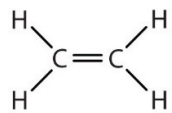
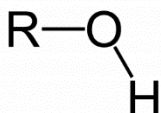
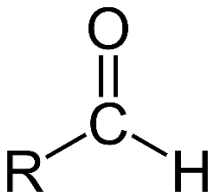
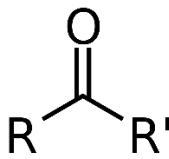
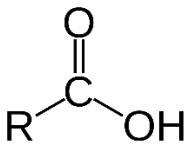
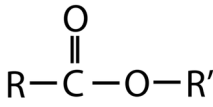
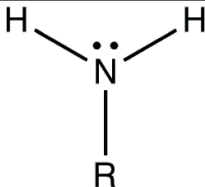
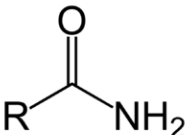


# Organic Chemistry

Class of Compound	Structural Formula	Semi-Structural Formula	Suffix	Prefix	Polarity
Alkene		-CHCH-	-ene		Slightly polar - Weak Dipole- Dipole -Dispersion
Haloalkane	<b>R—F</b>	-F -Cl -Br -I		-Fluoro -Chloro -Bromo -Iodo	Polar -H-Bonding only if another molecule has H-FON -Dipole-Dipole -Dispersion forces
Alcohol		-OH	-(an)ol	Hydroxy-	Very Polar -H-Bonding -Dipole-Dipole -Dispersion forces
Aldehyde		-CHO	-(an)ane	Oxo-	Polar -H-Bonding only if another molecule has H-FON -Dipole-Dipole -Dispersion
Ketone		-CO-	-(an)one	Oxo-	Polar -H-Bonding if another molecule has H-FON -Dipole-Dipole -Dispersion
Carboxylic Acid		-COOH	-(an)oic acid		Very Polar -H-Bonding -Dipole-Dipole -Dispersion
Ester		-COO-	-(an)oate		Very Polar <del>-H-Bonding if</del> <del>another has H-FON</del> -Dipole-Dipole -Dispersion
Amine		-NH <sub>2</sub>	-amine	amino	-Very Polar -H-Bonding -Dipole-Dipole -Dispersion

Amide		-CONH <sub>2</sub>	-amide		Very Polar -H-Bonding -Dipole-Dipole -Dispersion
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## Functional Groups

- As size of any molecule increases, dispersion forces become increasingly significant  $\Rightarrow$  interact primarily through dispersion  $\Rightarrow$  Soluble in non-polar molecules  $\Rightarrow$  Less soluble in Polar substances
- Side chains go in brackets:
  - Ex. methyl-propane: CH<sub>3</sub>CH(CH<sub>3</sub>)CH<sub>3</sub>
- Alphabetical order for functional group prefixes (Ethyl named and numbered before methyl)
- DON'T use di/tri prefixes for alphabetical ordering
- Isomers have same molecular formula but different structural formula**

## Cycloalkanes (cyclo-R)

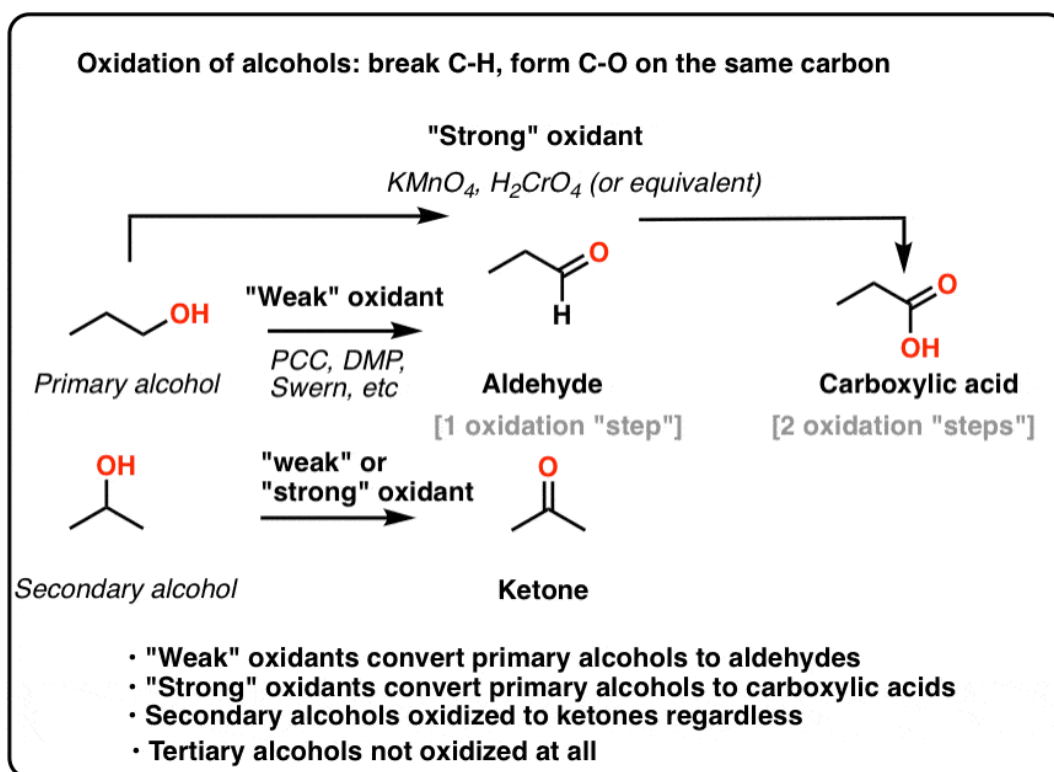
- General formula: C<sub>n</sub>H<sub>2n</sub>
- Ring structure with no double bonds
- Properties similar to alkanes
- Numbering of attached functional groups need to add up to lowest possible number

