

LEVEL 2 CHEMISTRY

# ORGANIC CHEMISTRY

NCEA Workbook Answers

# Section One

# The Foundations

Learning all of the fundamentals in organic chemistry can seem quite daunting, there appears to be a lot to remember. This is largely because organic chemistry is very cumulative, you learn little bits of information that is all related to the broader idea of organic chemistry. Unfortunately, most workbooks don't tell you that it's all related and so you end up learning a bunch of stuff that doesn't appear to be related.

We have tried to solve this by putting questions together that build towards a holistic understanding of the topic, starting from the absolute basics towards putting it all together. The catch is that we can't simply tell you this, you have to work it out for yourself, and put the effort into seeing the connections. This section goes through all of the basics, and where possible combines the concepts together to challenge you, just because it's fundamental doesn't mean it's easy!

We've put a lot of practice problems in this section, don't feel like you have to do it all at once! It's also ordered in roughly the same way as our Walkthrough Guide, so when you get stuck, go and have a read of that section and try again!

## Part One

# The Foundations

## 1. Functional Groups

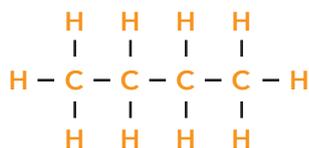
### Alkanes, Alkenes and Alkynes

a.

Number of carbon atoms	Prefix	Side Group
1	Meth-	Methyl
2	Eth-	Ethyl
3	Prop-	Propyl
4	But-	Butyl
5	Pent-	Pentyl
6	Hex-	Hexyl
7	Hept-	Heptyl
8	Oct-	Octyl
9	Non-	Nonyl
10	Dec-	Decyl

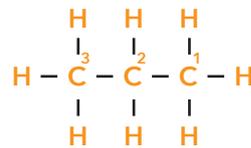
b.

i.



Name: Butane.

ii.



Name: Propane.

iii.

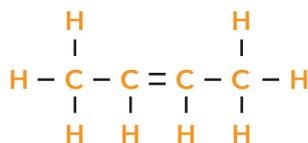
Position: First carbon.

Name: But-1-ene.

iv.

Name: 4-methylhex-2-ene.

v.



Name: But-2-ene.

vi.

Name: Ethyne.

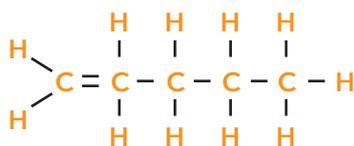
vii.

Name: Prop-1-ene.

viii.

Name: But-2-yne.

ix.



Name: Pent-1-ene.

c.

Saturated means that the maximum number of atoms are bonded to each carbon atom (each carbon atom is bonded to 4 other atoms). In practice, this means that there are no double or triple bonds anywhere in the molecule.

d.

i. Saturated: i, ii

ii. Unsaturated: iii, iv, v, vi, vii, viii, ix

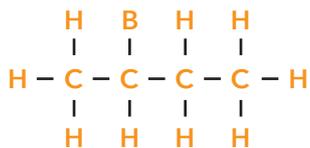
### Halogen containing organic compounds

e.

Bromine (Br), Chlorine (Cl), Fluorine (F), Iodine (I)

f.

i.



Name: 2-bromobutane.

ii.

Position: At the 2 position.

iii.

Name: 2,3-dichlorobutane.

iv.

Name: 1,4-dibromopentane.

v.

Name: 3-methyl-1,4-dibromopentane.

vi.

Name: Chloromethane.

vii.

Name: 4-chlorobut-1-ene.

viii.

Name: 2-chloro-3-bromopentane

g.

i.

Reactant: Propene (or prop-1-ene).

Reagent:  $\text{Br}_2$

Product: 1,2-dibromopropane.

ii.

Reactant: Pent-2-ene.

Reagent:  $\text{Cl}_2$

Product: 2,3-dichloropentane.

iii.

Reactant: Propene.

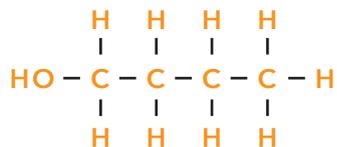
Reagent: Hydrochloric acid (HCl)

Product: 1-chloropropane and 2-chloropropane.

## Alcohols

h.

i.

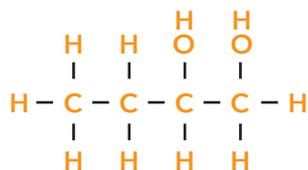


Name: Butan-1-ol.

iii.

Name: Propan-1-ol.

v.



i.

i.

Reactant: Butene.

Reagent: Acidified permanganate.

Product: Butan-1,2-diol.

ii.

Reactant: Propane.

Reagent: Potassium hydroxide solution.

Product: Propan-2-ol.

## Carboxylic Acids

j.

i.

Name: Ethanoic acid.

ii.

Name: Pentan-2-ol.

iv.

Name: Pentan-2,3-diol.

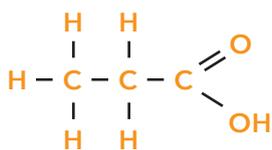
vi.

Name: Propenol.

ii.

Name: Pentanoic acid.

iii.



iv.

Name: Butanoic acid.

k.

i.

Reactant: Butan-1-ol.

Reagent: Acidified dichromate.

Product: Butanoic acid.

ii.

Oxidation to form carboxylic acids only happen with primary alcohols, this alcohol is tertiary and therefore will not react to form a carboxylic acid.

---

## 2. Naming and Drawing Organic Compounds

a. For the following organic compounds, name them using the IUPAC conventions.

i.

Name: Pentanoic acid.

ii.

Name: 1,2-dichloropropane.

iii.

Name: 2,2-dimethyl-4-bromopentane

iv.

Name: 1-aminobutane or butanamide

v.

Name: 3-chloro-2-methylpentane

vi.

Name: 1,3-dibromobutane.

vii.

Name: 1,1-diaminoethane.

viii.

Name: 3-chloropropanoic acid.

ix.

Name: 2-bromo-1,3-dichloropropane.

x.

Name: 3-chlorobute-1-ene.

xi.

Name: 1-chlorobut-1-ene.

xii.

Name: 2-fluoro-2-methylbutane.

xiii.

Name: Pent-2-yne.

xiv.

Name: 3-ethylpentane.

xv.

Name: Hept-2-ene.

xvi.

Name: 3-bromo-2,5-dichloro-5-methylhex-1-ene.

xvii.

Name: 3,3-dimethylpentan-2-ol.

xviii.

Name: 4-methylpentanoic acid.

xix.

Name: 1,2,3-trichloropropane.

xx.

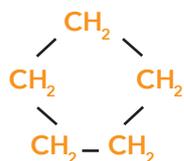
Name: Methanoic acid.

xxi.

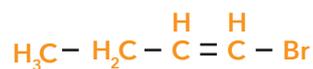
Name: Ethan-1,2-diol.

b.

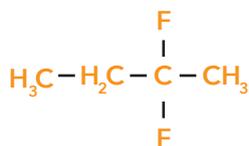
i.



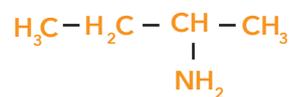
ii.



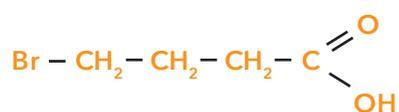
iii.



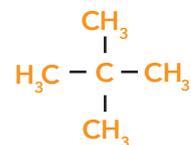
iv.



v.



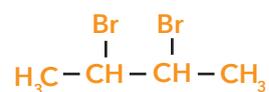
vi.



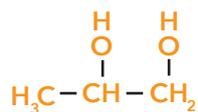
vii.



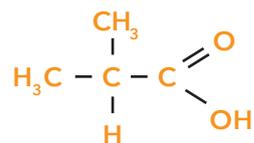
viii.



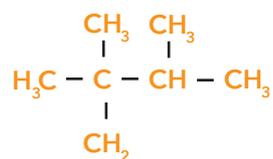
ix.



x.



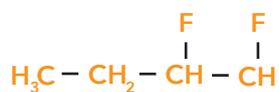
xi.



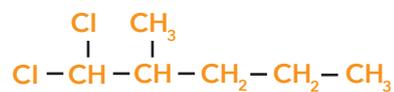
xii.



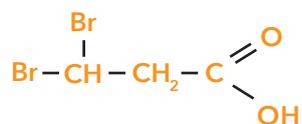
xiii.



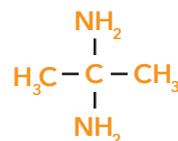
xiv.



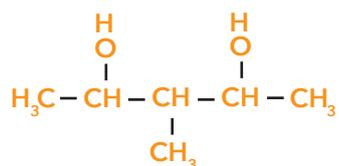
xv.



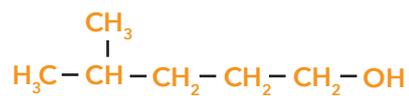
xvi.



xvii.



xviii.



---

### 3. Isomers and Structure

#### Primary, Secondary, Tertiary Structure

a.

Primary, secondary and tertiary refer to the number of carbons bonded to a carbon that has a functional group bonded to it. These functional groups can be things like halogens, an alcohol or an amine.

If the carbon that a functional group is attached to one carbon it is called primary, if it is attached to two carbons it is called secondary and if it is attached to three carbons it is called tertiary.

b.

Name the functional group circled in the following organic compounds, state whether they are primary, secondary or tertiary and explain why.

i.

The haloalkane is tertiary because the carbon is attached to 3 other carbons.

ii.

The alcohol is secondary because the carbon it is bonded to is attached to 2 other carbon.

iii.

This is a primary amine.

iv.

This is a primary alcohol.

v.

Carboxylic acids are always primary.

vi.

This haloalkane is secondary.

vii.

This is a tertiary alcohol.

viii.

The methyl group is secondary.

ix.

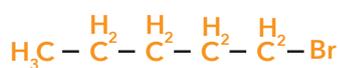
The haloalkane is primary.

## Structural Isomers

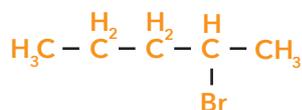
a.

Two molecules that have the same chemical formula but different structural formulas are isomers of each other.

