**Q1.**          The reaction scheme below shows the conversion of epoxyethane into sodium ethanedioate.

    Compound **X**    (COOH)2    Na2C2O4

(a)     Identify compound **X**. State the reagents and conditions required to convert **X** into ethanedioic acid. Draw the structure of the anion in sodium ethanedioate.

**(4)**

(b)     The addition of sodium ethanedioate to an aqueous solution containing [Co(H2O)6]2+ ions results in the formation of a more stable complex ion. Draw the structure of the complex ion formed and explain, in thermodynamic terms, why this substitution reaction occurs.

**(4)**

**(Total 8 marks)**

**Q2.**(a)     Compound **C**, H2N(CH2)4NH2, can be synthesised from ethene in three steps as shown below.

Step 1                           Step 2                         Step 3

Ethene    Compound    Compound    Compound  
addition             **A**         substitution           **B**                                   **C**reaction                          reaction          C4H4N2                       H2N(CH2)4NH2

Name compound **C** and draw a structure for each of compounds **A** and **B**.  
State the reagent(s) required for each step and name the type of reaction involved in the conversion of **B** into **C**.

**(7)**

(b)     Draw the repeating unit of the polyamide formed when **C** reacts with hexanedioic acid. Discuss the interactions between the chains of the polyamide.

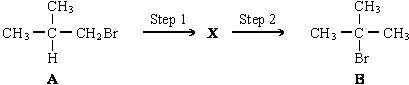
**(4)**

(c)     Explain why polyamides are degraded by sodium hydroxide whereas polymers such as poly(ethene) are not.

**(3)**

**(Total 14 marks)**

**Q3.**          The conversion of compound **A** into compound **B** can be achieved in two steps as shown below.



The intermediate compound, **X,** has an absorption at 1650 cm–1 in its infra-red spectrum.

(a)     Identify compound **X**. Explain your answer.

**(2)**

(b)     For each step in this conversion, give the reagents and essential conditions required and outline a mechanism.

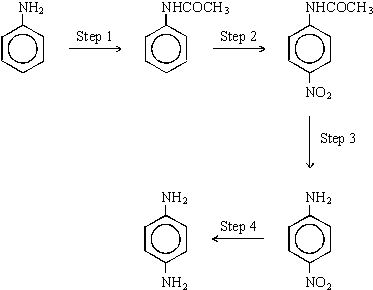
**(11)**

(c)     Show how the number of peaks in their proton n.m.r. spectra would enable you to distinguish between compounds **A** and **B**.

**(2)**

**(Total 15 marks)**

**Q4.**          A possible synthesis of 1,4-diaminobenzene is shown below.



(a)     Identify a suitable reagent or combination of reagents for Step 1. Name and outline a mechanism for the reaction.

**(6)**

(b)     Identify a suitable reagent or combination of reagents for Step 2. Name and outline a mechanism for the reaction.

**(6)**

(c)     Identify a suitable reagent or combination of reagents for Step 4. Draw the repeating unit of the polymer formed by reaction of 1,4-diaminobenzene with pentanedioic acid.

**(3)**

**(Total 15 marks)**

**Q5.**          Use the data given on the back of the Periodic Table (PT) to help you answer this question.  
Compounds **A** to **G** are all isomers with the molecular formula C6H12O2

(a)     Isomer **A**, C6H12O2, is a neutral compound and is formed by the reaction between compounds **X** and **Y** in the presence of a small amount of concentrated sulphuric acid.  
**X** and **Y** can both be formed from propanal by different redox reactions.  
**X** has an absorption in its infra-red spectrum at 1750 cm–1.  
Deduce the structural formulae of **A**, **X** and **Y**. Give suitable reagents, in each case, for the formation of **X** and **Y** from propanal and state the role of concentrated sulphuric acid in the formation of **A**.

**(7)**

(b)     Isomers **B**, **C**, **D** and **E** all react with aqueous sodium carbonate to produce carbon dioxide.  
Deduce the structural formulae of the three isomers that contain an asymmetric carbon atom.  
The fourth isomer has only three singlet peaks in its proton n.m.r. spectrum. Deduce the structural formula of this isomer and label it **E**.