## Cycloalkene (cyclo-R-ene-R')

- Same as cycloalkane but only one is hydrogen attached to carbons involved in double bond
- General formula: C<sub>n</sub>H<sub>2n-2x</sub> where x is number of double bonds
- Double bond needs to be between 1 and 2 in numbering (start at double bond)

## Alcohol (-OH)

- Alcohols can be described as primary, secondary or tertiary alcohols
  - Primary  $\Rightarrow$  -OH group at the end (bonded carbon only bonded to 1 other carbon atom)
  - Secondary  $\Rightarrow$  -OH group in middle (bonded carbon bonded to 2 other carbon atoms)
  - Tertiary  $\Rightarrow$  -OH group in middle (bonded carbon bonded to 3 other carbon atoms)
- Primary and secondary alcohols can be oxidised to form other substance; tertiary alcohols cannot be oxidised:

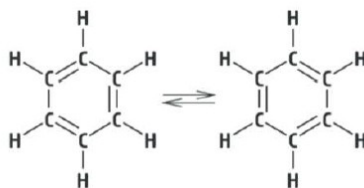


## Properties

- BP of any alcohol is much higher than parent hydrocarbon  $\Rightarrow$  -OH capable of H-Bonding and dipole-dipole and increases mass, hence higher dispersion forces
- Soluble in any other substance capable of H-bonding or dipole-dipole forces  $\Rightarrow$  Solute-Solvent forces overcome constituent Solute-Solute and Solvent-Solvent forces
  - o Completely miscible in  $\text{H}_2\text{O}$
- When 2+ functional groups are present, principal functional group is given priority (high to low):
  1. Ester (-COO-)
  2. Carboxylic acid (-COOH)
  3. Amide (-CONH<sub>2</sub>)
  4. Aldehyde (-CHO)
  5. Ketone (-CO-)
  6. Alcohol (-OH)
  7. Amine (-NH<sub>2</sub>)
  8. Aromatics
  9. Alkene (-C=C-)
  10. Alkyne (-C $\equiv$ C-)

## Benzene

- $\text{C}_6\text{H}_6$ , flat hexagonal structure
- C-C bonds are identical, intermediate in length
- C bonds alternatively double bonded to neighbouring C atoms



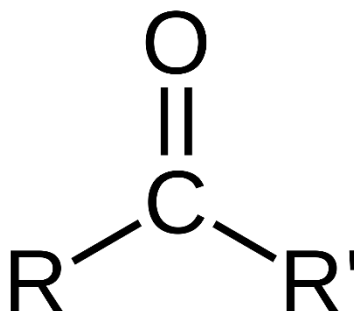
- Shorthand notations:



- **Aromatic** compounds are benzene based  $\Rightarrow$  H replaced with atoms or molecules
- **Carcinogen**

## Aldehyde (-CHO)

- Polar molecule but unable to bond through H-Bonding (lacks hydrogen atom bonded to FON)
  - o Can bond with other molecules with H-FON with lone electron pair on O atom
- Higher BP than parent alkane but lower BP than alcohols of same size
- Soluble in compounds with molecules capable of dipole-dipole interaction
- Carbonyl group:



## Ketones (-ROR<sub>1</sub>-)

- Polar molecule and will interact primarily through dipole-dipole interactions
- Similar BP to Aldehyde of same mass
- Product of 2<sup>nd</sup> degree alcohol oxidation

## Carboxylic Acid (-COOH)

- Short chain carboxylic acids have a **pungent vinegary odour**
- Contains -COOH, the Carboxyl functional group (Carbonyl + Hydroxyl)
- Polar molecule and will interact primarily through H-Bonding
- BP much higher than any other hydrocarbon of similar molecule size
- BP slightly higher than corresponding main-chain alcohol
- Soluble in polar solvents, especially those with H-Bonds
- As length of carboxylic acid increases greater than hexanoic acid, substance becomes virtually immiscible
- Long carboxylic acid molecules are known as fatty acids
  - o Soft, greasy feel
  - o Insoluble in water
- Fatty acids occur in many living systems

- Carbon chain in plant fatty acids are unsaturated (contain alkene and alkyne functional groups) and double bonds form **cis** configuration
- Animal fatty acids are saturated (contain no alkene or alkyne functional group)
- Fatty acids are related to, but not the same as fats and oils
- In plants and animals, fatty acids are converted to triglycerides (fats and oils)
  - Fats and oils are important for energy storage

## Amines (-NH<sub>2</sub>)

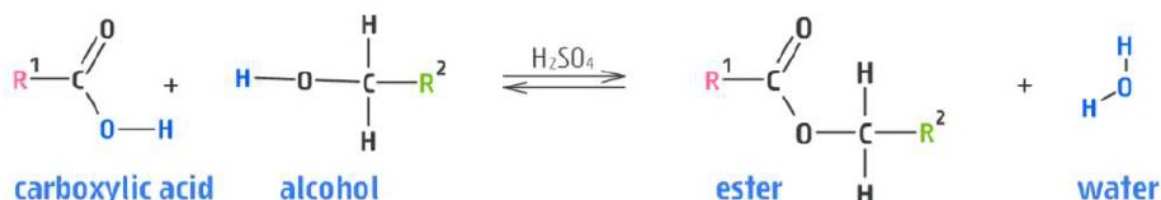
- Polar and capable of H-Bonding ⇒ BPs higher than hydrocarbons but lower than alcohols of similar molecular size
- Weaker H-bonding of amine than alcohol occurs due to lower electronegativity of nitrogen (3.0) compared to oxygen (3.5) ⇒ weaker dipole and H-Bond
- Soluble in polar solvents, especially those with H-bonds

## Amides (-CONH<sub>2</sub>)

- Individual H-Bonding strength is greater than similar amines or carboxylic acids:
  - Greater number of suitable lone electron pairs and H atoms available for H-bonding in amide (2 H-atoms and 3 lone pairs) than similar amine or carboxylic acid
  - Close proximity of highly electronegative O atom causes H atoms from NH<sub>2</sub> group to develop larger dipole than normal
- Therefore, BP of amides are higher than amines, alcohols, and carboxylic acid
- Soluble in other solvents which interact strongly through H-bonds

## Esters (-COO-)

- Ester group creates a degree of polarity at centre of ester molecule
  - Allows for dipole-dipole and dispersion interactions
  - H-Bonding?
- Therefore, BP is similar to aldehydes and ketones but lower than alcohols and carboxylic acids of similar molar mass
- **Pleasant fruity odours** for small molar mass esters
- High molar mass esters are **solid** with a **waxy feel**
- Lower molar mass esters are volatile
- Used as solvents
- Useful for adding fruity and floral odours in foods and cosmetics
- Leaves of most plants have protective wax coating of high molar mass esters
- Esterification:



- Reverse reaction occurs when acid is added to ester
- Base added ⇒ Ethanoate Salt + alcohol

## Fats and Oils

- Triglycerides  $\Rightarrow$  fats and oils (type of ester)
- Triglycerides contain fatty acid molecules attached to a main ester group
- Vegetable oils are unsuitable for cooking because they remain a liquid when heated
  - o Unsaturated fats from plants also tend to spoil quicker (due to more reactive double bonds, capable of addition reactions)
  - o Hydrogenation is solution  $\Rightarrow$  converts unsaturated liquid vegetable oils into more versatile solid products (ex. shortening, margarine)
    - Addition reaction where H atoms add to some double bonds in triglyceride carbon chains
    - Reduces degree of unsaturation and produces solid fat
    - Hydrogenation can produce an undesirable side reaction which converts some cis double bonds in triglyceride carbon chain into trans form
      - Trans isomers are unsaturated but their linear geometry increases dispersion forces and allows molecules to pack more efficiently than cis form
        - o Trans fats solidify more readily than cis  $\Rightarrow$  poses a risk to cardiovascular system