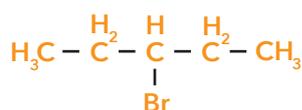
b.



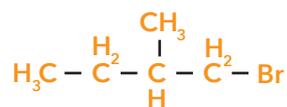
1-bromopentane



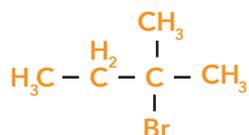
2-bromopentane



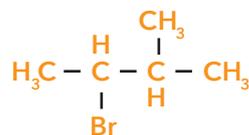
3-bromopentane



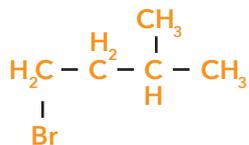
1-bromo-2-methylbutane



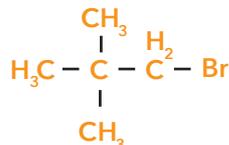
2-bromo-2-methylbutane



2-bromo-3-methylbutane

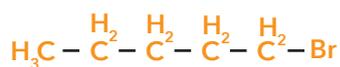


1-bromo-3-methylbutane



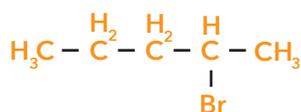
1-bromo-2,2-dimethylpropane

c.



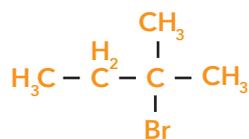
1-bromopentane

Primary



2-bromopentane

Secondary



2-bromo-2-methylbutane

Tertiary

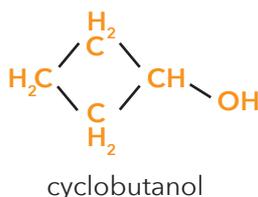
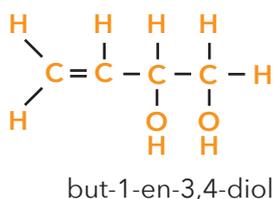
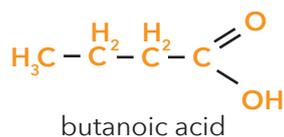
d.

In 1-bromopentane the bromine is bonded to carbon atom that is only bonded to one other carbon atom hence it is a primary bromoalkane.

For 2-bromopentane, the carbon bonded to the bromine is bonded to two other carbons which makes it a secondary bromoalkane.

For 2-bromo-2-methylpentane the carbon bonded to the bromine is bonded to three other carbons which makes it a tertiary bromoalkane.

e.



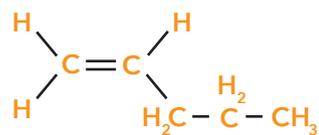
Other isomers of but-3-en-1-ol and butanoic acid are also acceptable.

### Geometric Isomers

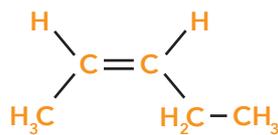
f.

- A molecule must have a carbon-carbon double bond.
- The carbons on either side of the double bond must have two different groups attached to them.
- There must be one group that is common to both sides of the double bond.

g.



pent-1-ene



pent-2-ene

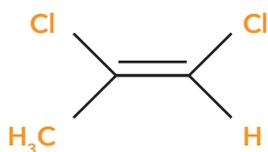
In order for a compound to exist as cis/trans isomers:

- A molecule must have a carbon-carbon double bond.
- The carbons on either side of the double bond must have two different groups attached to them.
- There must be one group that is common to both sides of the double bond.

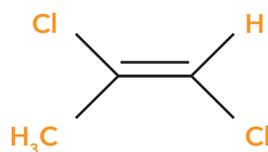
Pent-1-ene has two hydrogens bonded to the first carbon and so it breaks rule number 2 and therefore cannot exist as cis/trans isomers.

Pent-2-ene, on the other hand, meets all three requirements. It has a carbon-carbon double bond, the carbons on either side of the double bond have two different groups attached to them ( $\text{CH}_3$  and H, and H and  $\text{CH}_2\text{CH}_3$ ) and there is a group that is common to both sides of the double bond (an H is bonded to both carbons). Therefore, pent-2-ene can exist as cis/trans isomers.

h.

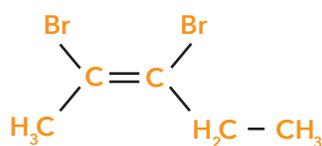


Cis

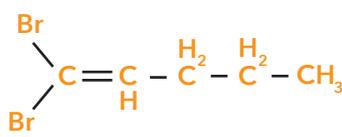


Trans

i.



2,3-dibromopent-2-ene



1,1-dibromopent-1-ene

There are many possible answers to this. The main thing is that to exist as a geometric isomer they must meet all three conditions.

---

## 4. Organic Reactions

a.

Addition, elimination, oxidation, and substitution.

b.

Alkenes and alkynes (although only alkenes really come up in Level 2).

c.

Primary alcohols can be oxidised to carboxylic acids by acidified potassium permanganate ( $\text{H}^+/\text{KMnO}_4^-$ ) or acidified potassium dichromate ( $\text{H}^+/\text{Cr}_2\text{O}_7^{2-}$ ).

Alkenes are oxidised by potassium permanganate to diols.

d.

Alcoholic KOH reacts with haloalkanes.

Concentrated sulfuric acid reacts with alcohols.

e.

Substitution is a swapping reaction where one functional group is swapped for another.

E.g. Methanol reacting with  $\text{PCl}_5$  to become chloromethane. The OH group in the methanol is being swapped out for a Cl group.

f.

i.

This is a substitution reaction. In this reaction, the C-Cl bond in the reactant is broken and a C-OH bond is formed. The Cl and OH have swapped places so this is a substitution reaction.

ii.

This is an addition reaction. The carbon-carbon double bond is being broken. An OH group is being put on one side of the double bond, forming a C-O bond and an H is being put on the other side making a C-H bond.

iii.

This is a substitution reaction. The C-Cl bond is being broken and a C-N bond is being formed. The Cl is being replaced by an  $\text{NH}_2$  group.

iv.

This is an oxidation reaction. To begin with, there is only one bond to oxygen in the molecule however after oxidation more bonds to oxygen are made, ending with 3 bonds to oxygen in the final product. (A double bonded O and a single bonded OH group).

v.

This is an addition reaction where the carbon-carbon double bond is broken and two new C-H bonds are formed on either side of where the double bond used to be.

vi. This is an elimination reaction. The C-Cl bond is being broken and an H is being taken from the next door carbon, breaking a C-H bond. A carbon-carbon double bond is then formed between those two carbons.

vii. This is also an elimination reaction. In this reaction, a C-O bond is being broken and the OH group removed. A C-H bond is being broken as an H is removed from the carbon next door to the OH group. A carbon-carbon double bond is then formed between the two carbon atoms.

viii. This is a substitution reaction. The C-O bond is being broken removing the OH group. A C-Cl bond is being formed in its place resulting in a substitution reaction.

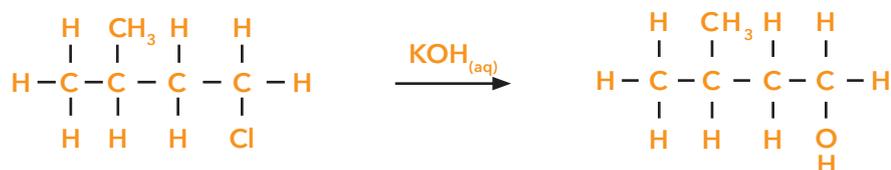
g. Draw the organic products of the following organic reactions and state the type of reaction occurring.

i.



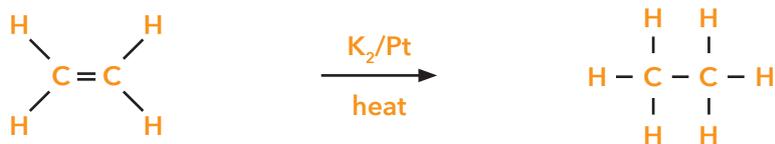
Reaction Type: Substitution.

ii.



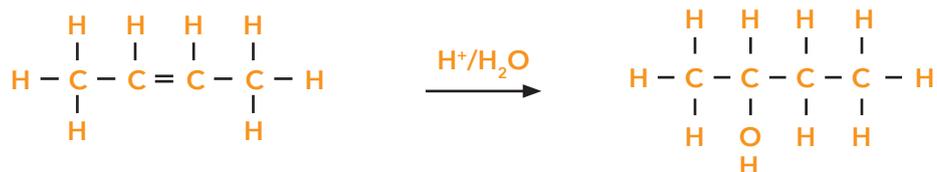
Reaction Type: Substitution.

iii.



Reaction Type: Addition.

iv.



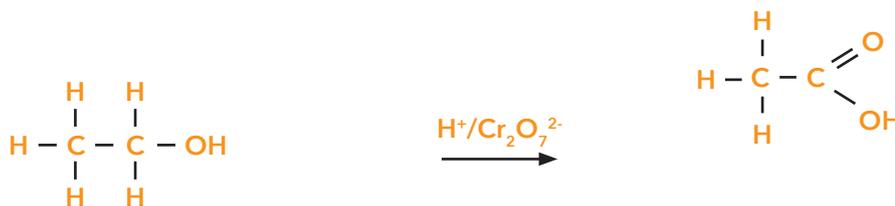
Reaction Type: Addition.

v.



Reaction Type: Addition.

vi.



Reaction Type: Oxidation.

vii.



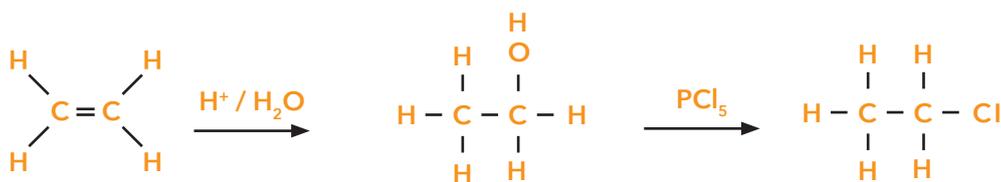
Reaction Type: Substitution.

viii.



