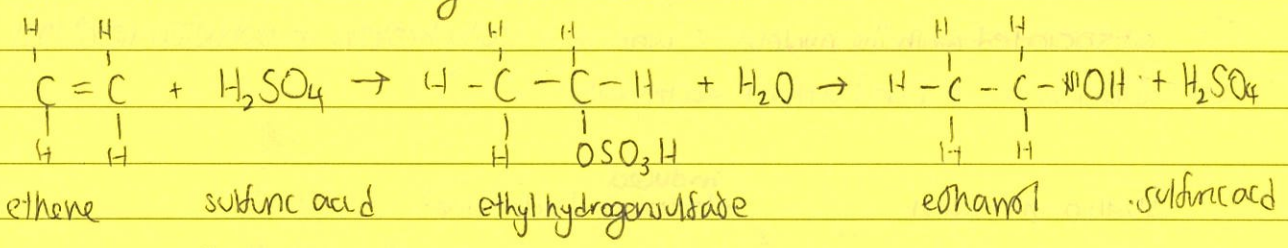


ethane + hydrogen bromide  $\rightarrow$  bromoethane

- reactivity ↑ as you descend group VII, because of decreasing H-X bond enthalpy, ↓ E<sub>a</sub>, ↑ rate of reaction

**Hydration** (addition reaction)

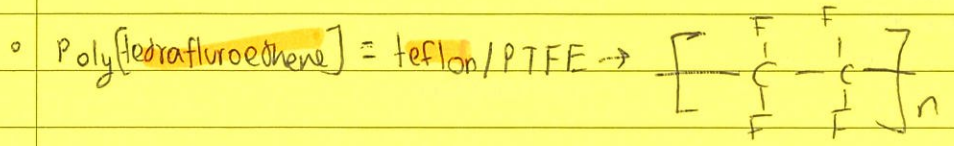
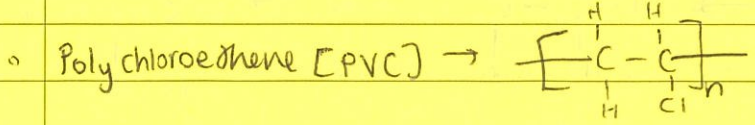
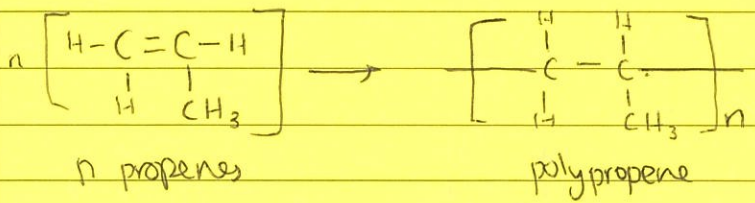
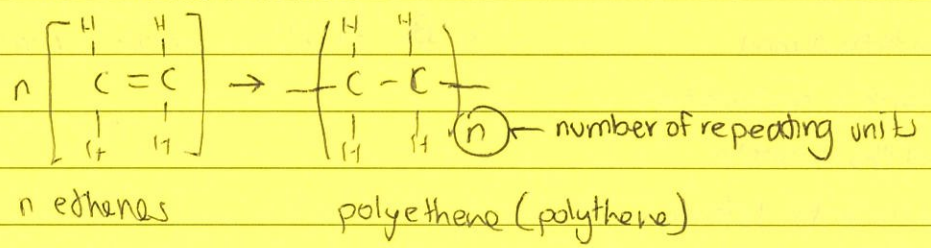
- reaction with H<sub>2</sub>O to form alcohol using concentrated HCl



- need steam as well, ethanol needed as a protic solvent

**Polymerisation**

- a series of addition reactions between identical alkenes
- alkene called the monomers



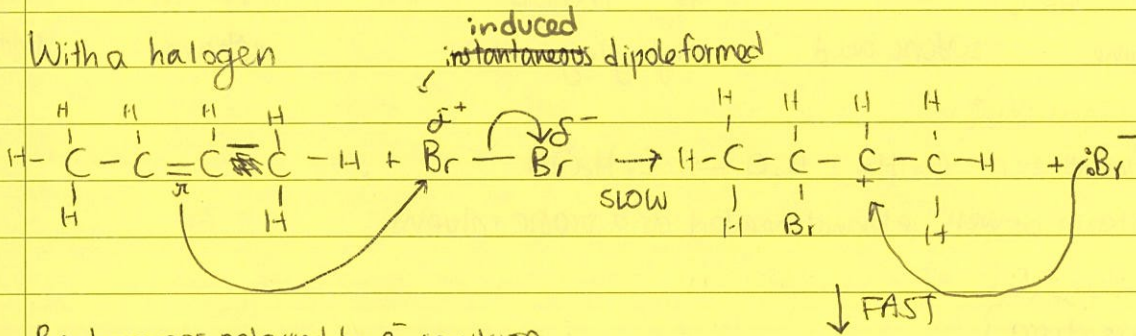
# 8 Electrophilic Addition

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- Electrophile: an electron deficient species that can accept electrons pairs [Lewis Acids]
  - Why do alkenes undergo electrophilic addition?
- ① C atoms are  $sp^2$  hybridised, hence trigonal planar shape with  $120^\circ$  bond angles formed. This creates an open structure which makes it easy for electrophiles to attack
  - ②  $\pi$  bond = area of electron density above and below the internuclear axis, hence less associated with the nucleus,  $\therefore$  weak and easily broken in addition reactions
  - ③ Electrons in  $\pi$  bond attract electrophiles

