Organic Chemistry
ANSWERS

Naming and Drawing Organic Compounds

The Main Carbon Chain
STOP AND CHECK (PAGE 7)

- Count out the carbons and find the chain with the longest consecutive carbon link.
  - **Note:** This won't always be a straight chain.

Number of Carbons	Prefix
1	Meth-
2	Eth-
3	Prop-
4	But-
5	Pent-
6	Hex-
7	Hept-
8	Oct-
9	Non-
10	Dec-

Functional Groups

STOP AND CHECK (PAGE 8)

- A functional group is the identifying trait of an organic compound that determines what it is and how it is different from the rest through physical and chemical traits. These groups include single bonds (alkanes), doubles bonds, and halogen atoms.

Branch Chains

STOP AND CHECK (PAGE 9)

- An addition to the carbon chain that does not contribute to the longest chain. Typically in Level 2, these side groups are methyl and ethyl groups (1 or 2 branched carbons).
- Use the prefix for the number of carbons in the branched-chain, and add “-yl” to the end, such as 1 = methyl, 5 = pentyl

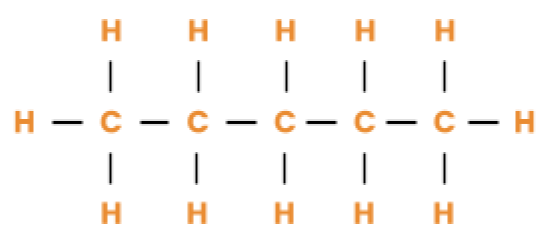
Numbering Carbon Atoms

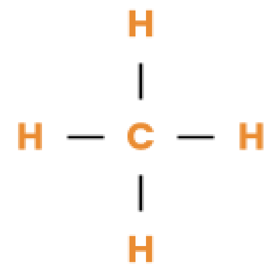
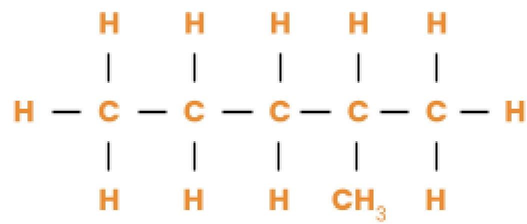
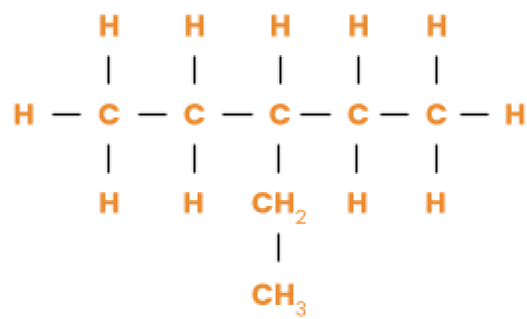
STOP AND CHECK (PAGE 10)

- The end of the chain closest to the functional group is number 1. Therefore the carbon(s) connected to the functional group has the lowest number possible.

Drawing Organic Molecules

STOP AND CHECK (PAGE 11)

Molecule Name	Diagram
Pentane	

Methane	
2-methyl pentane	
3-ethyl pentane	

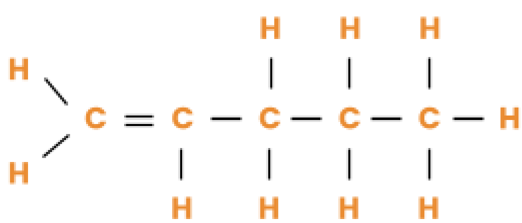
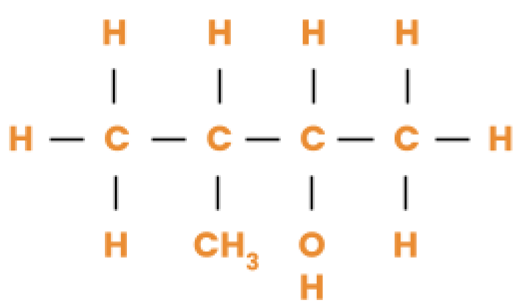
Naming and Drawing Organic Molecules