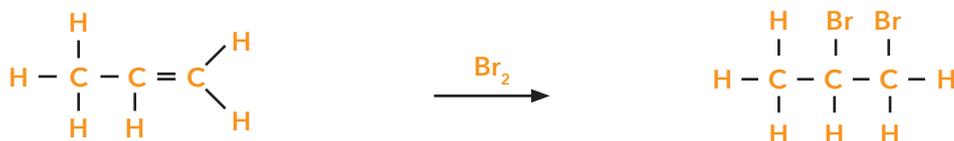
Reaction Type: Elimination.

ix.



Reaction Type: Addition and then substitution.

x.



Reaction Type: Addition.

## Major and Minor Products of Reactions

h.

The two reactions are addition and elimination reactions. An addition reaction is where an atom is added to either side of a C=C of an asymmetrical alkene, and elimination reactions to form a double bond.

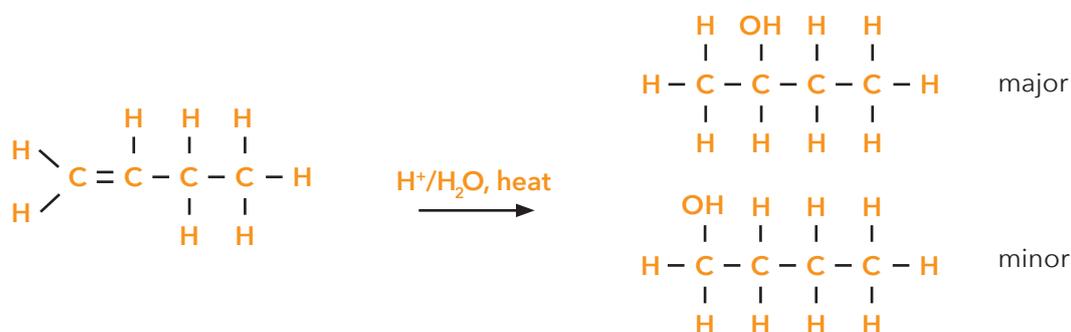
i.

or an addition reaction, such as an alcohol to an alkene, the new functional group can be bonded in two different places if the molecule is not symmetrical. This results in two different products referred to as the major and the minor.

i.

The rule that applies to addition reactions is Markovnikov's rule, which states that the major product formed is the one where the carbon with the most hydrogens attached gets the extra hydrogen, while the other carbon gets the new substituent (e.g. the halogen or alcohol).

ii.



In the addition reaction of but-1-ene with acidified water, the hydroxyl group can be added to either carbon when the double bond is broken. The one that the hydroxyl is added to in the major product is the one with the least number of hydrogens in the reactant (the second carbon). This is because the molecule is asymmetrical.

iii.



In the addition reaction of but-2-ene with HBr, the bromine can be added to either carbon in the double bond. However, the molecule is symmetrical, and the number of hydrogens on each carbon atom is the same. Therefore both products are identical, leading to only one product.

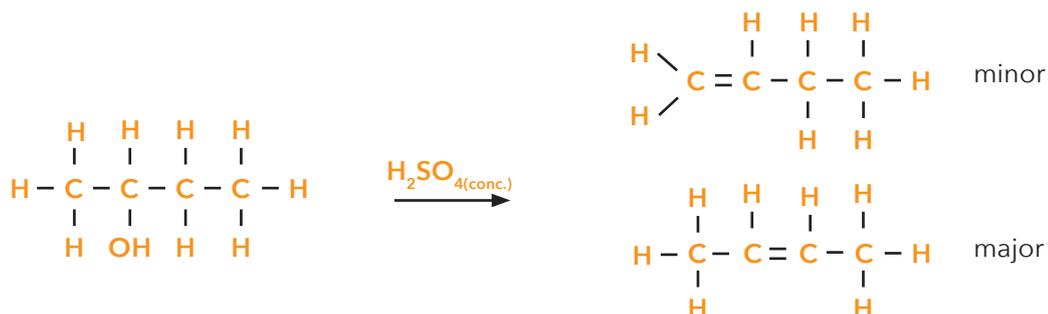
j.

For an elimination reaction, such as an alcohol to an alkene, the double bond can be made in two different places if the molecule is asymmetrical. This results in a major and minor product.

i.

The rule that applies to elimination reactions is the reverse Markovnikov's rule, or Saytzeff's/Zaitsev's/Saytzev's rule (Russian names are hard, and you don't actually have to name the rule, just explain it). This is where the carbon that initially has the least number of hydrogens attached to it has the hydrogen removed in the elimination reaction.

ii.



In the elimination reaction of butan-2-ol with concentrated  $\text{H}_2\text{SO}_4$  the double bond can be formed on either side of the carbon attached to the hydroxyl group. The major product formed is where the double bond forms between the carbon that had the least number of hydrogens attached to it in the reactant. The products are different because the molecule is symmetrical.

iii.



In the elimination reaction of propan-2-ol with concentrated  $\text{H}_2\text{SO}_4$  the double bond can form on either side of the carbon attached to the hydroxyl group. However, the molecule is symmetrical so the products are identical.

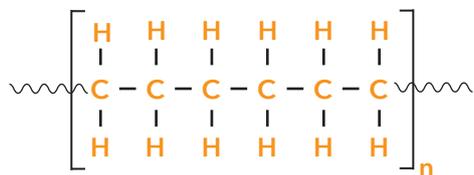
## 5. Polymers

a.

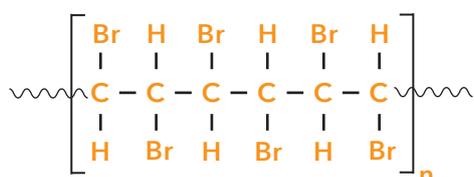
A molecule made up of many repeating units.

b.

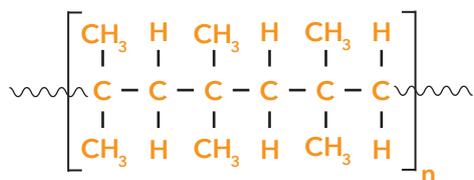
i.



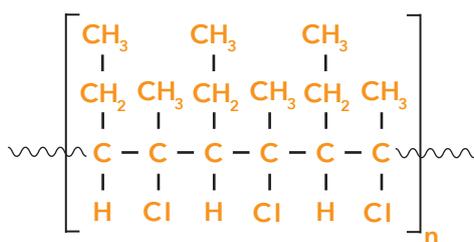
ii.



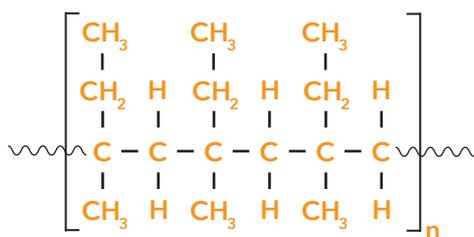
iii.



iv.

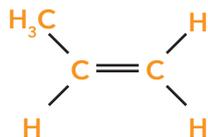


v.

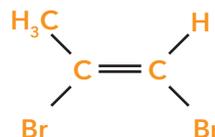


c.

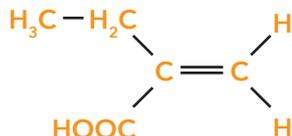
i.



ii.



iii.



---

## 6. Properties of Functional Groups

### Acids and Bases

a.

If you are doing chemical reactivity you would have learnt that acids are proton donors, this is totally fine to use here however for organic chemistry you are still allowed to use "reacts in water to release H<sup>+</sup> ions" both would be accepted for this paper.

b.

Carboxylic acids.

c.

If you are doing chemical reactivity you would have learnt that bases are proton acceptors, this is totally fine to use here however for organic chemistry you are still allowed to use "reacts in water to release OH<sup>-</sup> ions" both would be accepted for this paper.

d.

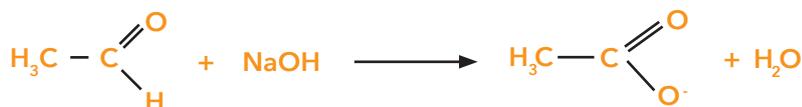
Amines.

e.

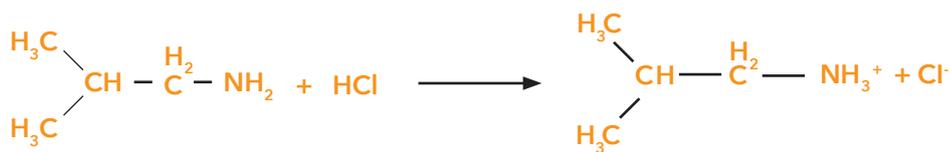
The amine will turn red litmus paper blue. The carboxylic acid will turn blue litmus paper red. The alkane will not change either the red or blue litmus paper, because it is neutral.

f.

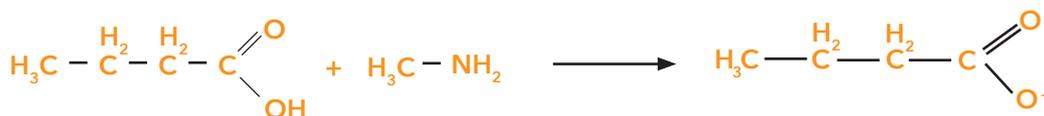
i.



ii.



iii.



You will remember from level 1 that an acid-base reaction is where we form a salt, which for i. is ethanoate ion (which could then form a salt with the  $\text{Na}^+$  but you are not required to draw this) and water.

When an amine reacts with HCl, it accepts the proton from HCl, which leaves behind a chloride ion.

When a carboxylic acid reacts with an amine, the carboxylic acid donates a proton, leaving a carboxylate ion and the amine accepts this proton, forming the amine ion.

### Boiling Point and Melting Point

g.

The melting point will increase, as will the boiling point.

i.

The number of carbons influences the intermolecular forces between molecules of a substance, with more carbon atoms the intermolecular forces are higher. This means that more heat energy is required to overcome them to melt/boil the substance.

ii.

Butane will have a lower melting point. It has fewer carbons, it is a smaller molecule.

### Polarity and Solubility

h.

Polarity is the property of molecules to have a permanent dipole (where electrons are found more often on one side of the compound). This gives the molecule a slight positive ( $\delta^+$ ) and slight negative ( $\delta^-$ ) charge. It is due to the difference in electronegativity between atoms in a bond.