## IMFs

- Intermolecular forces  $\Rightarrow$  forces between molecules
- Dispersion forces  $\Rightarrow$  a temporary dipole that exists as a result of fluctuations in the electron cloud
  - o Constantly moving electrons form a **temporary dipole**
  - o **All** molecules with electrons exhibit dispersion forces
  - o Packing density (**Steric Hindrance**)  $\Rightarrow$  Straight carbon chain molecules exhibit stronger dispersion forces (bent exhibit weaker)
- Dipole-dipole forces  $\Rightarrow$  permanent dipoles
  - o Two requirements for molecules to exhibit dipole-dipole:
    - Have to be polar bonds
      - Bonds involving elements with differences in electronegativity
      - Non-symmetrical molecule
  - o  $\delta^+$   $\Rightarrow$  positive dipole
  - o  $\delta^-$   $\Rightarrow$  negative dipole
- Hydrogen-Bonding  $\Rightarrow$  Extreme dipole-dipole bond between very electronegative ion and hydrogen attached to very electronegative ion
  - o H-FON (H bonded to F, O or N)
- Mention **SUM OF ALL IMFS** in answers
- Substitution reactions  $\Rightarrow$  one atom is swapped for another
- Addition reactions  $\Rightarrow$  double bond is broken, creating two reactive sites available for other atoms/molecules to bond
- Types:
  - o Halogenation (+ Halogen -  $F_2$ ,  $Cl_2$  etc)
  - o Hydrohalogenation (+ Hydrohalogen - HCl, HF etc)
  - o Hydrogenation (+ Hydrogen -  $H_2$ )
  - o Hydration (+ Water -  $H_2O$ )

- Addition reaction with alkene creates an alcohol ( $\text{H}^+$  and  $\text{OH}^-$  bonds separately)
- Long chain carboxylic acids  $\Rightarrow$ 
  - o Plant fatty acid, unsaturated (oleic acid) in cis configuration
  - o Animal fatty acid, saturated (stearic acid)

Model Answer (solubility)

- Detail cohesive forces in solute and how much solute-solute interactions resist mixing
- Detail cohesive forces in potential solvent and how much solvent-solvent interactions resist mixing
- Detail nature of any potential solute-solvent interactions and how much they assist mixing
- If it is soluble, solute-solvent interactions outweigh solute-solute and solvent-solvent forces

Mistakes

- **prefixes always in alphabetical order**  $\Rightarrow$  only suffixes require priorities

3. The boiling points and molar masses of three organic compounds are shown in the table.



Compound	Boiling Point (°C)	Molar Mass (g.mol <sup>-1</sup> )
Ethanoic Acid	118	60
Butan-1-ol	117	74
Butyl ethanoate	116	116
2-Methylheptane	116	114

Ethanoic acid, butan-1-ol and butyl ethanoate have very different molar masses but similar boiling points. Explain why in terms of the structure and bonding of the three compounds.

(6 marks)

Ethanoic acid, butan-1-ol and butyl ethanoate have very different molar masses but similar boiling points. Explain why in terms of the structure and bonding of the three compounds.

(6 marks)

- **Despite having different molar masses, all four molecules have similar boiling points due to their different structures and resulting total sum of intermolecular forces.**
- **2-methylheptane is a branched chain alkane. Its only has dispersive forces operating between its molecules however, due to the large number of atoms (and as a result electrons) has a relatively high boiling point.**
- **Butyl ethanoate has the largest molar mass and therefore greatest dispersion forces but it is also slightly polar, so has dipole-dipole forces, but is unable to hydrogen bond.**
- **Butan-1-ol has lower molar mass than butyl ethanoate and 2-methylheptane and therefore smaller dispersion forces but it is polar and contains a hydrogen covalently bound to an oxygen. Therefore, it exhibits hydrogen bonding between particles resulting in strong intermolecular forces.**
- **Ethanoic acid has the lowest molar mass and so the weakest dispersion forces but it is polar and contains a hydrogen bound to an oxygen allowing the formation of hydrogen bonds between molecules.**
- **The presence of a second oxygen (with it's lone pairs of electrons) in ethanoic acid increases the hydrogen bonding compared with butan-1-ol.**