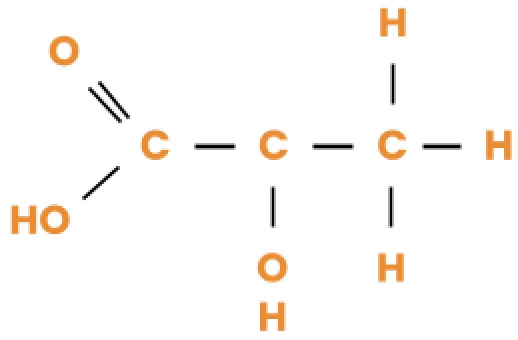
QUICK QUESTIONS (PAGE 11)

- There are 3 carbons, so the prefix used is "prop-"
- The longest chain has 4 carbons. This is because although there are a total of 5 carbons in the molecule, they are not all connected together, and only a continuous line of 4 carbons exist.
- There are 4 carbons, so the prefix used is "but-"
- There is 1 branched-chain off the second carbon.
- There is 1 carbon, so the prefix used is "meth-", therefore the name of the branched-chain is a methyl group.

Side Chain	Prefix
1	Methyl-

2	Ethyl-
3	Propyl-
4	Butyl-
5	Pentyl-
6	Hexyl-
7	Heptyl-
8	Octyl-
9	Nonyl-
10	Decyl-

Compound	IUPAC Name
 **Note:** Compound is $CH_2CHCH_{\mathbf{2}}CH_2CH_3$ not $CH_2CHCH_{\mathbf{3}}CH_2CH_3$	Pent-1-ene
	3-methylbutan-2-ol

	2-hydroxypropanoic acid

Functional Groups

Organic Compounds with Just Carbon and Hydrogen

STOP AND CHECK (PAGE 15)

- Count the main carbon chain, and use this number to work out the prefix. Add "-ane" to the end of the prefix. Such as, "methane".
- Saturated means that all the carbons have single bonds between one another. Unsaturated means there is at least 1 double or triple bond between carbons. Alkanes only have single bonds, therefore they must be saturated.
- Alkenes have the functional group double bond.
- Identify what carbons the double bonds are connected to. Name the carbons to ensure these functional carbons have the lowest numbers possible. Out of these two functional carbons, pick the smaller number. The name of the alkene will then be "prefix-number-ene", such as "pent-2-ene".
- Alkynes have the functional group triple bond.
- Identify what carbons the triple bonds are connected to. Name the carbons to ensure these functional carbons have the lowest numbers possible. Out of these two functional carbons, pick the smaller number. The name of the alkyne will then be "prefix-number-yne", such as "hept-3-yne".

Organic Compounds with Other Atoms Attached

STOP AND CHECK (PAGE 18)

- Halogens are in Group 17. Fluorine, Chlorine, Bromine, Iodine.
- A hydroxyl group, -OH.
- A hydrogen and an oxygen.
- Identify the longest chain of carbons and use the prefix used for that number. Identify the carbon number that the hydroxyl group (-OH) is attached to, start counting at the end that will make this carbon have the smallest number possible. The molecule will be named "prefix-an-number-ol". Such as hexan-2-ol.
- A diol is when there are two hydroxyl groups within the same molecule. This is different from an alcohol as an alcohol only has one hydroxyl group attached to a molecule.
- Identify the longest chain of carbons and use the prefix used for that number. Identify the carbon number(s) that the hydroxyl groups (-OH) are attached to, start counting at the end that will make these carbons have the smallest numbers possible. The molecule will be named "prefix-an-number, number-diol". Such as butan-2,3-diol.

Acidic and Basic Organic Compounds

STOP AND CHECK (PAGE 23)

- -COOH, which is a carbon and oxygen, and an oxygen and a hydrogen (this is a hydroxyl group within the carboxyl group).
- Carboxylic acids will always be on the first carbon. They must always be on the end, and the carbon it is attached to will be called carbon number 1. Therefore you name the molecule as normal, with "-anoic acid" on the end, such as propanoic acid.
- It is not necessary to indicate the position of the carboxyl group as they will always be connected to an end carbon, and this carbon will always be called carbon number 1.
- The carboxyl group will release a hydrogen ion (H^+) and become $-COO^-$ the carboxylate group. To release a hydrogen ion is to be acidic.
- $-NH_2$ is a nitrogen with two hydrogens attached.
- Amines can either have the prefix "amino-" or the suffix "-amine".