One example of a polar compound is  $\text{H}_2\text{O}$ . An example of a nonpolar compound is cyclohexane. (Any alkane with no other functional groups is also non-polar).

i.

Molecule	Structure	Polarity
Methanol	$\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{OH} \\   \\ \text{H} \end{array}$	Polar
Propanoic acid	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{O} \\   \quad   \quad // \\ \text{H}-\text{C}-\text{C}-\text{C} \\   \quad   \quad \backslash \\ \text{H} \quad \text{H} \quad \text{OH} \end{array}$	Polar
Octan-1-ol	$\begin{array}{cccccccc} \text{H} & \text{H} \\   &   &   &   &   &   &   &   \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{OH} \\   &   &   &   &   &   &   &   \\ \text{H} & \text{H} \end{array}$	Non-polar
Hex-1-ene	$\begin{array}{ccccccc} \text{H} & & \text{H} & \text{H} & \text{H} & \text{H} & \\ & \backslash & / &   &   &   &   \\ & \text{C}=\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{H} \\ & / &   &   &   &   & \\ \text{H} & & \text{H} & \text{H} & \text{H} & \text{H} & \end{array}$	Non-polar
1,2-diaminoethane	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}_2\text{N}-\text{C}-\text{C}-\text{NH}_2 \\   \quad   \\ \text{H} \quad \text{H} \end{array}$	Polar
1-chloroethane	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{C}-\text{Cl} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$	Polar
Propan-1,3-diol	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\   \quad   \quad   \\ \text{HO}-\text{C}-\text{C}-\text{C}-\text{OH} \\   \quad   \quad   \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$	Non-polar
Nonane	$\begin{array}{cccccccc} \text{H} & \text{H} \\   &   &   &   &   &   &   &   \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\   &   &   &   &   &   &   &   \\ \text{H} & \text{H} \end{array}$	Non-polar
Heptanoic acid	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{O} \\   \quad   \quad   \quad   \quad   \quad   \quad // \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C} \\   \quad   \quad   \quad   \quad   \quad   \quad \backslash \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{OH} \end{array}$	Polar
Ethyne	$\text{H}-\text{C} \equiv \text{C}-\text{H}$	Non-polar

j.

The rule is 'like dissolves like', this means that polar compounds will only readily dissolve in polar solvents and non-polar compounds will only readily dissolve in non-polar solvents.

k.

i.

Polar

ii.

Non-polar

iii.

Nonpolar

iv.

Polar because it has a short carbon chain

v.

Nonpolar

l.

You would see two layers forming since water is a polar solvent and 'like dissolves like' (polar compounds dissolve in polar solvents).



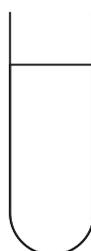
m.

Again you would see two layers as polar compounds only dissolve in polar solvents.



n.

You would only see one layer, the two compounds would mix since you are adding a polar compound to water which is a polar solvent.



# Section Two

## Problem Solving & Mixed Practice

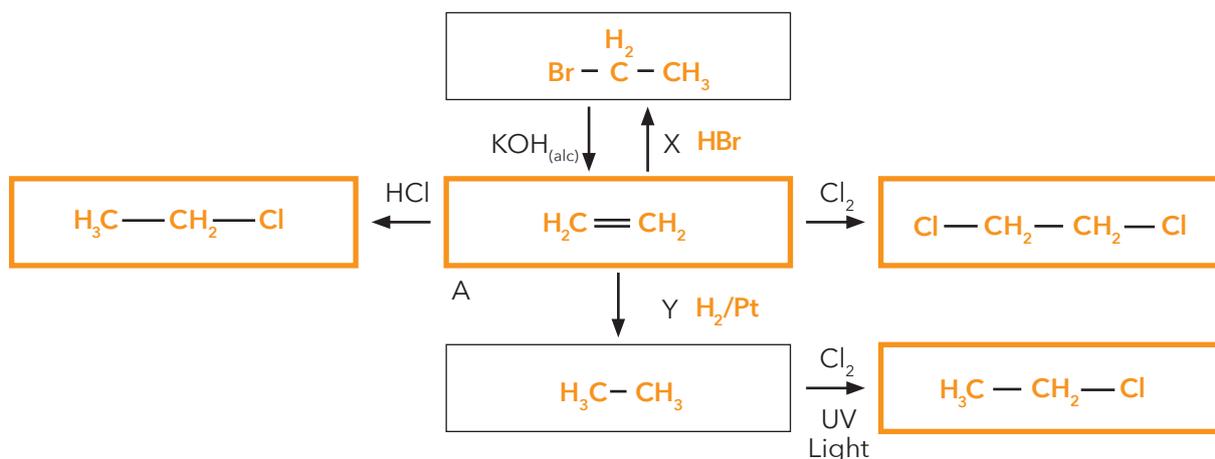
After mastering the basics of organic chemistry, the next step is to start applying that knowledge to exam problems. You are expected to bring together your understanding to answer questions and explain your reasoning. It can be difficult to approach these problems and know where to start so we have done some of that work for you. We've written exam-type problems and broken them up into the individual problem-solving steps that would be required to solve them in the exam.

With your understanding, you should be able to put it all together and answer the questions fully. Make sure you are asking yourself how we came up with these questions, they are the kinds of questions you should be asking yourself in the exam. If you get stuck with a problem, make sure to go back to earlier sections, or refer to the Walkthrough Guide before looking at the answers.

Some of the questions we've written are pretty tricky, but will be extremely useful for your learning, so make sure you push yourself!

## 1. Organic Reactions

a.



b.

i.

It is an addition reaction. The carbon-carbon double bond in the ethene molecule breaks and becomes a carbon-carbon single bond. The  $\text{Cl}-\text{Cl}$  bond in  $\text{Cl}_2$  also breaks to generate two  $\text{Cl}$  atoms. Each of these then bond with carbon atom (making two separate  $\text{C}-\text{Cl}$  bonds) to replace the bond that was lost by the double bond-breaking this results in the product 1,2-dichloroethane.

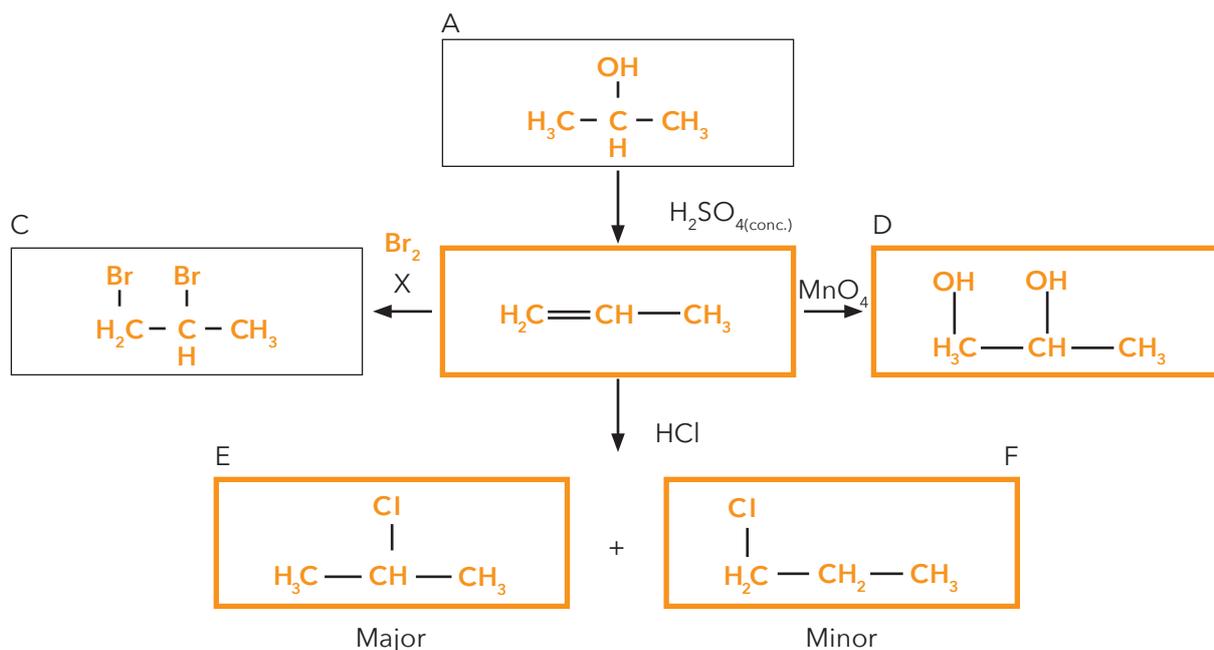
ii.

This is a substitution reaction. One of the  $\text{C}-\text{H}$  bonds is being broken as well as the  $\text{Cl}-\text{Cl}$  bond. A  $\text{C}-\text{Cl}$  bond is then formed as well as an  $\text{H}-\text{Cl}$  bond. This leads to the product chloroethane.

iii.

There is not enough energy to get the reaction started, we need to input energy (in the form of  $\text{UV}$  light) to give the molecules enough energy to get over the activation energy barrier and react.

c. Use the following questions to fill out the organic reaction scheme.



i.

The reaction of propan-2-ol is with concentrated sulfuric acid which we identify as an elimination reaction. This produces a carbon-carbon double bond between the carbon that has the OH group and one of its next door carbons. In this example, there is only one product possible and so prop-1-ene is the central product.

ii.

Reagent X Must contain 2 Br atoms as that is the only thing different between the chemical formula of prop-1-ene and the 1,2,dibromopropane, therefore reagent X is  $\text{Br}_2$ .

iii.

The  $\text{MnO}_4^-$  reaction with prop-1-ene produces a diol, this is an oxidation reaction but it is one of the ones we really just need to know rather than being able to work it out, that leads to that product being propan-1,2-diol.

iv.