With a halogen

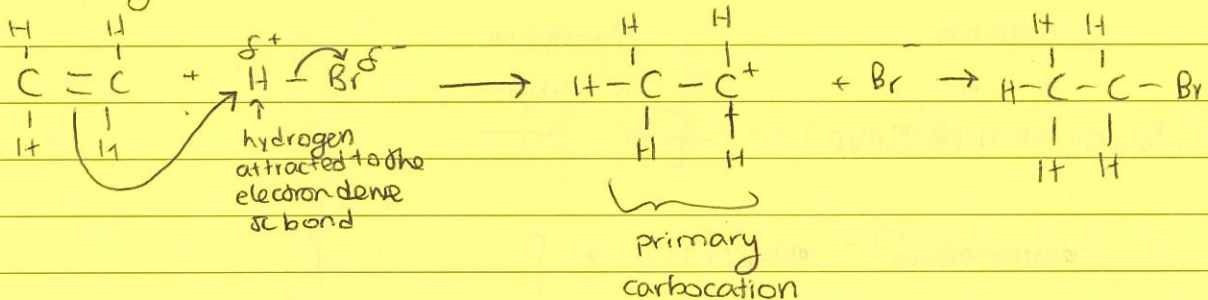


$\text{Br}_2$  becomes polarised by  $e^-$  repulsion from  $\pi$  bond, resulting in heterolytic fission to form  $\text{Br}^+$  and  $\text{Br}^-$ .

The  $\text{Br}^+$  is attracted to the  $\pi$  bond and attacks it to form a carbocation.

The step is slow and the unstable carbocation reacts with  $\text{Br}^-$  to form 2,3-dibromobutane

With a hydrogen halide





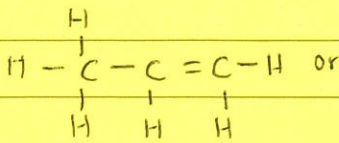
# Markovnikov's Rule

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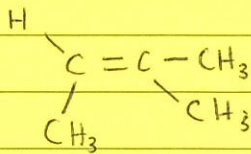
## Asymmetric Alkenes

e.g 1)



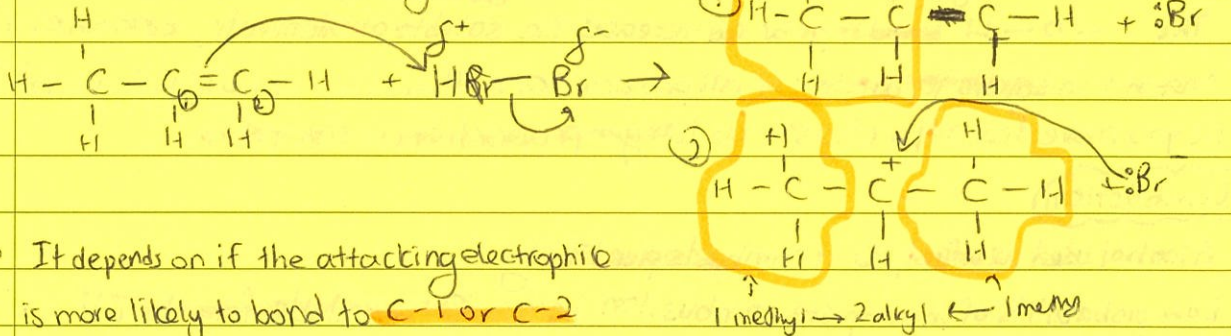
propene

2)



There are 2 theoretical products.

Consider propene + hydrogen bromide



It depends on if the attacking electrophile is more likely to bond to C-1 or C-2

We look for the most stable carbocation, primary < secondary < tertiary

More alkyl groups, greater positive inductive effect by moving electrons to stabilise the positive charge. ∴ 2 more stable as it is a secondary carbocation, more stable than the primary → this is the major product, due to lower  $E_a$

Markovnikov's rule states that the H will bond to the carbon with the most hydrogens bonded to it [ergo, the adjacent one will be stabilised by more alkyl groups]

Formal Definition: The most electropositive atom of the reacting species bonds to least highly substituted carbon atom in the alkene [least alkylly]

i - inductive effect, e.g double inductive effect

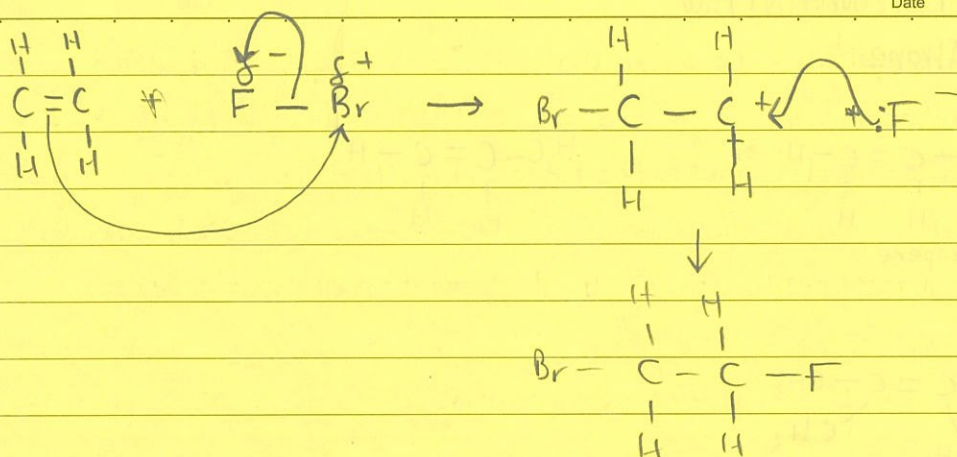
Note: write equation in structural form [  $\text{CH}_3\text{CH}(\text{Br})\text{CH}_2$  ]

## Interhalogen compounds



$\text{Br}^{\delta+} - \text{F}^{\delta-} \rightarrow$  bromofluoride ← because  $\delta^-$