- The $-NH_2$ group will accept a hydrogen ion (H^+) and become $-NH_3^+$. To accept a hydrogen ion is to be basic.

Primary, Secondary and Tertiary Molecules

STOP AND CHECK (PAGE 24)

- Primary alcohols can be oxidised to carboxylic acids. Other kinds of alcohols can also be oxidised, but we won't worry about that until Level 3.
- Primary, secondary, and tertiary haloalkanes are dependent on the carbon the functional group is attached to. If the carbon is attached to only 1 other carbon it is primary, if it is attached to 2 other carbons it is secondary, and for 3 carbons it is tertiary. If the carbon is tertiary, the haloalkane is tertiary. The difference in these haloalkanes results in different properties.

Isomers

Molecular Formulae

STOP AND CHECK (PAGE 26)

- The molecular formula has what types of atoms are present in a molecule, and how many of each atom are present.
- Many molecules with the same molecular formula have a different structure, such as pentan-1-ol and pentan-2-ol. These are two different molecules with the molecular formula $C_5H_{12}O$.

Structural Formulae

STOP AND CHECK (PAGE 24)

- Structural formula informs us which atoms are present, how many, and how they are bonded together.
- Structural formulae inform us how atoms are bonded together, whereas molecular formulae only inform us about what atoms are present and how

many of each there are. No information is given by molecular formulae about how atoms are bonded together.

Structural/Constitutional Isomers

STOP AND CHECK (PAGE 28)

- Structural isomers are where molecules have the same number and type of atoms but are bonded together differently.
- Positional isomers are where a functional group is located in a different place on the molecule. Branched-chain isomers are when the distribution of the carbon chains are altered so side chains form, thus isomers of the original chain are formed. Functional group isomers are when functional groups are altered due to the new structure of the molecule. The similarities between these three types of isomers are that they are all isomers, and are to do with the movement and positioning of the atoms in and around the carbon chain. The difference between them is that they are defined differently, as mentioned above, and are separate functions.

Geometric Isomers

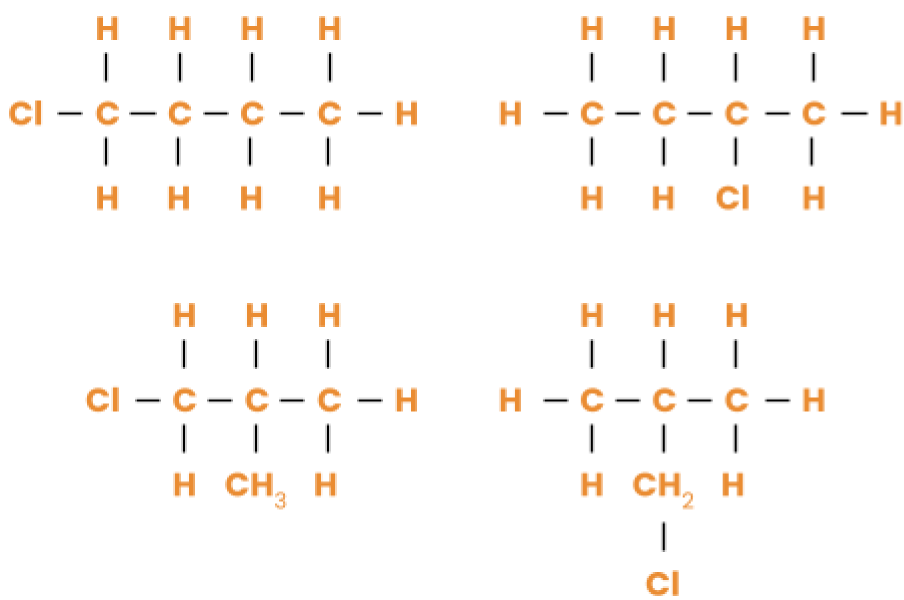
STOP AND CHECK (PAGE 30)