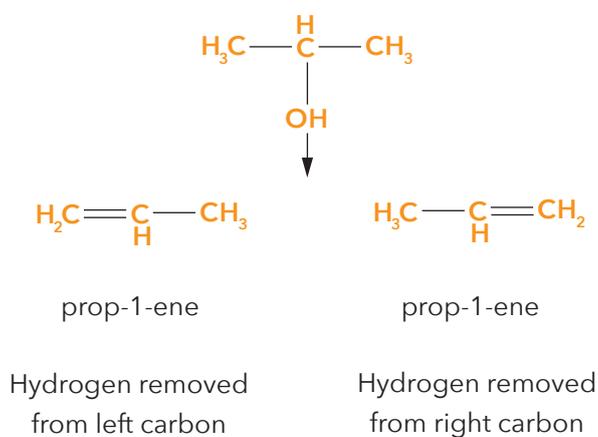
Markovnikoff's rule (Markovnikov's rule is also an acceptable spelling). In an addition reaction, the carbon with the most hydrogens preferentially gets the hydrogen. This is the major product. The minor product is formed when the carbon with the least hydrogens gets the hydrogen in an addition reaction.

v.

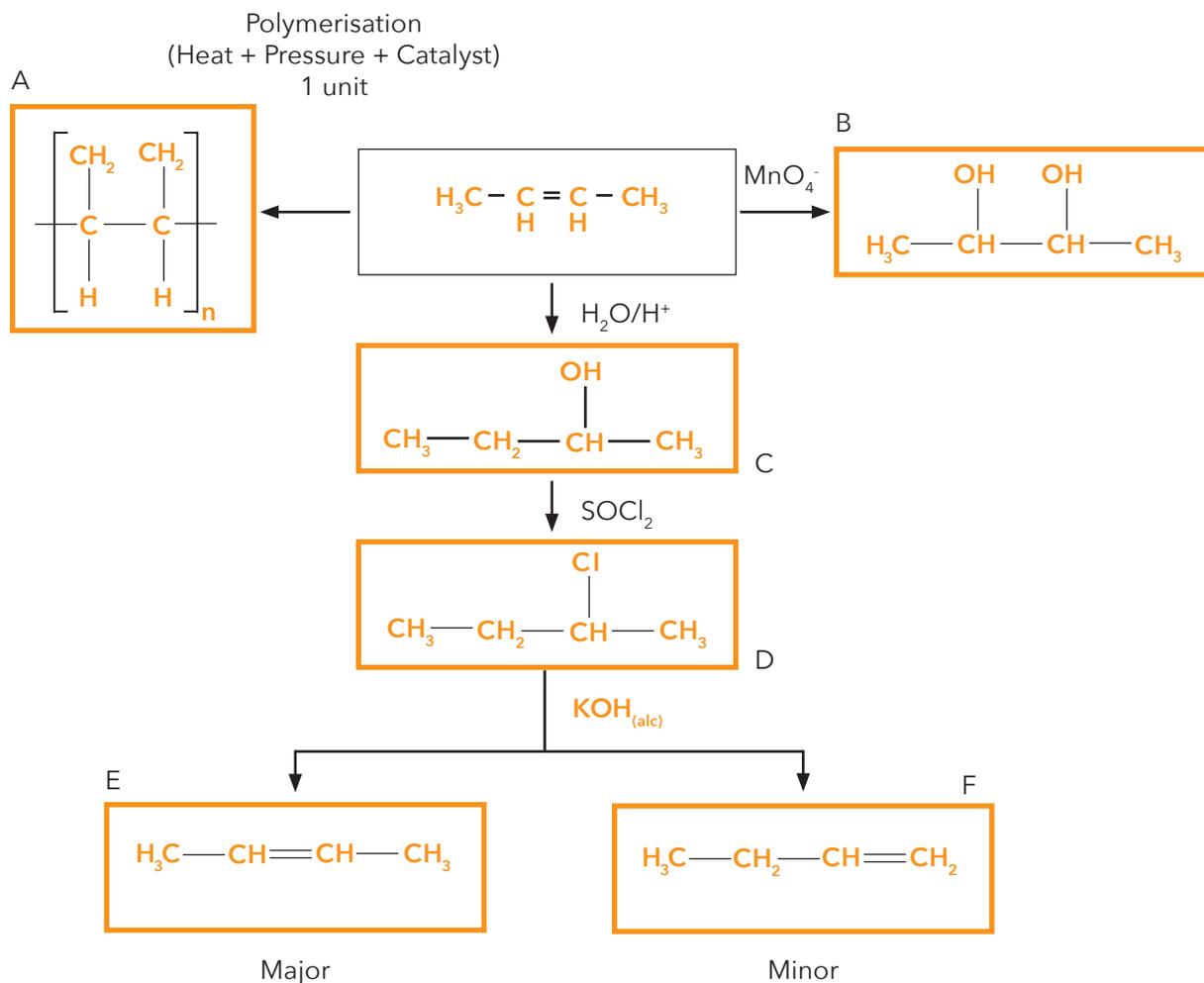
The final reaction of prop-1-ene with HCl produces major and minor products. In this case, we are told which box to put the major product in and which to put the minor product in. It might be helpful to draw the two products out off to the side and then try and match them up. The two possible products of this addition reaction are when the H from the HCl goes on the end and Cl from the HCl in the middle, and when the Cl from the HCl goes on the end and when the H from the HCl goes in the middle. This gives our two products 1-chloropropane and 2-chloropropane. 1-chloropropane is the minor product (because the carbon with the least H's in prop-1-ene got the H) and so 2-chloropropane is the major product (because the carbon with the most H's got the H).

vi.

The OH group is removed and an H is removed from a next door carbon. It does not matter which carbon they hydrogen is removed from as the product is the same in both cases prop-1-ene.



d.



i.

Starting with the polymerisation, we can redraw but-2-ene in a similar way to what we did in the polymers section. Then we can break that double bond (since it is addition polymerisation) and show the repeating units as shown.

ii.

The reaction of but-2-ene with  $\text{MnO}_4^-$  is an oxidation reaction (we can tell because we are using an oxidising agent). This is one of the ones it's hard to work out logically but we know it is going to involve oxygens in some way.

iii.

The reaction of  $\text{MnO}_4^-$  with alkenes produces diols with an OH group on either side of the double bond which gets broken in the reaction. This leads to the product of butan-2,3-diol.

iv.

The reaction of but-2-ene with acidified water ( $\text{H}_2\text{O}/\text{H}^+$ ) is going to be an addition reaction since we are reacting an alkene. The double bond is going to be broken and something is going to be put on each of those carbons. Looking at the reagent, the pieces we have to play with are OH and H.

v.

It doesn't matter where we put the OH and where we put the H as in both cases we get butan-2-ol (try this out for yourself if you haven't already!) But-2-ene is symmetrical and therefore regardless of where the OH groups end up we have the same compound.

vi.

We are then reacting product C, butan-2-ol with  $\text{SOCl}_2$ . This is going to be a substitution reaction as it is the only real option we have in this case. Looking at  $\text{SOCl}_2$  the most logical thing to replace our OH group with is one of those chlorine atoms. Therefore we can deduce the product would be 2-chlorobutane.

vii.

We don't have too many clues about the next one because we don't know the reagent or product. All we see is that there are 2 possible products from the same reaction. Looking at all of our options (addition elimination substitution and oxidation) only addition and elimination reactions can produce two possible products. The molecule we are reacting is not an alkene therefore it is not an addition reaction. Therefore there must be an elimination reaction taking place!

viii.

It is  $\text{KOH}_{(\text{alc})}$ . The molecule we are eliminating is a haloalkane and so we are going to need some alcoholic KOH ( $\text{KOH}_{(\text{alc})}$ ) as our reagent. We are going to lose the Cl and one hydrogen from a next door carbon and form a carbon-carbon double bond between them.

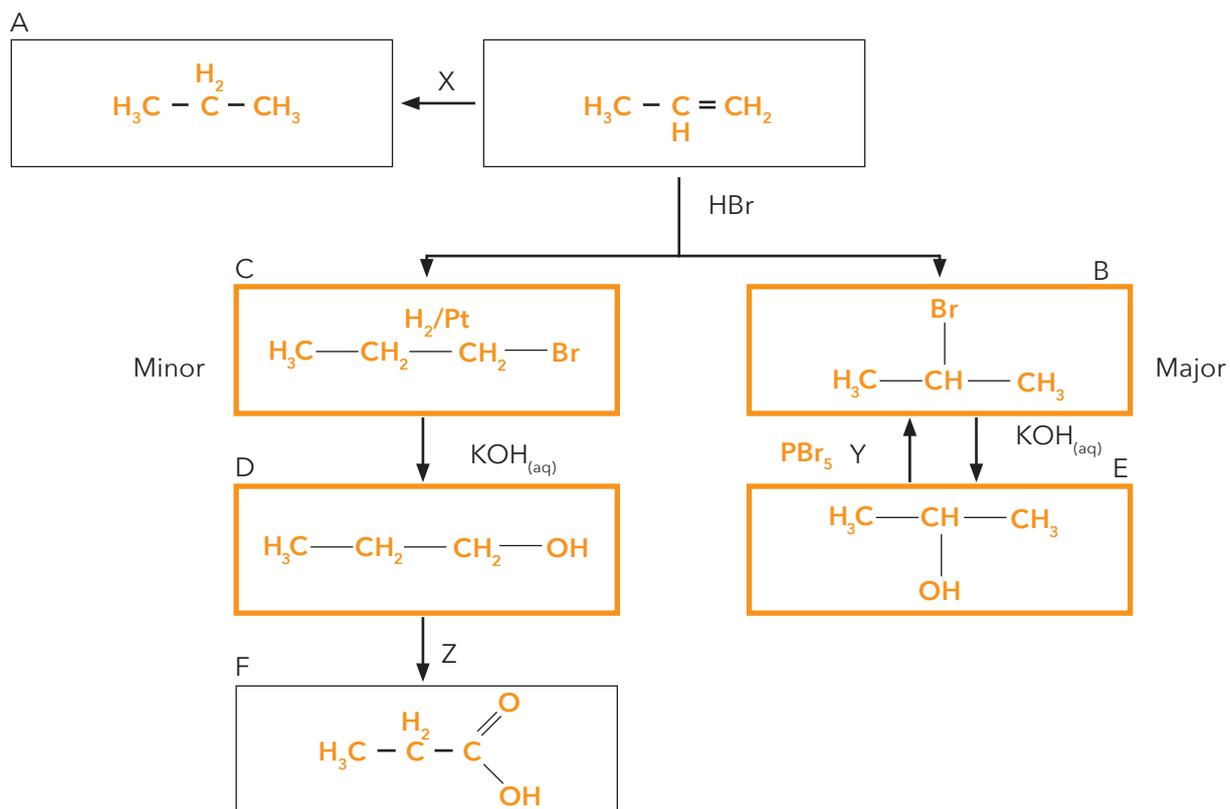
ix.