**(4)**

(c)     Isomer **F**, C6H12O2, has the structural formula shown below, on which some of the protons have been labelled.



A proton n.m.r. spectrum is obtained for **F**. Using Table 1 at the back of the Periodic Table (PT), predict a value of δ for the protons labelled *a* and also for those labelled *b*. State and account for the splitting patterns of the peaks assigned to the protons *a* and *b*.

**(6)**

(d)     Isomer **G**, C6H12O2, contains six carbon atoms in a ring. It has an absorption in its infra-red spectrum at 3270 cm–1 and shows only three different proton environments in its proton n.m.r. spectrum. Deduce a structural formula for **G**.

**(2)**

**(Total 19 marks)**

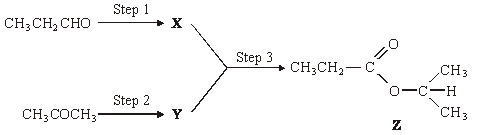
**Q6.**          (a)     Describe how propanal, CH3CH2CHO, and propanone, CH3COCH3, can be distinguished using

(i)      a chemical test and

(ii)     the number of peaks in their proton n.m.r. spectra.

**(5)**

(b)     Compound **Z** can be produced by the reaction of compound **X** with compound **Y** as shown in the synthesis outlined below.

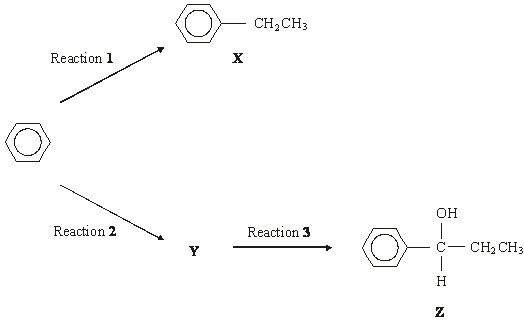


Identify compounds **X** and **Y**.  
For each of the three steps in the synthesis, name the type of reaction involved and give reagents and conditions. Equations are **not** required.

**(10)**

**(Total 15 marks)**

**Q7.**          Two reactions of benzene are shown below.



(a)     Name **X** and give the reagent and catalyst required for Reaction **1**.  
Write an equation for the formation of the reactive intermediate involved in this reaction.  
Name and outline a mechanism for the reaction of this reactive intermediate with benzene to form **X**.

**(8)**

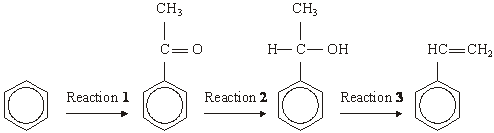
(b)     (i)      Deduce the structure of **Y** and give the organic reagent needed for Reaction **2**.

(ii)     Give the reagent(s) needed for Reaction **3**.

**(3)**

**(Total 11 marks)**

**Q8.**          A possible synthesis of phenylethene *(styrene)* is outlined below.



(a)     In Reaction **1**, ethanoyl chloride and aluminium chloride are used to form a reactive species which then reacts with benzene.  
Write an equation to show the formation of the reactive species.  
Name and outline the mechanism by which this reactive species reacts with benzene.

**(6)**

(b)     NaBH4 is a possible reagent for Reaction **2**.  
Name and outline the mechanism for the reaction with NaBH4 in Reaction **2**.  
Name the product of Reaction **2**.

**(6)**

(c)     Name the type of reaction involved in Reaction **3** and give a reagent for the reaction.

**(2)**

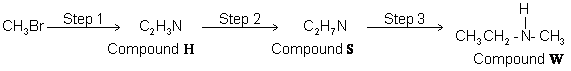
**(Total 14 marks)**

**Q9.**          A chemist has discovered that the labels have fallen off four bottles each of which contains a different organic liquid. These liquids are known to be propan-2-ol, propanal, hexene and 1-bromopropane.

Suggest a series of test-tube reactions which a chemist could use to confirm the identities of the four compounds. State the reagents used and the observations expected.