- Geometric isomers are different from structural isomers as geometric isomers have the same structural formulae. Geometric isomers are the different arrangement of atoms around double-bonded carbons, and in particular with the positioning of a common group attached to both double bonded carbons in a molecule.
    1. Double bonded carbons are present to prevent free rotation.
    2. Each double-bonded carbon has two different groups attached to it.
    3. There is a common group on each side of the double bond.
- Looking at the common group of both carbons, if they are both in the up position, then the prefix "cis-" is added to the front of the name. The same occurs if they are both in the down position. However, if one is in the up position, and one is in the down position, then the prefix "trans-" is added to the front of the name.

Isomers

QUICK QUESTIONS (PAGE 29)

- CH_3-CH_2-CH_2-CH_2-CH_3
- C_5H_{12}
- The structural formula tells us that the molecule pentane has five carbons and 12 hydrogens arranged in one chain with the carbons singularly bonded together and with hydrogens attached so each carbon has four bonds. The molecular formula tells us that the molecule pentane is made up of five carbon atoms and 12 hydrogen atoms.



- In the original drawing of the organic molecule, drawn in 1-chlorobutane, a primary haloalkane, and 2-chlorobutane, a secondary haloalkane. The second branched-chain isomer drawn is a positional isomer as the functional group, the haloalkane has been moved to be a tertiary haloalkane. The first branched-chain isomer drawn is a primary haloalkane, therefore is not a positional isomer.
- There is no functional group isomer for this molecule! This is a haloalkane that can't be arranged in any other way to form another functional group.
- A geometric isomer requires a double bond, as geometric isomers cannot exist if free rotation in space can occur. Therefore the second molecule cannot form a geometric isomer. Geometric isomers also require the double-bonded

carbons to have two different functional groups attached and to have a common group on either side of the double bond. The first molecule meets all three of these conditions.

Organic Reactions

Addition Reactions

STOP AND CHECK (PAGE 36)

- An addition reaction is when something new is added to the molecule. This requires the breaking of a double bond.
- An alkene (or an alkyne) as a non-singular bond must be broken.
- Possible organic molecules that can be formed are alkanes, haloalkanes, dihaloalkanes, and alcohols.
- Reagents include: HCl, Br_2, H_2O/H^+

Markovnikov's Rule

STOP AND CHECK (PAGE 34)

- A hydrogen-rich carbon (the carbon that begins the reaction with the most carbons) will receive the new hydrogen atom introduced to the molecule during the reaction.
- A major product is produced the most in a reaction and is when Markovnikov's Rule is observed and the hydrogen-rich carbon receives the new hydrogen atom. The minor product is produced in much smaller quantities and is when the hydrogen poor carbon receives the new hydrogen atom.

Elimination Reactions

STOP AND CHECK (PAGE 40)

- An elimination reaction is when two atoms are removed from the molecule, one each off two neighbouring carbons, forming a double bond, and therefore an alkene.
- Alcohols and haloalkanes can take part in elimination reactions as they are both single-bonded carbon chains with one functional group.
- The product is an alkene.
- Reagents used are $H_2SO_{4(conc.)}$ and $KOH_{(alc)}$. Side products formed are the combination of the atoms removed from the reactants, H_2O from alcohol, and H (Hydrogen atom) from haloalkane.

Reverse Markovnikov's Rule

STOP AND CHECK (PAGE 41)

- Alcohol to alkene. Haloalkane to alkene.
- To determine what will be produced in the largest quantity (the major product). The hydrogen taken from the molecule during the reaction will most likely come from the hydrogen poor carbon, the carbon with the least hydrogens attached that is neighbouring the functional group carbon.
- The major product is produced in the largest quantity and follows the Reverse Markovnikov Rule, the minor product does not follow this rule and is only produced in small quantities during the experiment.

