Chem Factsheet

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Answering Questions on Organic Pathways and Conversions

To succeed in this topic you need to:-

- **Have a good knowledge and understanding of the organic chemistry covered so far (Factsheets 27, 31, 32, 33 and 34).**

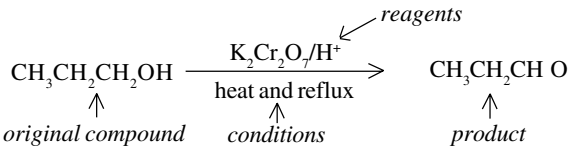
After working through this Factsheet you will have covered:

- **the types of examination questions that are set on this topic;**
- **what you need to know and understand to be able to answer the questions;**
- **various techniques to help you answer these questions.**

This Factsheet assumes that you have the basic knowledge detailed above; it concentrates on showing you how to use it.

What are 'organic conversions' and 'pathways'?

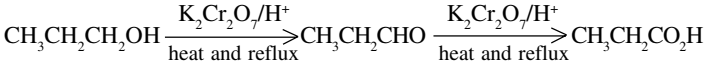
Consider the reaction below:



This is the basic **conversion** and shows all the facts about it:

a) What are we starting with?
b) What are the reagents used to convert it?
c) What conditions are used?
d) What is made?

If we go one step further:

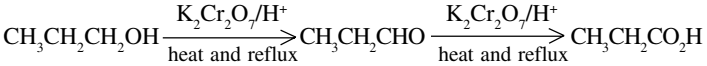


This is a **pathway** because it contains more than one step i.e. a⇒b⇒c not just a conversion (a⇒b).

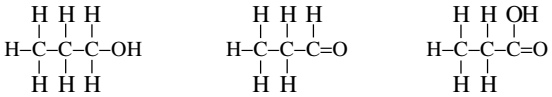
In this example the **pathway** shows $CH_3CH_2CH_2OH$ being changed to $CH_3CH_2CO_2H$.

The techniques and methods to answer flow diagram questions

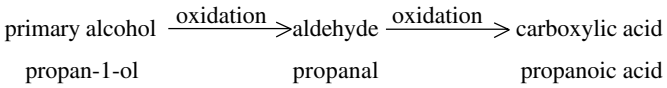
Let us return to our original example:



Rule 1 - wherever possible re-write the pathway using DISPLAYED FORMULAE – this helps you to identify compounds.



Rule 2 - (a) identify the FAMILIES
(b) identify the REACTION TYPE
(c) name the SPECIFIC COMPOUNDS



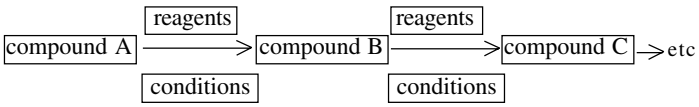
Rule 3 - treat the pathway as a type of 'crossword puzzle'. When you are doing a crossword puzzle you rarely do it in the order of the clues i.e. 1 across, 5 across, etc.

You find a clue you can answer, put it in and use these letters to find other word answers i.e. YOU START WHERE YOU CAN! - THIS IS HOW YOU DO PATHWAY QUESTIONS. (i.e. identify one of the families/compounds and work back or forwards from it).

The method is: (1) look at the pathway before the questions about it
(2) apply Rules 1+2+3 to see what you can find out before looking at the questions.

What happens in questions?

There are three types of question:
(a) Conversions and pathways are always:



All the examiner has to do is give you some of the information in a pathway and ask you to find the 'missing pieces'. To be successful in this you need to have recognised which reactions are taking place.

This is the **commonest type of question** on conversions and pathways.

(b) More difficult is the question which gives you the least amount of information of all:

e.g. 'Starting with compound A how would you convert it into compound X? You should show all the necessary reagents, conditions and intermediate compounds'

In effect the question is asking you to produce the type of flow-chart used in part (a) above.

c) These conversion/pathway questions will always have supplementary parts to enable more marks to be given to a particular question:

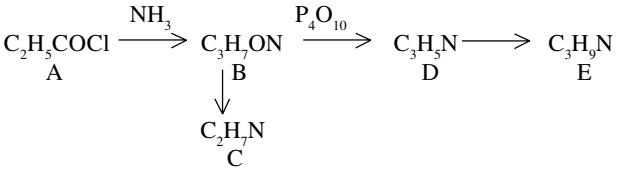
e.g. (i) 'How would you test for compound C?
(**Tests for compounds**)
(ii) 'Draw a structural isomer of compound B?
(**Isomerism**)
(iii) 'Identify the asymmetric carbon atom in compound X'
(**Optical isomerism**)

These questions may draw upon all of the A2 Chemistry specification. While these 'supplementary parts' are important, this Factsheet will not use them in its questions unless they provide information that helps to complete the pathway.

e.g. 'Compound W decolourises bromine water' i.e. we can deduce W is unsaturated and so belongs to the family **alkene**.