**(Total 10 marks)**

**Q10.**          Compound **W** can be formed via compounds **H** and **S** in the three-step synthesis shown below.



Identify compounds **H** and **S** and give reagents and conditions for Steps 1 and 2.

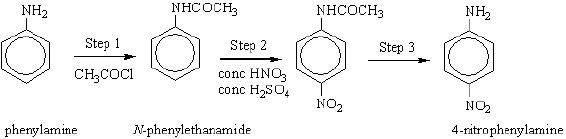
State the **type** of compound of which **W** is an example.

**W** reacts with a large excess of bromomethane to form a solid product. Draw the structure of this product and name the type of mechanism for this reaction.

**(Total 9 marks)**

**Q11.**          Synthetic dyes can be manufactured starting from compounds such as 4-nitrophenylamine.

A synthesis of 4-nitrophenylamine starting from phenylamine is shown below.



(a)     An equation for formation of *N*-phenylethanamide in Step 1 of the synthesis is shown below.

2C6H5NH2 +   CH3COCl   →   C6H5NHCOCH3   +   C6H5NH3Cl  
*N*-phenylethanamide

(i)      Calculate the % atom economy for the production of *N*-phenylethanamide  
(*M*r = 135.0).

(ii)     In a process where 10.0 kg of phenylamine are used, the yield of *N*-phenylethanamide obtained is 5.38 kg.

Calculate the percentage yield of *N*-phenylethanamide.

(iii)     Comment on your answers to parts (i) and (ii) with reference to the commercial viability of the process.

**(7)**

(b)     Name and outline a mechanism for the reaction in Step 1.

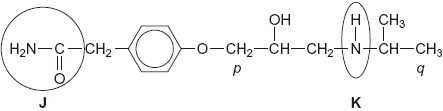
**(5)**

(c)     The mechanism of Step 2 involves attack by an electrophile. Write an equation showing the formation of the electrophile. Outline a mechanism for the reaction of this electrophile with benzene.

**(4)**

**(Total 16 marks)**

**Q12.**          Atenolol is an example of the type of medicine called a beta blocker. These medicines are used to lower blood pressure by slowing the heart rate. The structure of atenolol is shown below.



(a)     Give the name of each of the circled functional groups labelled **J** and **K** on the structure of atenolol shown above.

Functional group labelled **J** .........................................................................

Functional group labelled **K** .........................................................................

**(2)**

(b)     The 1H n.m.r. spectrum of atenolol was recorded.

One of the peaks in the 1H n.m.r. spectrum is produced by the CH2 group labelled *p* in the structure of atenolol.  
Use **Table** **2** on the Data Sheet to suggest a range of δ values for this peak.  
Name the splitting pattern of this peak.

Range of δ values .......................................................................................

Name of splitting pattern ……......................................................................

**(2)**

(c)     N.m.r. spectra are recorded using samples in solution.  
The 1H n.m.r. spectrum was recorded using a solution of atenolol in CDCl3

(i)      Suggest why CDCl3 and **not** CHCl3 was used as the solvent.

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**(1)**

(ii)     Suggest why CDCl3 is a more effective solvent than CCl4 for polar molecules such as atenolol.

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**(1)**

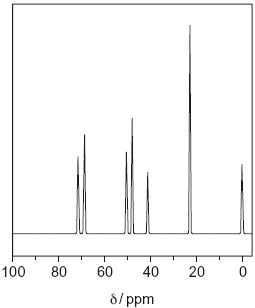
(d)     The 13C n.m.r. spectrum of atenolol was also recorded.

Use the structure of atenolol given to deduce the total number of peaks in the  
13C n.m.r. spectrum of atenolol.

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**(1)**

(e)     Part of the 13C n.m.r. spectrum of atenolol is shown below. Use this spectrum and **Table 3** on the Data Sheet, where appropriate, to answer the questions which follow.



(i)      Give the formula of the compound that is used as a standard and produces the peak at δ = 0 ppm in the spectrum.