Saytseff's rule OR Zaitsev's rule OR Zaitseff's rule or Saytsev's rule. Spell it however you want honestly. Calling it reverse-Markovnikoffs is also fine too since they are basically the same rule but opposites.

x.

Saytseff's rule states that in an elimination reaction the carbon with the least number of hydrogens preferentially loses the hydrogen. See explanation above.

e.



i.

The reaction of the prop-1-ene with reagent X is an addition reaction since our double bond is being broken. We need to add two H atoms during the course of this reaction (one to each side of the double bond) and so our reagent is going to be  $\text{H}_2/\text{Pt}$  or  $\text{H}_2/\text{Pd}$ , we need to remember to add some sort of catalyst or else it will not be marked correct.

ii.

Markovnikov's rule states that the carbon with the most hydrogens preferentially gets the hydrogen in an addition reaction to make the major product. Therefore our major product is 2-bromopropane and the minor is 1-bromopropane.

iii.

For the reaction of the major product (2-bromopropane) with aqueous KOH, this is going to be a substitution reaction where the Br on the 2-bromopropane is going to be substituted with the OH from the KOH, this leads to propan-2-ol as the product.

iv.

In order to go back from propan-2-ol to 2-bromopropane, we need to do another substitution reaction, reagent X must involve bromine in some respect and  $\text{PBr}_3$ ,  $\text{PBr}_5$  or HBr are all acceptable answers here.  $\text{Br}_2$  is not acceptable here as it only performs substitutions on C-H bonds and only in the presence of UV light.

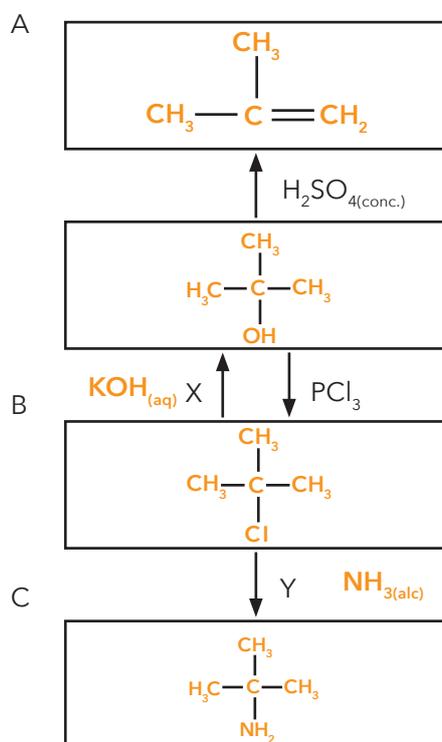
v.

The reaction of the minor product (1-bromopropane) with aqueous KOH will be similar to the reaction of the 2-bromopropane. It will be a substitution reaction swapping the Br for an OH making propan-1-ol as the product.

vi.

The final reaction takes this propan-1-ol and turns it into a carboxylic acid. This is an oxidation reaction since more bonds to oxygen are being added. You can use either  $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$  or  $\text{MnO}_4^-/\text{H}^+$  in for reagent Y but if you do not write the  $/\text{H}^+$  it might not be marked correct.

f.



i.

First, the reaction of 2-methylpropan-2-ol with concentrated  $\text{H}_2\text{SO}_4$  is an elimination reaction since concentrated  $\text{H}_2\text{SO}_4$  is one of the two eliminating reagents. This will take away the OH and a hydrogen from a next door carbon and form a carbon-carbon double bond between them. In this case, there is one product, 2-methylprop-2-ene (you may want to draw out a few different possibilities and name them to see if they really are the same).

ii.

Then the reaction of 2-methylpropan-2-ol with  $\text{PCl}_3$  will be a substitution reaction where a Cl is swapped on to the 2-methylpropan-2-ol in place of the OH. This leaves us with 2-chloro-2-methylpropane in this spot.

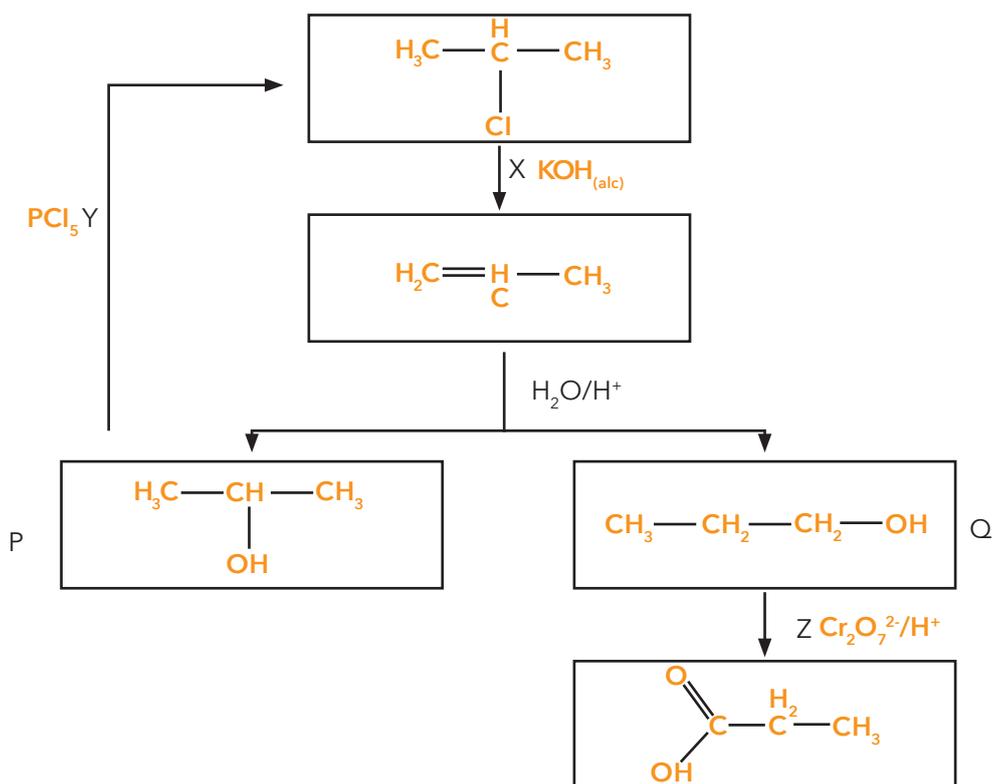
iii.

To move back to 2-methylpropan-2-ol from 2-chloro-2-methylpropane we need to do another substitution reaction which is done in this case with aqueous KOH (because we need something with an OH to put on there) so that is what reagent X is.

iv.

Lastly, reagent Y converts 2-chloro-2-methylpropane to 2-amino-2-methylpropane again this is a substitution reaction where the Cl is being swapped out for an  $\text{NH}_2$  group. This is done with  $\text{NH}_3$  (because we need something with at least  $\text{NH}_2$  and  $\text{NH}_3$  is the closest thing) we might like to specify that this is concentrated or alcoholic but they don't mind that too much at level 2.

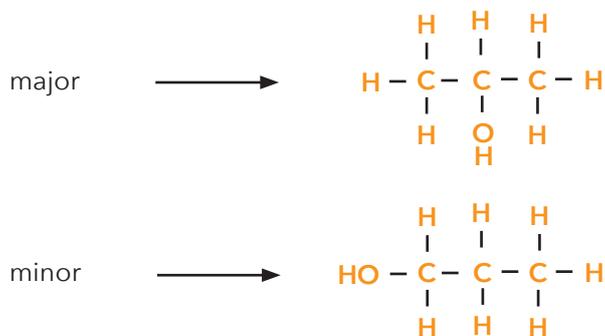
g.



i.

We can fill in reagent X to begin with we are forming a carbon-carbon double bond which means an elimination reaction is taking place. Since we are going from a haloalkane, it means that the reagent with need is alcoholic KOH ( $\text{KOH}_{(\text{alc})}$ ).

ii.



The crux of this scheme is really which of P and Q are the major and minor products in the addition reaction of propene with acidified water. As always it might be a good idea to write the two possible products of this reaction off to the side so we know what options we have, in this case, we have propan-2-ol and propan-1-ol.

iii.

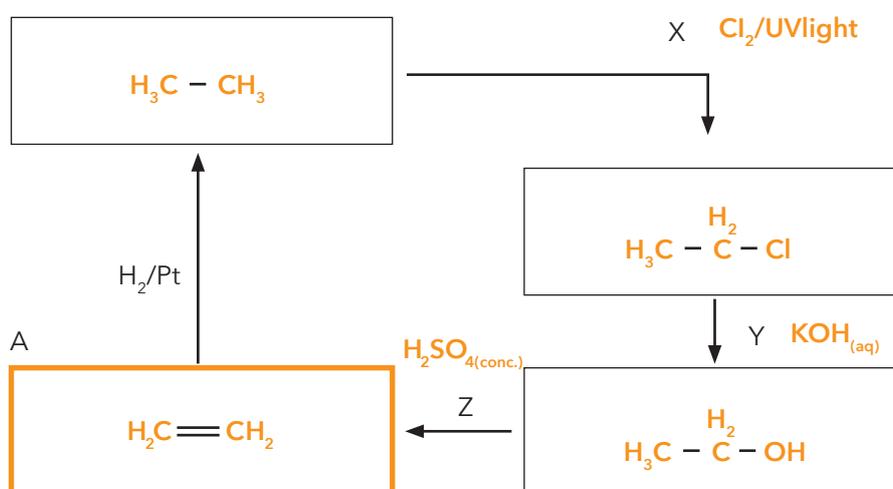
Looking at the carboxylic acid down the bottom of the scheme. We only know one way to make carboxylic acids, that is by oxidation so we know that you can use either  $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$  or  $\text{MnO}_4^-/\text{H}^+$  in for reagent Z. But we also might realise that the starting material for these reactions can only be a primary alcohol. Therefore we can deduce that Q must be a primary alcohol, in this case, it must be propan-1-ol. That means that P must be propan-2-ol.

iv.