$\text{Br}^{\delta-} - \text{I}^{\delta+} \rightarrow$  iodine bromide



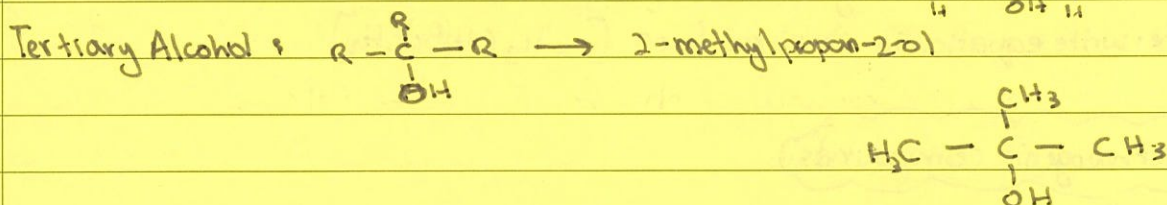
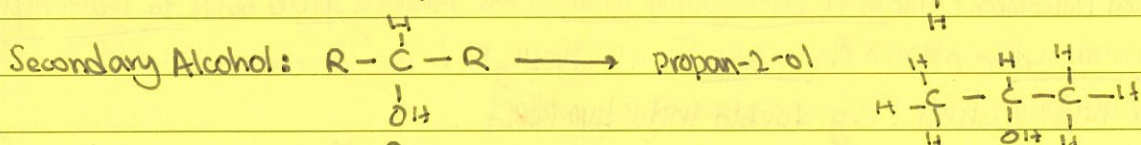
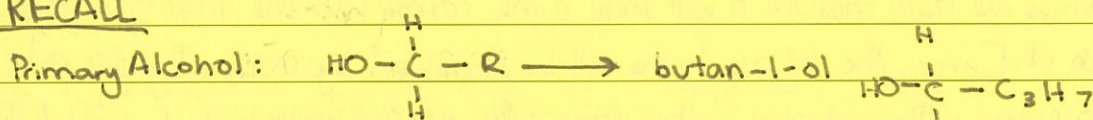
## Alcohols

- $C_n H_{2n+1} OH$
- OH-functional group
- The  $-O-H$  bond is polar and increases the solubility of alcohols, ethanol for instance is soluble in water of all proportions. However, solubility of alcohols decreases as you move down the chain, as larger proportion is non-polar

## Combustion

- Alcohol used as a fuel, as it combusts plentifully
- Low probability of incomplete combustion because O is available from the OH  
e.g.  $C_3 H_7 OH + \frac{9}{2} O_2 \rightarrow 3CO_2 + 4H_2O$
- $\Delta H$  becomes more exothermic as you descend the series as more moles of  $CO_2$  produced

## RECALL

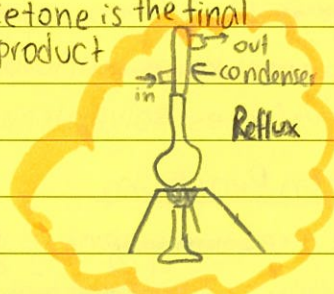
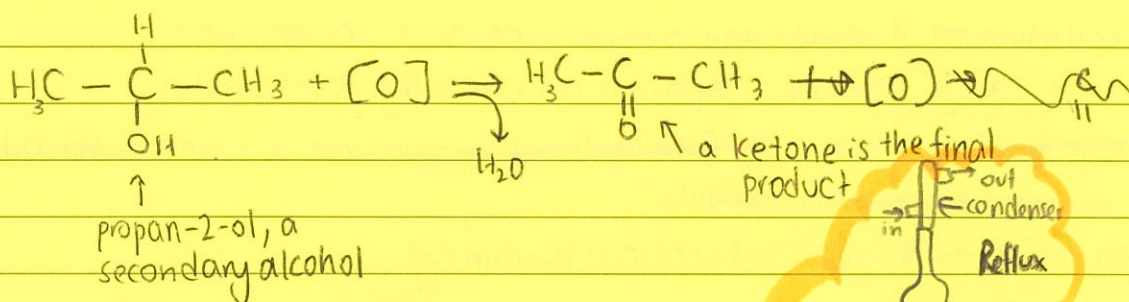
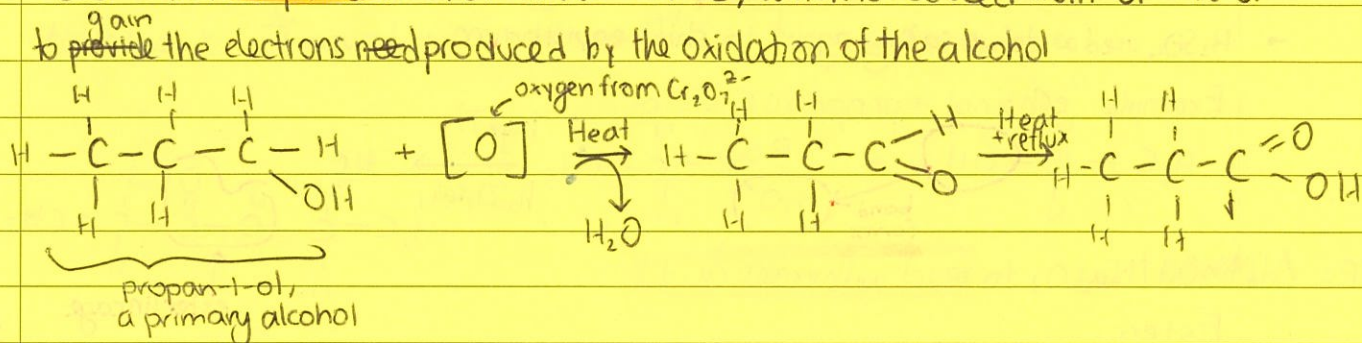


## Oxidation

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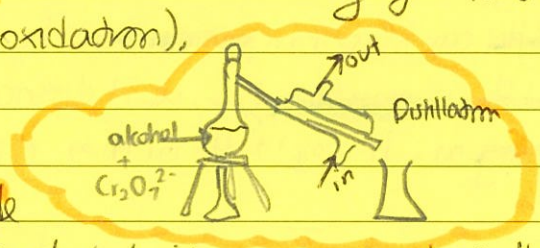
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- Alcohols can be oxidised to aldehydes, ketones or carboxylic acids
- Tertiary Alcohols cannot be oxidised because of the lack of individual H atoms bonded to the C which is connected to the OH, hence it is difficult for it to be oxidised
- Need acidified potassium dichromate [VI], which is reduced from  $\text{Cr}^{6+}$  to  $\text{Cr}^{3+}$  to provide the electrons needed produced by the oxidation of the alcohol



## Reflux

- a Liebig condenser placed above the set up
- Aldehydes formed would evaporate due to the loss of a strong H-bond, but would condense and fall back down, keeping it in contact with the oxidising agent for a prolonged period of time to increase P (second oxidation).