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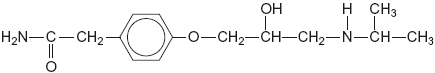
**(1)**

(ii)     One of the peaks in the 13C n.m.r. spectrum above is produced by the CH3 group labelled *q* in the structure of atenolol.  
Identify this peak in the spectrum by stating its δ value.

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**(1)**

(iii)     There are three CH2 groups in the structure of atenolol. One of these CH2 groups produces the peak at δ = 71 in the 13C n.m.r. spectrum above.  
Draw a circle around this CH2 group in the structure of atenolol shown below.



**(1)**

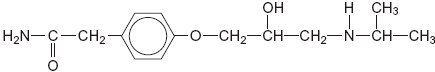
(f)      Atenolol is produced industrially as a racemate (an equimolar mixture of two enantiomers) by reduction of a ketone. Both enantiomers are able to lower blood pressure. However, recent research has shown that one enantiomer is preferred in medicines.

(i)      Suggest a reducing agent that could reduce a ketone to form atenolol.

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**(1)**

(ii)     Draw a circle around the asymmetric carbon atom in the structure of atenolol shown below.



**(1)**

(iii)     Suggest how you could show that the atenolol produced by reduction of a ketone was a racemate and **not** a single enantiomer.

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**(2)**

(iv)    Suggest **one** advantage and **one** disadvantage of using a racemate rather than a single enantiomer in medicines.

Advantage ...........................................................................................

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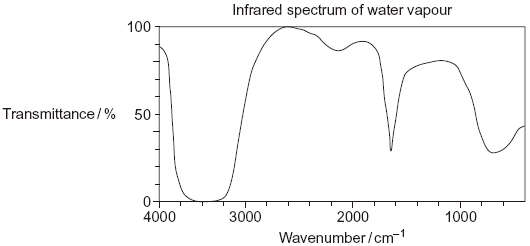
Disadvantage ......................................................................................

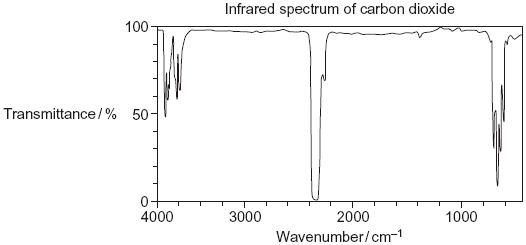
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**(2)**

**(Total 16 marks)**

**Q13.**          A student used the infrared spectra of water vapour and of carbon dioxide to try to find a link between infrared radiation and global warming.





(i)      Use information from the infrared spectra to deduce **one** reason why the student concluded that water vapour is a more effective greenhouse gas than carbon dioxide.

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**(1)**

(ii)      Use your knowledge of the bonds in CO2 to state why the infrared spectrum of carbon dioxide is **not** as might be predicted from the data provided in **Table 1** on the Data Sheet.

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**(2)**

**(Total 3 marks)**

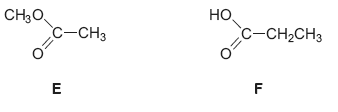
**Q14.**          Organic chemists use a variety of methods to distinguish between compounds. These methods include analytical and spectroscopic techniques.

(a)     The following compounds can be distinguished by observing what happens in test-tube reactions.

For each pair, suggest a suitable reagent or reagents that could be added separately to each compound in order to distinguish them.

Describe what you would observe with each compound.

(i)



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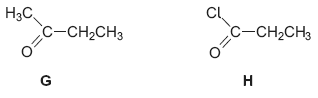
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**(3)**

(ii)



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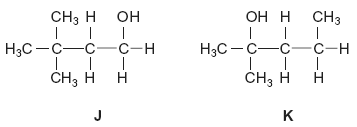
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**(3)**

(iii)



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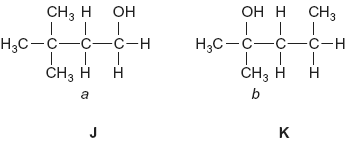
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**(3)**

(b)     Compounds **J** and **K** can also be distinguished using spectroscopic techniques  
such as 1H n.m.r.