Looking at the reaction that turns P into 2-chloropropane, we can deduce that this is a substitution reaction. We know that P is definitely an alcohol and swapping out the OH group with a Cl would give us a haloalkane. We also know that in the course of a substitution reaction, the position of the functional group does not change. If the product has a functional group on the 2 carbon, then the starting material must have had its functional group on the 2 carbon. Therefore we can deduce that P is propan-2-ol which means that Q must be propan-1-ol.

After that, we just need to figure out what reagent Y is which needs to have some Cl's in it so  $\text{PCl}_3$   $\text{PCl}_5$  or  $\text{HCl}$  are all acceptable answers here.  $\text{Cl}_2$  is not acceptable here as it only performs substitutions on C-H bonds and only in the presence of UV light.

h.



i.

Starting with reagent X we see a substitution reaction is taking place where one H is being swapped for a Cl. The only time we can substitute an H is by doing a reaction with a halogen ( $\text{Br}_2$  or  $\text{Cl}_2$ ) in the presence of UV light, we need to put a Cl on in this case so reagent X will be  $\text{Cl}_2 / \text{UV light}$  (no UV light no marks).

ii.

Then there is another substitution reaction taking the chloroethane and making ethanol. Y will need some OH's and aqueous KOH is the reagent we need here.

iii.

Last bit is a bit trickier, we need to do something with ethanol that makes something we can then react with  $\text{H}_2/\text{Pt}$ . The only context in which we have seen  $\text{H}_2/\text{Pt}$  is addition reactions with alkenes where the carbon-carbon double bond is broken and 2 hydrogen atoms are added to either side of it. That means the product in the bottom left-hand corner must be an alkene in this case ethene since it only has two carbons in it still.

That means that ethanol undergoes an elimination reaction to make ethene since it makes a carbon-carbon double bond. Out of the two elimination reactions we know we are eliminating an alcohol and so we need concentrated sulfuric acid ( $\text{H}_2\text{SO}_{4(\text{conc.})}$ ).

## 2. Identification Tests

a.

i.

Litmus paper. If you added blue litmus paper to both the butanoic acid would change the litmus paper red and the 1-aminobutane would leave the blue litmus unchanged. Alternatively, add red litmus paper to both, the 1-aminobutane would change the red litmus paper blue and the butanoic acid would not change the red litmus paper.

Alternatively:

Add some  $\text{NaHCO}_3$  this will react with the butanoic acid to produce  $\text{CO}_2$  gas which is seen as bubbles in the solution. No reaction will be observed with 1-aminobutane.

ii.

Add bromine water to both. The hex-1-ene is an alkene and so will undergo a rapid addition reaction with the bromine and turn it from orangey-brown to colourless quickly. The hexane is an alkane and so will only react with bromine water when it is exposed to UV light (at which point it will decolourise it from orange brown to colourless).

Alternatively,

Add  $\text{MnO}_4^-$  to both. The hex-1-ene which is an alkene can be oxidised to a diol by the  $\text{MnO}_4^-$ . This will be accompanied by a change in colour from purple to colourless (or brown in this case) no reaction will be observed when permanganate is added to hexane as it is an alkane

iii.

Add acidified dichromate to both solutions. The propan-1-ol will oxidise to a carboxylic acid since it is a primary alcohol. The colour change observed during this reaction will be orange to green. Since 2-methylpropan-2-ol is a tertiary alcohol it will not be oxidised so it will stay orange.

Alternatively,

Add acidified permanganate to both solutions. The propan-1-ol will oxidise to a carboxylic acid since it is a primary alcohol. The colour change observed during this reaction will be purple to colourless. Since 2-methylpropan-2-ol is a tertiary alcohol it will not be oxidised so it will stay purple.

iv.

Since these are both alkanes the chemical reactions they undergo will all be the same as each other. However, you could measure the melting point or boiling point of these two liquids. Since the octane has more carbons its melting point/boiling point will be higher than that of hexane.

v.

Using water. Since propan-1-ol is polar it will dissolve in the water whereas 1-chloropropane will form two layers in the test tube.

Alternatively,

Could also use an oxidant as above for propan-1-ol and 2-methylpropan-2-ol where propan-1-ol will react as above and no reaction would be observed for 1-chloropropane for either reagent.

vi.

Litmus paper. If you added blue litmus paper to both the ethanoic acid would change the litmus paper red and the ethanol would leave the blue litmus unchanged.

Could try oxidation as above for propan-1-ol where the ethanol could be oxidised and the ethanoic acid no change would be observed.

Also could add  $\text{NaHCO}_3$  where ethanoic acid would bubble because  $\text{CO}_2$  would be released but there would be no reaction for ethanol.

vii.

Litmus paper. Adding red litmus to both solutions. The 1-amino propane will turn the red litmus blue and the pent-2-ene will leave it unchanged.

Alternatively,

Bromine water will decolourise rapidly (from orangey brown to colourless) when reacted with pent-2-ene since it is an alkene, but no reaction with 1-aminopropane will be observed.

Alternatively,

React them both with  $\text{MnO}_4^-$ , the alkene will be oxidised to the diol and the colour will change from purple to colourless whereas no reaction will be observed for 1-aminopropane.

viii.

These cannot be told apart on their own using techniques at level two, we have to make some changes.

If we do a reaction with concentrated ammonia, no reaction will happen to hexane but we will substitute the 1-bromopropane and make 1-aminopropane. We will not be able to make any observations however since everything involved is colourless. We would then have to test the leftover solutions with red litmus paper, which will turn blue when reacted with the 1-aminopropane but will remain unchanged when added to the hexane. We can then know which solution was the 1-bromopropane originally.

We could do a similar thing by reacting both solutions with aqueous KOH. This will make propan-1-ol out of the 1-bromopropane and leave the hexane unchanged. Then we can react both of those solutions with acidified dichromate or acidified permanganate. The one with the propan-1-ol will react with the oxidising agent but the hexane will not.

b. Develop a method that could be used to distinguish between the following compounds.

i.

You only have water and a potassium permanganate ( $\text{KMnO}_4$ ) solution available. In your answer, you should include any observations that would be made. You do not need to include any reactions.

First, add water to samples of all of them. Pentane and pent-1-ene will not dissolve and form two layers because they are both non-polar. 1-aminopropane and propan-1-ol will dissolve completely in the water because they are polar.

Take new samples of the two that didn't dissolve in water. Add some potassium permanganate to both of these samples. The one that goes from purple to colourless is the pent-1-ene as it is oxidised to a diol whereas the pentane will remain purple.

Take samples of the other two liquids that did dissolve in water. Add potassium permanganate to these two. The one that goes purple to colourless is the propan-1-ol as it is oxidised to a carboxylic acid. The 1-aminopropane will remain purple.

ii.

First, add water to samples of all of the liquids. 1-bromopropane and hex-2-ene will not dissolve in water and form two layers in the test tube because they are non-polar. The other liquids will all dissolve because they are all polar.

Take new samples of the two non-polar liquids and add bromine water. The one that rapidly decolourises the bromine water from orangey-brown to colourless is the hex-1-ene as it undergoes a rapid addition reaction. The other sample is, therefore, the 1-bromopropane.

To the polar liquids add blue litmus paper. The one that turns the blue litmus paper red is the propanoic acid since it is an acid.

To the remaining polar liquids add red litmus paper, the one that turns the red litmus paper blue is the aminoethane since it is a base.

The remaining polar liquid is therefore ethanol.

iii.

You only have water, acidified potassium dichromate and a solution of sodium carbonate available. In your answer, you should include any observations that would be made. You do not need to include any reactions.

Add water to samples of all the liquids. The ones that are hexan-1-ol and hexane will not dissolve and form two layers because they are non-polar. The others will all dissolve in the water since they are polar.

Take new samples of the non-polar liquids and add acidified potassium dichromate. The one that goes from orange to green is the hexan-1-ol because it is oxidised to a carboxylic acid. The one that remains orange is the hexane.

Next, to fresh samples of the polar liquids, add acidified potassium dichromate. The one that goes from orange to green is the ethanol as it is oxidised to the carboxylic acid. The other two will remain orange since they cannot be oxidised.

To the final two liquids, add the sodium carbonate solution. The ones that fizzes (shows bubbles) is the ethanoic acid because the reaction of an acid with a carbonate produces  $\text{CO}_2$  gas. The final liquid is, therefore, the 2-aminopropane.

# Section Three

# Practice Exam

Now that you have ample amounts of practice, it's time for a practice exam. This section contains a practice exam, similar to what you may see on game day. To get a good idea of timing, it would be a good idea to have a go at completing this within an hour.

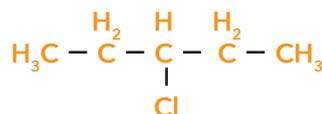
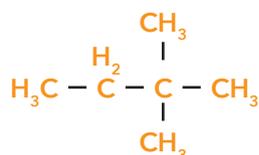
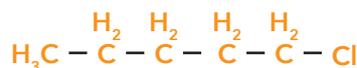
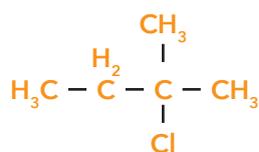
Once you've finished, make sure to mark your work and reflect by writing how you could have improved your answer. It's also a good idea to write down the skills you've found difficult and focus on learning that material.

## Question One

a.