## Distillation

- We use this if we only want the aldehyde
- As the aldehyde has a lower bp than the alcohol, it evaporates, hence they move through a Liebig condenser at the adjacent side

Note: The orange to green colour change is only seen if an oxidation occurs, not seen in tertiary alcohols

To test for aldehydes, add Fehling's solution, it oxidises aldehydes to ketones, turning the solution red-brown from blue blue to red-brown

Interestingly, isomers of carboxylic acid are ester.

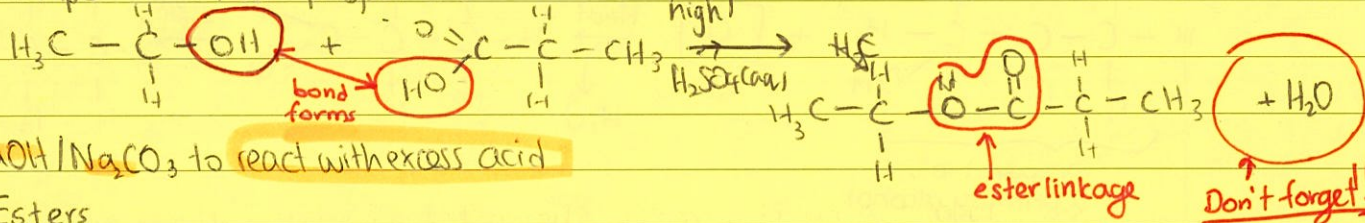
## Esterification

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- a condensation reaction between a carboxylic acid and alcohol
- The OHs bond to form an ester linkage and release a H<sub>2</sub>O
- It is an equilibrium, hence H<sub>2</sub>SO<sub>4</sub> used to shift equilibrium to the right [catalyst]
- esters formed have low m.p and b.p, hence can be separated by distillation
- H<sub>2</sub>SO<sub>4</sub> used as dehydrating agent to shift equilibrium + lowers E<sub>a</sub> ∴ catalyst

Example: ethanol + propanoic acid



T/P: Add NaOH/Na<sub>2</sub>CO<sub>3</sub> to react with excess acid

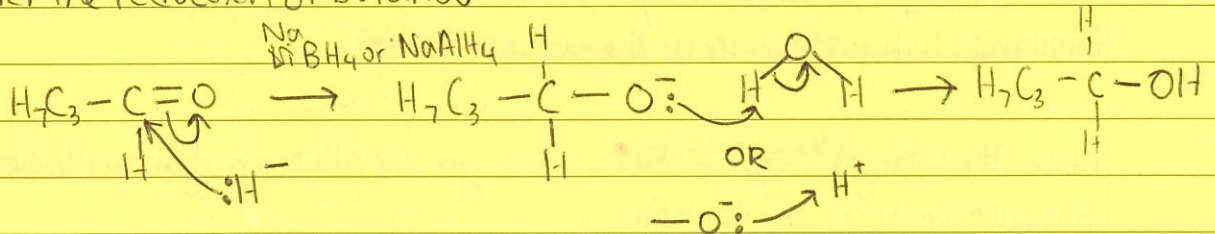
## Esters

- Nomenclature → if alcohol + acid → ester, ester is alcohol, acid  
E.g. ethanol + propanoic acid → ethyl propanoate
- Low m.p and b.p because no free hydroxyl groups, hence cannot form H-bonds, and are insoluble in protic solvents
- used as perfumes, solvents and artificial flavouring

## Reduction Reactions

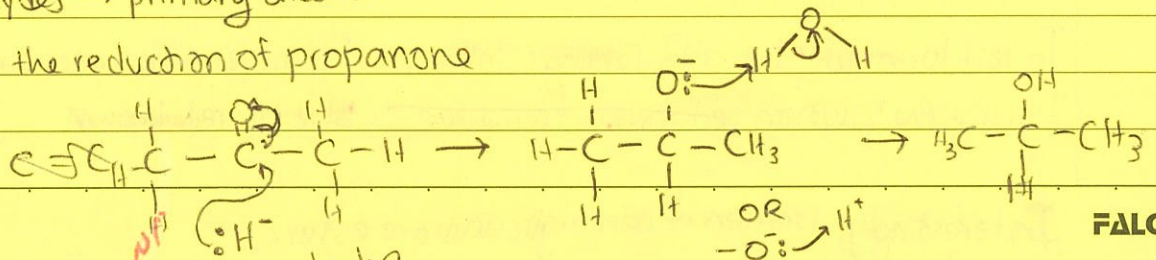
- we need a reducing agent, e.g. NaBH<sub>4</sub>, sodium tetrahydridoborate, which forms highly unstable H<sup>-</sup> ions that act as a reducing agent
- The H<sup>-</sup> undergo a nucleophilic addition reaction with the electron deficient carbon of a species
- NaBH<sub>4</sub> can be used in protic solvents but cannot reduce carboxylic acids
- LiAlH<sub>4</sub> is ~~more~~ stronger, as it dissociates into more H<sup>-</sup> ions, but must be kept dry as H<sup>-</sup>(aq) + H<sub>2</sub>O(l) → OH<sup>-</sup>(aq) + H<sub>2</sub>(g). Hence, only aprotic solvents e.g. ethers

→ Consider the reduction of butanal



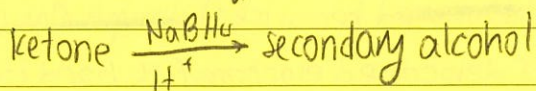
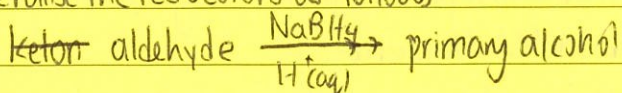
→ ∴ aldehydes → primary alcohols

→ Consider the reduction of propanone

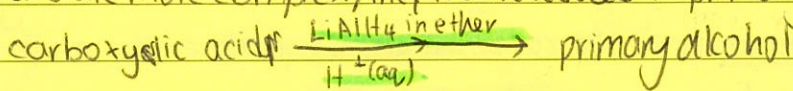


→ ∴ ketone → secondary alcohol

◦ We can generalise the reductions as follows



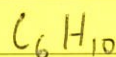
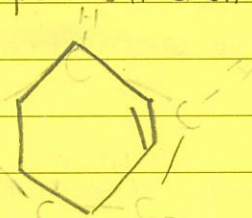
→ Carboxylic acids are more complex, they too are reduced to primary alcohols



### Benzene Rings

#### Cyclic Compounds

→ We have a lot of cyclic compounds in chemistry, such as cyclohexene.