Worked Examples

Consider the following reaction scheme:



Compounds C and E have the same functional group.

(a) Draw the structural formulae of B and D

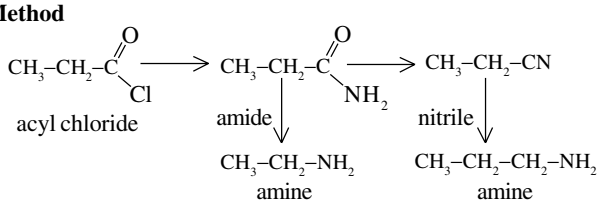
(b) What is the functional group in C and E?

(c) Give the reagents and conditions to convert

(i) D to E

(ii) B to C

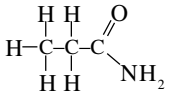
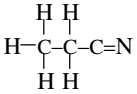
Method



'Thinking process'

- A is an acid chloride, so NH_3 creates an amide (B)
- counting atoms for B to D shows loss of 2H's and 1O i.e. H_2O, dehydration so amide (b) to amine (C)
- D to E shows 4H's being added, reduction, so must be nitrile to amine
- B to C shows loss of 1C and 1O, this must be decarboxylation, so amide to amine.

Answer

(a) B =  D = 

(b) Amine i.e. $–NH_2$

(c) (i) anhydrous $LiAlH_4$ (or $NaBH_4$) + heat

(ii) P_2O_5/Br_2 in aqueous alkali

Answer the questions about the following organic conversions:

(a) Suggest the structural formula of W

(b) Give the reagents and conditions for:

(i) Step 1

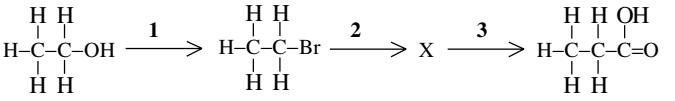
(ii) Step 2

(c) State the type of reaction taking place in:

(i) Step 1

(ii) Step 2

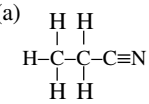
Method



'Thinking process'

- the carboxylic acid has an 'extra C' atom in it
- how to go from bromoalkane to get 'extra C'?
- usually via nitrile i.e. –CN
- so Step 3 would work i.e. $–CN \Rightarrow CO_2H$

Answer

(a) 

(b) Step 1 – KBr/ cone. H_2SO_4 + heat under reflux
Step 2 – KCN/ethanol + heat under reflux

(c) Step 1 – nucleophilic substitution
Step 2 – hydrolysis

Questions 1, 2 , 3 and 4 provide further practice on these types of problem.

Questions where only start and finish compounds are given

These questions tend to be more complex for all candidates and there is much more of 'trial and error' involved in answering them.

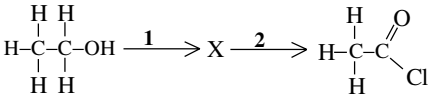
Because of this there is only **one rule** and **one method**

• **Rule** - Create your own flow chart for the pathway using the information provided in the question

• **Method** - From the flow chart you have made use your knowledge of the reactions of the starting compound and when you have met the final compound to identify the intermediate compound(s).

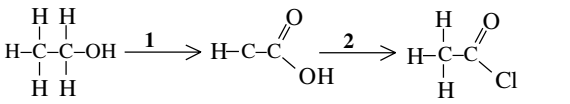
Suggest a two step method by which ethanol could be converted into ethanoyl chloride. (You should give reagents and conditions for each conversion)

Method and 'thinking process'



- ethanoyl chloride is an acid chloride; these are usually made from the corresponding **carboxylic acid**
- ethanol is a primary alcohol, typical reactions are oxidation to aldehydes and **carboxylic acids**
- X is probably a **carboxylic acid** i.e. CH_3CO_2H.

Answer



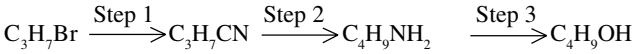
Step 1 Oxidation of ethanol to ethonoic acid using potassium dichromate (VI) in sulphuric acid and heating under reflux.

Step 2 Substitution by adding **anhydrous** PCl_5 to ethanoic acid.

Questions 5 and 6 provide further practice on this type of problem.