Oxidation Reactions

STOP AND CHECK (PAGE 43)

- At least one oxygen atom is added to the molecule.
- Both primary alcohols and alkenes can undergo oxidation reactions.
- H^+/MnO_4^- or $H^+/Cr_2O_7^{2-}$

Substitution Reactions

STOP AND CHECK (PAGE 43)

- A substitution reaction is when a functional group on the molecule is replaced by a different functional group.
- Haloalkane to alcohol, haloalkane to amine, alcohol to haloalkane, alkane to haloalkane.

Neutralisation Reactions with Carboxylic Acids

STOP AND CHECK (PAGE 47)

- Butanoic acid + Water → Butanoate acid + Hydronium
- Butanoic acid + Sodium carbonate → Sodium butanoate + Water + Carbon dioxide
- Butanoic acid + Ammonia → Butanoate acid + Ammonium

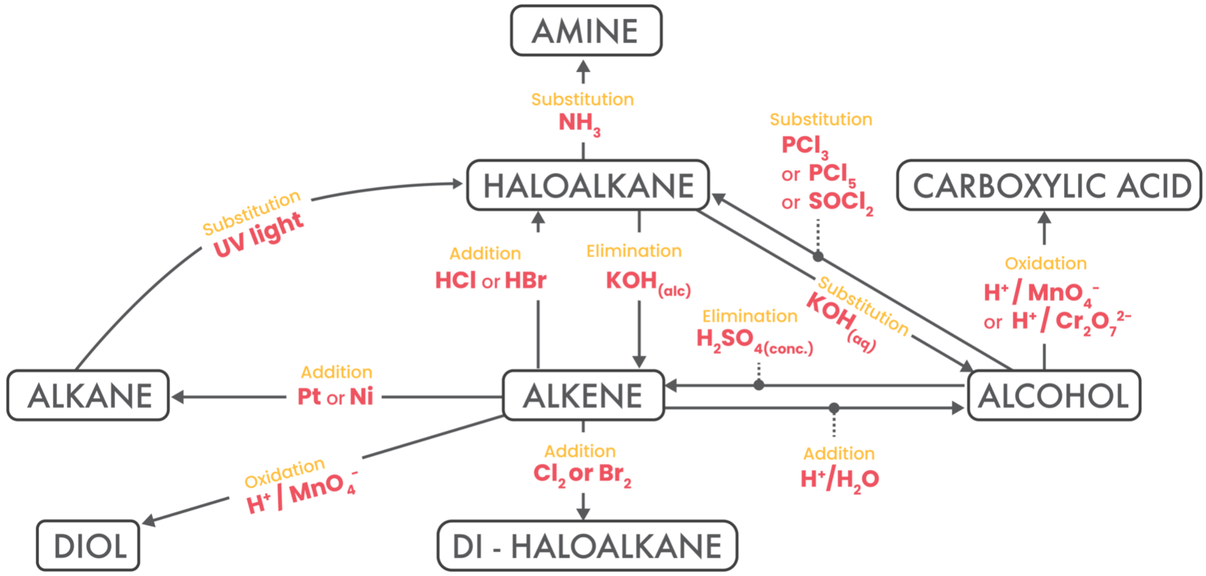
Acid-Base Reactions Involving Amines

STOP AND CHECK (PAGE 47)

- Butanamine + Water → Butanammonium + Hydroxide
- Butanamine + Hydrochloric acid → Butanammonium + Chloride

Organic Reactions

QUICK QUESTIONS (PAGE 48)



Polymers

Polymerisation Reactions

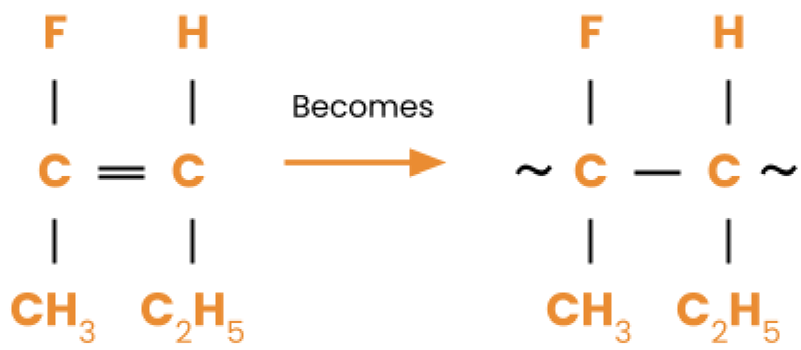
STOP AND CHECK (PAGE 51)