→ Benzene is a prime example, it is an aromatic [has delocalized e<sup>-</sup>] unsaturated hydrocarbon.

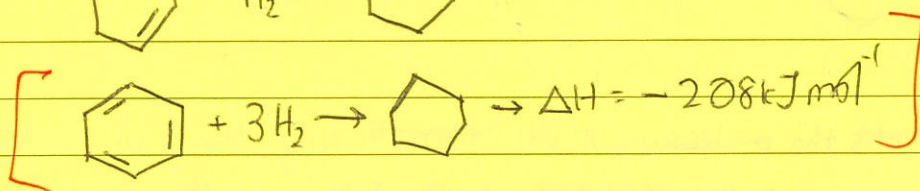
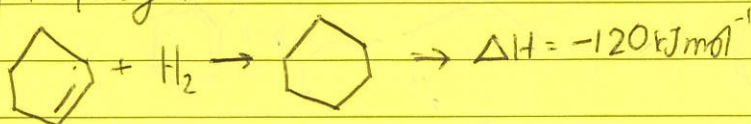
→ Kekule thought benzene had this structure



→ In fact, this theory has been falsified because of the 4 pieces of evidence here

- (1) Low reactivity → with bromine, only bromobenzene, no 1,2-bromobenzene, unlike what is expected of a compound with 3 double bonds. Dibromobenzene unstable as only 1 position
- (2) Bond length → all the C-C bonds and C=C bond lengths were 0.140 nm, a value between 0.154 nm [C-C] and 0.134 nm [C=C], indicating resonance, as it varies the number of electrons in covalent bonds, varying their strengths and therefore, their lengths

(3) Enthalpy of hydrogenation



This was expected to be 3(-120), as you need to break 3 x as many bonds. It was more stable by about 152 kJ mol<sup>-1</sup>!

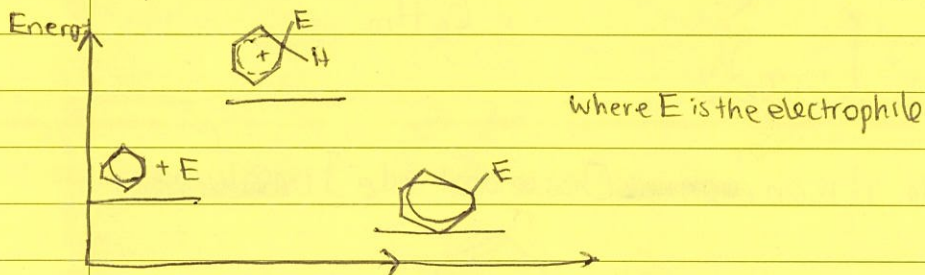
This energy is the amount by which the internal energy of the benzene is reduced. This energy would have to be supplied to overcome the stability of C<sub>6</sub>H<sub>6</sub>. Hence it is dubbed resonance energy

- ④ Isomers  $\rightarrow$  only one isomer exists per compound, e.g. 1,2-dibromobenzene  
 $\rightarrow$  1 isomer for every disubstituted benzene

Note: Addition reactions not favoured because it disrupts the aromatic ring of benzene (cloud / ring of delocalised electron /  $\pi$  bond conjugation); and resonance energy would be needed. Additionally, the lack of an aromatic ring decreases the stability of benzene. Hence, substitutions preferred, as they preserve the aromatic ring. Benzene is  $sp^2$  hybridised.

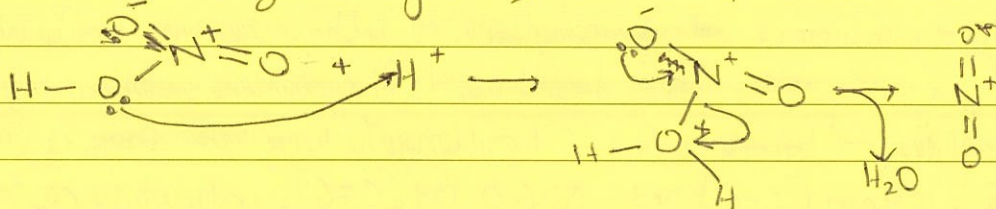
### Electrophilic Addition Substitution

- $\rightarrow$  Benzene is attractive to electrophiles because of its aromatic ring  
 $\rightarrow$  High  $E_a$  as the first step disrupts the  $\pi$  bond conjugation (aromatic ring).

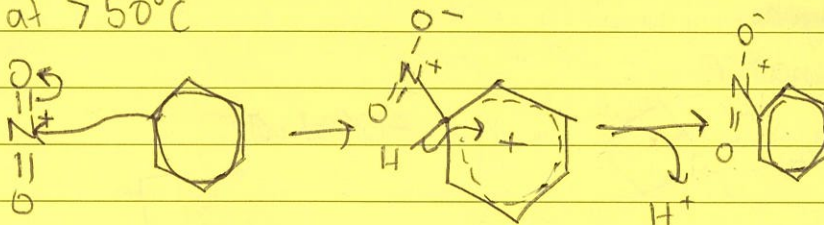


Consider the nitration [add  $\text{NO}_2$ ] of benzene

- ① We form  $\text{NO}_2^+$  by reacting  $\text{HNO}_3$  and  $\text{H}_2\text{SO}_4$



- ②  $\text{NO}_2^+$  then is reacted with benzene at no more than  $50^\circ\text{C}$ , because further nitration occurs at  $75^\circ\text{C}$



Be wary of this; ensure the arrow from the H bond goes through the ring, no need to go through C atom.