Questions

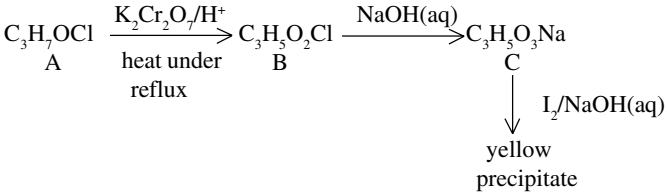
1. This questions relates to the following scheme of reactions:



   (a) Give the reagents and conditions needed for:
   (i) Step 1
   (ii) Step 2
   (iii) Step 3

   (b) What type of reaction is taking place in
   (i) Step 1
   (ii) Step 2

2. Consider the following reaction pathway:



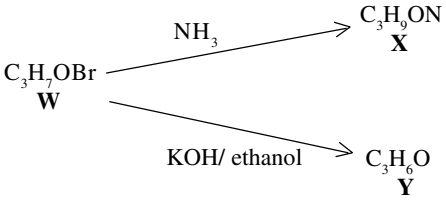
   A reacts with PCl_5 and produces steamy fumes, but A does not do this with water.
   B reacts with sodium hydrogen carbonate to form CO_2.

   (a) Write the structural formulae for A, B and C.

   (b) What type of reaction is taking place when A converts to B.

   (c) What is the name of compound A?

3. This question is about the reaction scheme:

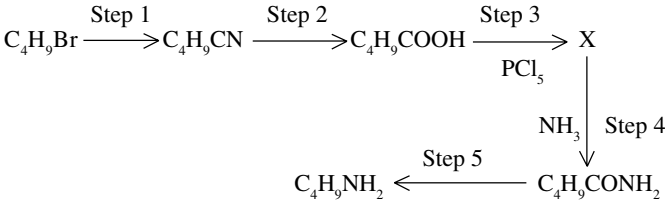


   W is chiral, can be oxidised to an aldehyde and gives steamy fumes with anhydrous PCl_5.
   Y decolourises acidified potassium manganate (VII) solution.

   (a) Draw the structural formulae of W, X and Y

   (b) Name the functional groups in Y.

4. This question is about the following organic pathway:



   (a) Give the reagents and conditions necessary for
   (i) Step 1
   (ii) Step 2
   (iii) Step 5

   (b) Draw the structural formula of X and give its systematic name.

5. Outline how you would convert C_2H_5Br into $C_2H_5CH_2OH$ via a Grignard Reagent.

   You should state clearly the reagents and conditions for the steps you propose, as well as drawing structural formulae of any intermediate compounds.

6. Outline a series of steps by which you could synthesise $CH_3\ CH_2\ CH_2\ NH_2$ from C_2H_5COCl.

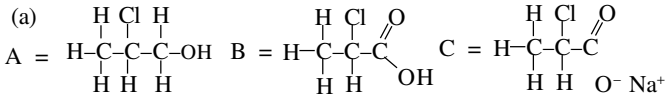
   Reagents and conditions for each step should be given as well as the formulae of any intermediate compounds.

Answers

1. (a) (i) KCN in ethanol + heat/boil
   (ii) $LiAlH_4$ + anhydrous conditions
   (iii) HCl and $NaNO_2$ + room temperature

   (b) (i) nucleophilic substitution
   (ii) reduction

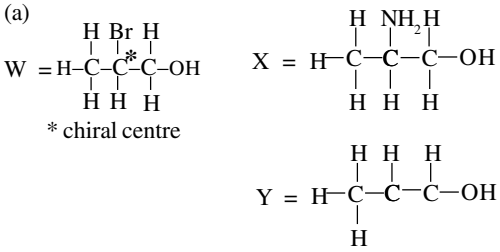
2. (a)



   (b) Oxidation

   (c) 2 – chloropropan –1-ol

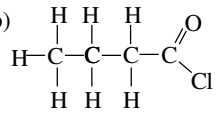
3. (a)



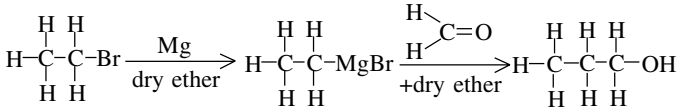
   (b) alkene + alcohol.

4. (a) (i) KCN in ethanol + boil/heat
   (ii) dilute acid
   (iii) P_2O_5/Br_2 in aqueous alkali

   (b)

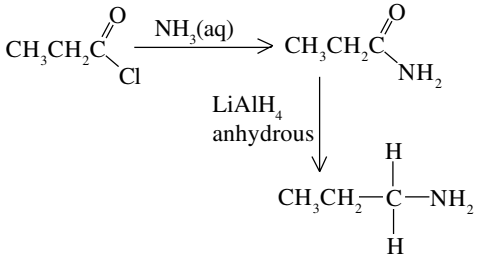


   butanoyl chloride



5.

6.



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