- A polymer is a large molecule composed of repeating units. A monomer is one of these units, a small molecule.
- For polymerisation to occur there needs to be high pressure, high temperature, a catalyst, and a monomer with a double bond.
- To name a polymer, add the prefix “poly-“ onto the name of the molecule.

Polymers

QUICK QUESTIONS (PAGE 51)

- Polymers are large molecules containing repeating units. These repeating units are called monomers. Polymers are formed when the conditions are met (high pressure, high temperature, the addition of a catalyst) and the double bond in a monomer is broken and the carbons on either side of the double join with other monomers to form a long chain of carbons. The other groups that are connected to the carbons are not a part of the chain and are connected to the carbons.



Properties of Organic Compounds

Introducing Polarity

STOP AND CHECK (PAGE 54)

- Polarity in chemistry is defined as the separation of charge This charge is the difference in the electronegativity of atoms within a molecule.
- Polarity is the difference in electronegativity between the atoms in a molecule. This is seen when there's a difference that occurs over a covalent bond, and if the molecule is asymmetrical, these dipoles will not cancel out, and the molecule will be polar.
- Electronegativity is the ability an atom has to hold onto its valence electrons.
- Oxygen, fluorine and nitrogen have the highest electronegativities. Caesium and francium have the lowest.
- For a non-polar covalent bond, there needs to be no difference in electronegativity, so the atoms must be the same.
- There is no separation of charge as in non-polar covalent bonds the atoms are the same and so there is no difference in electronegativity (charge).
- To make a polar covalent bond there must be a difference in electronegativity, therefore the atoms must be different,

- A separation of charge occurs as the atoms are different, so have different electronegativities, therefore a difference in electronegativity can occur, the separation of charge.

Polarity of Organic Compounds

STOP AND CHECK (PAGE 56)

- Alkanes, alkene and alkynes are nonpolar as they are symmetrical in shape and therefore any dipoles caused between the C-H bond are cancelled and the chain is nonpolar.
- Haloalkanes are nonpolar as the dipole caused by the haloalkane and the carbon covalent bond is "drowned out" by the symmetry of the rest of the carbon chain.
- Compounds containing nitrogen and oxygen tend to be polar as both atoms are very electronegative. However, this polarity only occurs in small carbon chains with these atoms present such as alcohols, amines and carboxylic acids. This is because the longer chains have the strong non-polar carbon chains to "drown out" the dipoles caused by the haloalkanes present in the molecule.

Introduction to Melting/Boiling Points

STOP AND CHECK (PAGE 59)

- When temperature increases, the energy of the molecule increases. This will cause state changes from a state with less energy to one with more. This is how solids can be converted to liquids, and liquids converted to gases.

Melting/Boiling Points of Organic Compounds

STOP AND CHECK (PAGE 59)

- Molecules are held together by intermolecular forces.
- Alcohols have a high melting/boiling point as they are polar and therefore are held together by strong intermolecular forces, versus alkanes, alkenes, alkynes

and haloalkanes that are nonpolar and are held together by weak intermolecular molecules.
- When the carbon chain increases the melting/boiling point also increases.

Introduction to Solubility

STOP AND CHECK (PAGE 60)

- Solubility is if something will dissolve in something else. A thing will only dissolve in something that has the same existence of polarity. So only non-polar molecules dissolve in nonpolar molecules, and only polar molecules dissolve in polar molecules.

Solubility of Organic Compounds

STOP AND CHECK (PAGE 61)

- Alkanes, alkenes and alkynes are non-polar. Water is polar. This is why they are insoluble in water.
- A haloalkane is nonpolar and therefore will not dissolve in water. So if they were mixed there would be a separation and layers would form.
- Small carboxylic acids and amines are soluble in water as they too are polar. Larger alcohols and amines are insoluble in water as they are non-polar due to the long carbon chain.