IUPAC (systematic) name	Compound
But-2-ene	$\begin{array}{c} \text{H}_3\text{C}-\text{C}=\text{C}-\text{CH}_3 \\   \quad   \\ \text{H} \quad \text{H} \end{array}$
2-bromo-3-chloropentane	$\begin{array}{c} \text{H}_2 \quad \text{Cl} \quad \text{Br} \\   \quad   \quad   \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{C}-\text{CH}_3 \\   \quad   \\ \text{H} \quad \text{H} \end{array}$
3-methylbutanoic acid	$\begin{array}{c} \text{H} \quad \text{H}_2 \\   \quad   \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{C} \\   \quad \diagup \quad \diagdown \\ \text{CH}_3 \quad \text{O} \quad \text{OH} \end{array}$
3,3-dimethylpentan-2-ol	$\begin{array}{c} \text{CH}_3 \quad \text{OH} \\   \quad   \\ \text{H}_2 \quad \text{H} \\   \quad   \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{C}-\text{CH}_3 \\   \quad   \\ \text{CH}_3 \quad \text{H} \end{array}$

b.



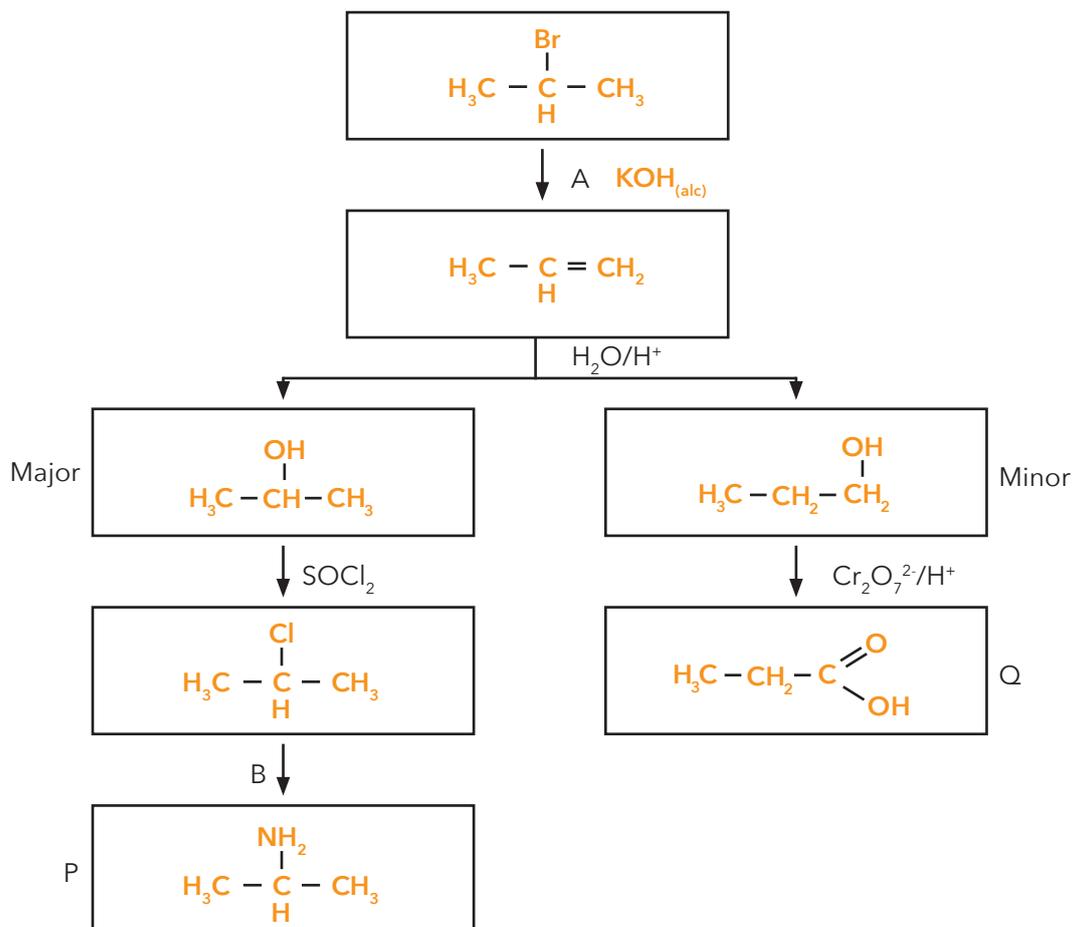
i.

Structural isomers have the same chemical formula but different structural formula. All of the molecules above have the formula  $\text{C}_5\text{H}_{11}\text{Cl}$  but the arrangement of the atoms are different and thus they have different names.



## Question Two

a.



b.

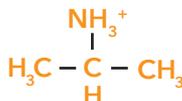
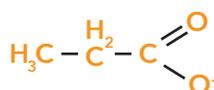
This is an elimination reaction. The carbon-bromine bond is broken as is a C-H bond from a next door carbon. HBr is therefore eliminated from the compound. A carbon-carbon double bond is also formed between the two carbon that had groups removed from them.

c.

By adding sodium carbonate to each solution, the one that was product Q would start fizzing due to the fact that it is a carboxylic acid and so is acidic. When an acid reacts with a carbonate, the neutralisation reaction releases  $\text{CO}_2$  which would be observed as fizzing. Product P would not react with the sodium carbonate since it is an amine and is therefore basic.

d.

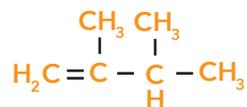
This reaction is a neutralisation reaction (acid-base reaction also acceptable) which is a proton transfer reaction. Protons ( $\text{H}^+$  ions) are released from carboxylic acid (Q) which leave behind a  $-\text{COO}^-$  group, these protons ( $\text{H}^+$  ions) are then accepted by the base (product P) and the  $-\text{NH}_2$  group becomes an  $-\text{NH}_3^+$  group.



## Question Three

a. i.

The reaction that is occurring is an addition reaction. The structure of 2,3-dimethylbut-1-ene is:



The two possible products are:

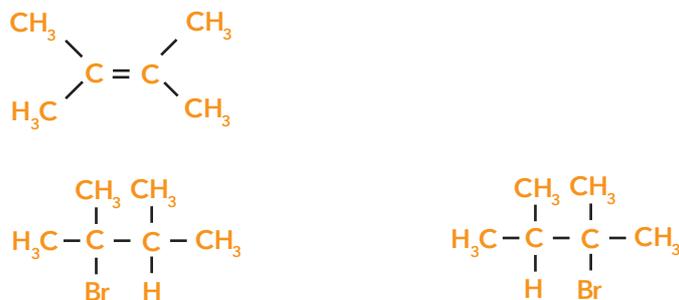


During an addition reaction the carbon-carbon double bond breaks. In this instance, HBr is added across this double bond. An H atom will go to one side of the double bond and a Br will go on the other side. There are two possible ways in which this could occur, as shown above, one where the H goes on the end and the Br on the second carbon and one where the Br goes in the end carbon and the H goes on the second carbon.

The first option (2-bromo-2,3-dimethylbutane) will be produced in greater amounts because of Markovnikoff's rule. This states that in addition, the carbon with the most hydrogens preferentially gets the hydrogen. Before the reaction, the carbon on the end has 2 hydrogens whereas the second carbon has only 1. Therefore the major product is the one where the hydrogen goes on the first carbon and the bromine goes on the second one.

ii.

When HBr is added to 2,3-dimethylbut-2-ene there is only one possible product because it doesn't matter which way around you put the hydrogen and the bromine you get the same molecule (2-bromo-2,3-dimethylbutane).

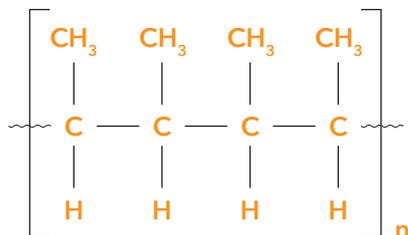


Would also accept: Because it is a symmetrical alkene.

Would also accept: Because it is a symmetrical alkene.

Would not accept: Because each of the carbons on the double bond has the same number of hydrogens so Markovnikoffs rule does not apply. There can still be two possible products even if they have the same number of hydrogens, to convince yourself try adding HBr to pent-2-ene and naming the products you come up with.

iii.



2,3, dimethylbut-2-ene.

b.

i.

Using bromine water,  $\text{Br}_2$ . When adding some bromine water to both samples of both liquids, the hex-1-ene will rapidly decolourise the bromine water from orangey-brown to colourless. The hexane will react much more slowly and will only decolourise in the presence of UV light.

Alternatively,

$\text{MnO}_4^-$ . When adding permanganate to samples of both the hex-1-ene will react to form a diol and will decolourise the permanganate from purple to colourless. The hexane will remain purple.

ii.

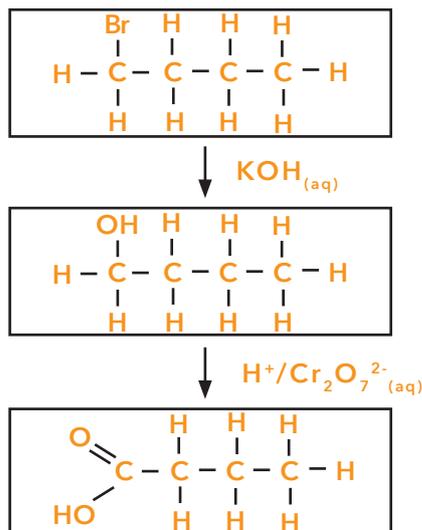
Add acidified dichromate to both solutions. The propan-1-ol will oxidise to a carboxylic acid since it is a primary alcohol. The colour change observed during this reaction will be orange to green. Since 2-methylpropan-2-ol is a tertiary alcohol it will not be oxidised so it will stay orange.

Alternatively,

Add acidified permanganate to both solutions. The propan-1-ol will oxidise to a carboxylic acid since it is a primary alcohol. The colour change observed during this reaction will be purple to colourless. Since 2-methylpropan-2-ol is a tertiary alcohol it will not be oxidised so it will stay purple.

c.

i.



ii.

The intermediate product is butan-1-ol.

First, a substitution reaction takes place where the bromine atom on 1-bromobutane is swapped out for an OH group from the KOH to make the butan-1-ol. The next reaction where the butan-1-ol is oxidised by the acidified dichromate (or acidified permanganate) to give the final product of butanoic acid.

If 2-bromobutane was used as the starting material instead, the substitution would work the same way with the Br being swapped out for an OH. However, the last step would not work as only primary alcohols can be oxidised to carboxylic acids and so the final product would not be butanoic acid as the OH group is in the wrong place.