The  $\text{NO}_2^+$  ion attacks the  $p$  electrons in the aromatic ring, hence an electron is used by the ring to form a covalent bond to the  $\text{NO}_2^+$ . Simultaneously, the double bond  $\text{N}^+=\text{O}$ , splits to  $\text{N}^+-\text{O}^-$ . The  $\pi$  bond delocalisation of electrons is now broken and a positive charge is distributed amongst the benzene, forming a carbocation. A bond to hydrogen is subsequently broken, releasing a proton and the aromatic ring is restored.

Conditions

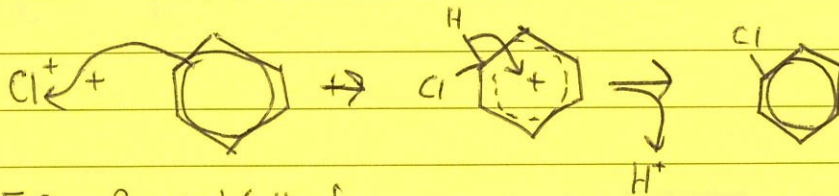
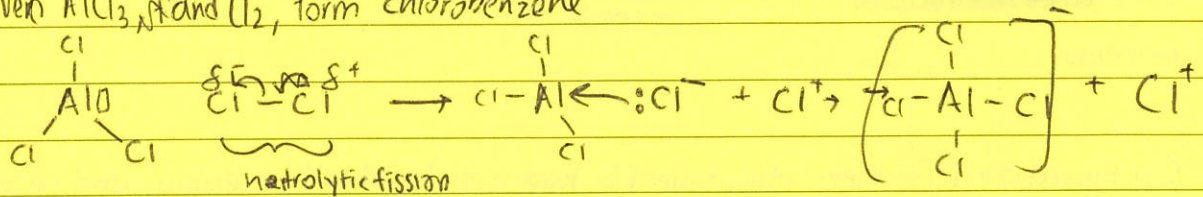
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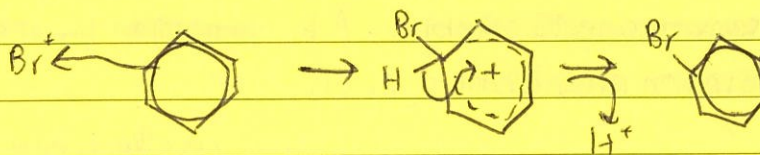
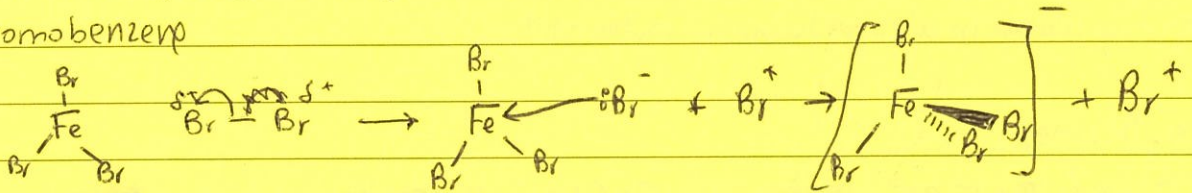
- ①  $H_2SO_4$  - catalyst.  $H^+$  generated can react with hydrogensulfate ion  $[HSO_4^-]$  to reform  $H_2SO_4$
- ②  $HNO_3$  - source of  $NO_2^+$
- ③  $50^\circ C$ .  $\uparrow$  rate, but no higher as it facilitates further nitration

Similar Reaction

given  $AlCl_3$  and  $Cl_2$ , form chlorobenzene

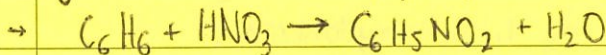


OR, with  $FeBr_3$ ,  $Br_2$  and  $C_6H_6$ , form bromobenzene

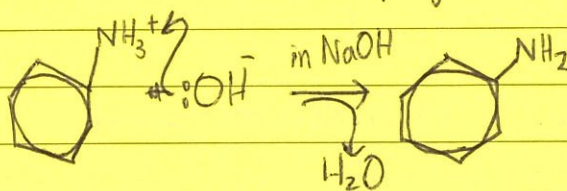
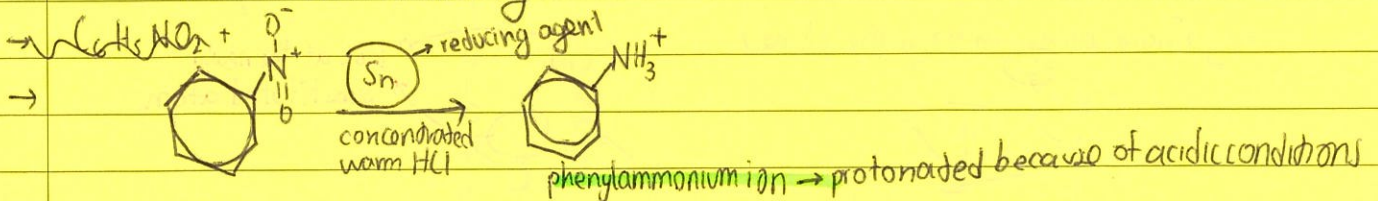


Back to Reduction

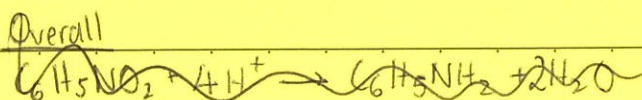
By a reduction reaction, phenylamine  $[C_6H_5NH_2]$  can be formed



then, under reflux in a boiling water bath

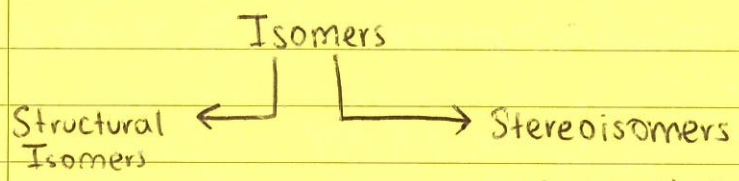


The NaOH neutralises any remaining  $H^+$  (aq).