Properties of Organic Compounds

QUICK QUESTIONS (PAGE 61)

- Alkanes, alkenes and alkynes have the same properties as they are all nonpolar, have low melting/boiling points, and are insoluble in water. There are no substantial differences between their properties.
- The halogen functional group gives haloalkanes a dipole with strong negativity by the halogen atom. However, this electronegativity is cancelled by the very polar carbon chain. The presence of the halogen gives the haloalkane a slightly higher melting/boiling point than alkanes, alkenes and alkynes, but not that much larger.

- Alcohols, with the presence of oxygen in their functional group, are polar. This polarity is only present in small carbon chain alcohols as longer carbon chains are very nonpolar and cancel out the polarity of the alcohol. This functional group means there are strong intermolecular forces present which means that alcohols (and diols) have high melting/boiling points, and are soluble in water when they are small and polar.
- Carboxylic acids, with the presence of multiple atoms in their functional group, are polar. This polarity is only present in small carbon chain carboxylic acids as longer carbon chains are very nonpolar and cancel out the polarity of the carboxylic acid. This functional group means there are strong intermolecular forces present which means that carboxylic acids have high melting/boiling points, and are soluble in water when they are small and polar.
- Amines, with the presence of nitrogen in their functional group, are polar. This polarity is only present in small carbon chain amines as longer carbon chains are very non-polar and cancel out the polarity of the amine. This functional group means there are strong intermolecular forces present which means that amines have high melting/boiling points, and are soluble in water when they are small and polar.
- Polar organic molecules dissolve in polar solutions, and nonpolar organic molecules dissolve in nonpolar solutions. Polar organic molecules, due to their polarity, are held together by strong intermolecular forces and therefore have higher melting/boiling points than nonpolar molecules that are held together by weak intermolecular forces.

Identification Tests

Red and Blue Litmus Paper

STOP AND CHECK (PAGE 63)

- Red remains red, blue turns red.
- Red turns blue, blue remains blue.
- Red remains red, blue remains blue.

Dichromate and Permanganate Solution

STOP AND CHECK (PAGE 64)

- Carboxylic acids are formed.
- Primary reaction, the solution changes from orange to green. Secondary or tertiary reaction, the solution remains orange.
- Chromium ions Cr^{3+}.
- Primary, solution changes from purple to colourless. Secondary or tertiary reaction, the solution remains purple.
- Manganese ions Mn^{2+}.
- To oxidise a secondary or tertiary alcohol, a chain (at least one) of carbon must be removed from the functional carbon to allow for the double-bonded oxygen to attach. This is a lot of effort, and not possible with the use of dichromate and permanganate.

Bromine Water

STOP AND CHECK (PAGE 65)

- The Solution changes from yellow-brown to colourless and a haloalkane is formed.
- No reaction occurs.

Identification Tests

QUICK QUESTIONS (PAGE 65)

- Carboxylic acid is acidic, so will turn blue litmus paper red. Amines are basic, so will turn red litmus blue. Alcohols are neutral, so both blue and red litmus paper will remain unchanged in colour.
- Propanol is a primary acid and so will be oxidised with acidified permanganate and a colour change of purple to colourless will occur. 2-methylpropan-2-ol is a tertiary alcohol, and so no reaction will occur, and the solution will remain purple.
- Octane is an alkane. When bromine water is added without UV light, the alkane will not react and the bromine water will remain yellow-brown.

Oct-1-ene is an alkene, and when added to bromine water, the solution will turn colourless.

- Taking samples of each solution, adding both red litmus and blue litmus, the ethanoic acid (which is acidic) will turn blue litmus red, and ethanamine (which is basic) will turn red litmus blue. Next, add bromine water to the three remaining samples. One sample will turn from yellow-brown to colourless, this is the alkene hex-1-ene. Take two new samples from the remaining two beakers. Add water. The ethanol, a small chain alcohol, will be soluble and dissolve in the water. The hexane, which is nonpolar, will not dissolve in the water and will form separate layers.