# Isomers [Ewww]

Date \_\_\_\_\_ No. \_\_\_\_\_



→ molecules with the same molecular formula but different structural isomers

→ molecules with the same structural formula but different atom arrangements in space

configurational  
 → can only be interconnected (mapping) by breaking a bond  
 → Restricted Rotation  
 E/Z and cis/trans  
 optical isomers

Configurational isomers interconvert between each other by breaking and reforming a bond

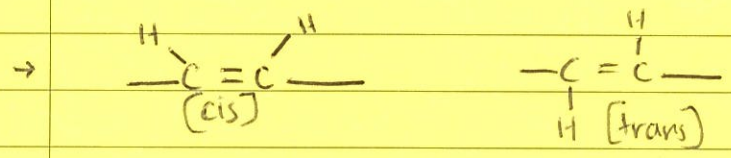
## Cis/trans

- exist where there is restricted rotation around atoms
- e.g. always in alkenes because of double bond

We only use cis/trans for rings systems, otherwise use E/Z or optical

### Alkenes

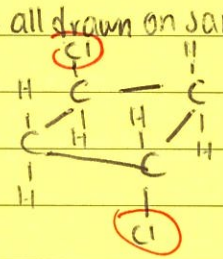
→ Why?  $\pi + \sigma$  bonds make up the C=C bond, the  $\pi$  is formed from an overlap of 2 p orbitals which need to be on the same plane to combine. A bond rotation breaks the  $\pi$  bond, hence there is restricted rotation around atoms, ∴ cis-trans



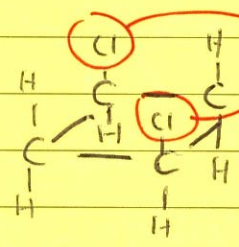
Note: cis alkenes have higher b.p.s because of inductive effects on same top/bottom, granting polarity, ↑ b.p.

### Cyclic Compounds (specifically disubstituted ones, e.g. 1,2-dichlorocyclohexane)

→ Why? Rotation restricted because of C-C bonds are part of a ring system e.g. (note, all drawn on same plane)



trans-1,3-dichlorocyclobutane



cis-1,3-dichlorocyclobutane

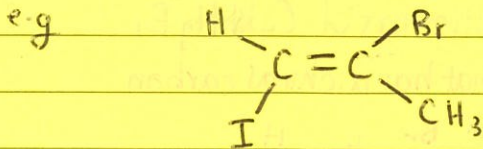


## E/Z isomerism

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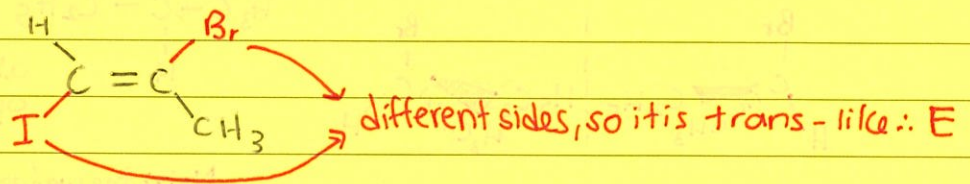
- like cis/trans, when we have atomic rotational restriction
- but when C atoms of C=C bonded to more than 2 different molecules



- Using the Cahn Ingold Prelog rules of priority, we decide whether we have a E or Z isomer.

① Identify heaviest ATOM bonded to <sup>a side</sup> C=C. So it is clearly I, as Mr(I) > <sup>for LHS</sup> Mr(H) > <sup>Mr(CH)</sup> Mr(CH<sub>3</sub>) > Mr(Br)

② Now, check RHS, Mr(Br) > Mr(C), so it is Br



- E → reverse of its cis implication, so trans, 2 diff sides, unlike the 3 bits on the E
- Z → same plane, unlike the 2 bits on the Z
- Z and E are written in brackets. Hence, the example would simply be (E)-Iodo, 2-bromo pent-1-ene

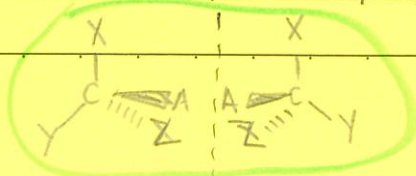
## E vs Z

- different physical properties, e.g b.p, solubility, m.p.
- different chemical properties as different possible reactions can occur

## Optical Isomers

### Enantiomers

- Definition: isomers that are non superimposable mirror images of one another
- a chiral carbon is required
- A chiral carbon is a carbon bonded to 4 different atoms or groups, also called asymmetric
- 2 enantiomers per optically active molecule
- We draw them as tetrahedrons, with the chiral carbon at the centre.
- If asked for both enantiomers, write as the following

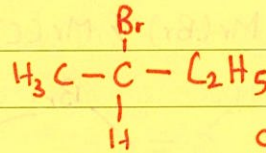
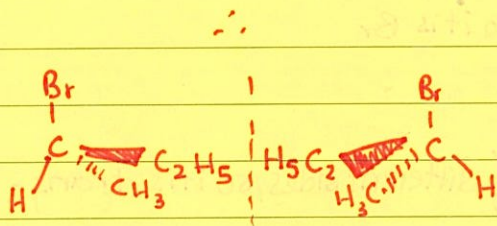
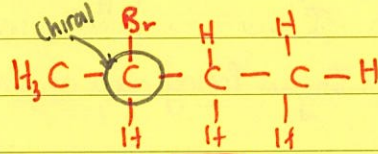
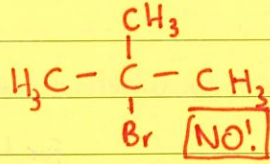


→ a mixture containing a 50-50 mix of each enantiomer is a racemic mixture, and is optically inactive

→ Identifying chiral carbons. Draw the enantiomers of  $C_4H_9Br$

We need an isomer of ~~but~~ bromobutane that has a chiral carbon

Rotations in opposite directions with equal magnitudes

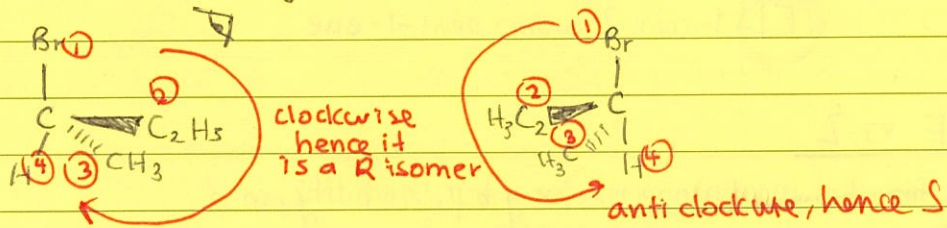


all different groups, hence optically active!

Note: the wedges and dashes must be used!

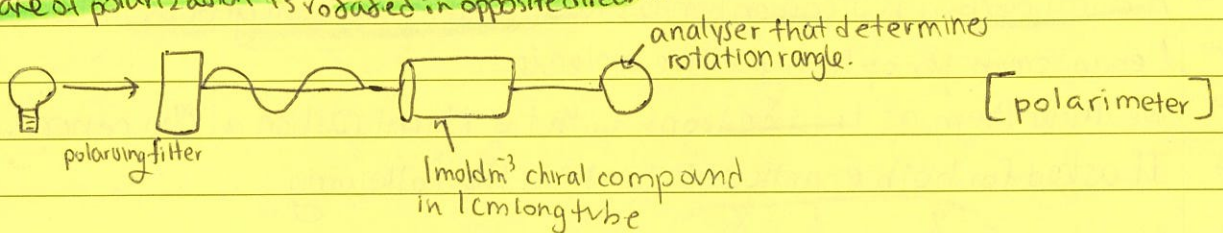
Something interesting [not in syllabus]

- Distinguishing R and S optical isomers
- Look at the heaviest atom bonded heaviest atoms bonded in order and number them. If 1 → 4 go clockwise, it is R, if anti clockwise then S



### Plane polarised Light

- a transverse wave of light
- normal light vibrates in every plane, but plane polarised light moves perpendicular to the wave. Plane Polarised (PP) light generated by shining light through a polarising filter
- Enantiomers rotate plane polarised light, if plane polarised light passed through, the plane of polarization is rotated in opposite directions



- if we have a racemate, there is no net rotation as both chiral compounds rotate clockwise and anti-clockwise, cancelling each other out, ∴ not optically active
- Note: naturally occurring chiral compounds are optically active, only 1 type of enantiomer
- clockwise [ + rotation ] is an R isomer, anti is an S

### Comparing properties of enantiomers

#### ① Chemical

- different reactivities, and because biological systems (e.g. enzymes) are chiral, it has significant impacts. E.g. thalidomide [listen to "We Didn't Start the Fire,"], 1 enantiomer reduced morning sickness, another caused birth defects
- To produce a single enantiomer, asymmetric synthesis is used, a process using a chiral catalyst

#### ② Physical - also differ

#### Effect

- Distinct chemical and physical properties allow for separation
- Hence, 2 enantiomers in a racemate can be separated by "resolution."

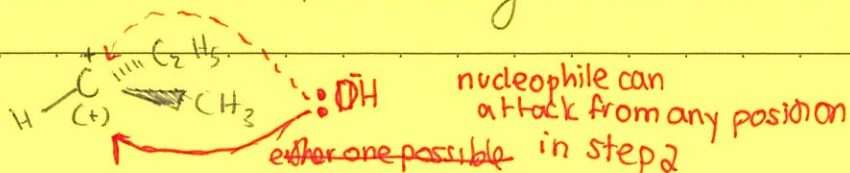
### SN1 and SN2 w.r.t stereoisomers

#### SN2

- it is stereospecific, causes an inversion of spatial arrangement of atoms around a C atom
- Called stereospecific because the spatial arrangement of atoms in reactants determines 3D configuration of the products
- \* → This is because bond formation is before bond cleavage in the transition state, ∴ no loss of stereochemistry

#### SN1

- non stereospecific as there are 2 possible bonding sites on carbocation intermediate because it is planar



→ hence an  $S_N1$  mechanism produces a racemate, as a mix of optically active isomers are produced.

### Question Tips

i) Structure of benzene - C's are  $sp^2$  hybridised,  $120^\circ$  angles, hexagonal, resonance, all equal C-C bonds, bond order of 1.5



Reductions

Date

No.

→ With  $\text{LiAlH}_4$  and  $\text{H}_2\text{O}$  / protic solvent

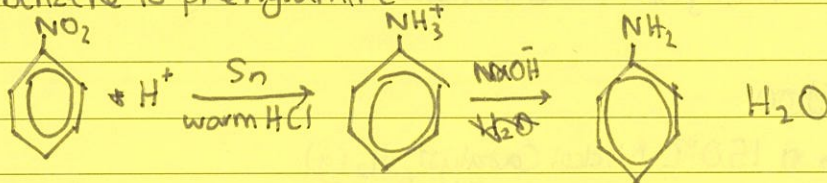
1) ketone → secondary alcohol

2) primary aldehyde → primary alcohol

→ with  $\text{NaBH}_4$  and aprotic solvent (because otherwise  $\text{H}^-$  ions gone)

1) carboxylic acid → primary alcohol

→ Nitrobenzene to phenylamine

Esterification

→ alcohol + carboxylic acid

→  $\text{H}_2\text{SO}_4$  catalyst + dehydrating agent (shifts equilibrium)

Electrophilic substitution

• Production of nitrobenzene

→  $\text{H}_2\text{SO}_4$  and  $\text{HNO}_3$  at  $50^\circ\text{C}$ , all conc