(i)      Name compound **J**.

Give the total number of peaks in the 1H n.m.r. spectrum of **J**.

State the splitting pattern, if any, of the peak for the protons labelled *a*.

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**(3)**

(ii)     Name compound **K**.

Give the total number of peaks in the 1H n.m.r. spectrum of **K**.

State the splitting pattern, if any, of the peak for the protons labelled *b*.

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**(3)**

**(Total 15 marks)**

**Q15.**(a)     A chemist discovered four unlabelled bottles of liquid, each of which contained a different pure organic compound. The compounds were known to be propan-1-ol, propanal, propanoic acid and 1-chloropropane.

Describe four **different** test-tube reactions, one for each compound, that could be used to identify the four organic compounds.  
Your answer should include the name of the organic compound, the reagent(s) used and the expected observation for each test.

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*(Extra space)* .................................................................................................

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**(8)**

(b)     A fifth bottle was discovered labelled propan-2-ol. The chemist showed, using infrared spectroscopy, that the propan-2-ol was contaminated with propanone.

The chemist separated the two compounds using column chromatography. The column contained silica gel, a polar stationary phase.

The contaminated propan-2-ol was dissolved in hexane and poured into the column.  
Pure hexane was added slowly to the top of the column. Samples of the eluent (the solution leaving the bottom of the column) were collected.

•        Suggest the chemical process that would cause a sample of propan-2-ol to become contaminated with propanone.

•        State how the infrared spectrum showed the presence of propanone.

•        Suggest why propanone was present in samples of the eluent collected first (those with shorter retention times), whereas samples containing propan-2-ol were collected later.

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**(4)**

**(Total 12 marks)**

**Q16.**Benzene reacts with ethanoyl chloride in a substitution reaction to form C6H5COCH3.  
This reaction is catalysed by aluminium chloride.

(a)     Write equations to show the role of aluminium chloride as a catalyst in this reaction.

Outline a mechanism for the reaction of benzene.

Name the product, C6H5COCH3.

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**(6)**

(b)     The product of the substitution reaction (C6H5COCH3) was analysed by mass spectrometry. The most abundant fragment ion gave a peak in the mass spectrum with *m/z* = 105.  
Draw the structure of this fragment ion.

**(1)**

(c)     When methylbenzene reacts with ethanoyl chloride and aluminium chloride, a similar substitution reaction occurs but the reaction is faster than the reaction of benzene.  
Suggest why the reaction of methylbenzene is faster.

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**(2)**

**(Total 9 marks)**

**Q17.**Acyl chlorides and acid anhydrides are important compounds in organic synthesis.

(a)     Outline a mechanism for the reaction of CH3CH2COCl with CH3OH and name the organic product formed.

Mechanism

Name of organic product ...............................................................................

**(5)**

(b)     A polyester was produced by reacting a diol with a diacyl chloride. The repeating unit of the polymer is shown below.



(i)      Name the diol used.

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**(1)**

(ii)     Draw the displayed formula of the diacyl chloride used.

**(1)**

(iii)     A shirt was made from this polyester. A student wearing the shirt accidentally splashed aqueous sodium hydroxide on a sleeve. Holes later appeared in the sleeve where the sodium hydroxide had been.

Name the type of reaction that occurred between the polyester and the aqueous sodium hydroxide. Explain why the aqueous sodium hydroxide reacted with the polyester.

Type of reaction ....................................................................................

Explanation ...........................................................................................

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**(3)**

(c)     (i)      Complete the following equation for the preparation of aspirin using ethanoic anhydride by writing the structural formula of the missing product.

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| --- | --- |
|  | ...................... |

**(1)**

(ii)     Suggest a name for the mechanism for the reaction in part (c)(i).

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**(1)**

(iii)     Give **two** industrial advantages, other than cost, of using ethanoic anhydride rather than ethanoyl chloride in the production of aspirin.

Advantage 1 ..........................................................................................

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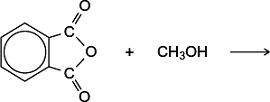
Advantage 2 ..........................................................................................

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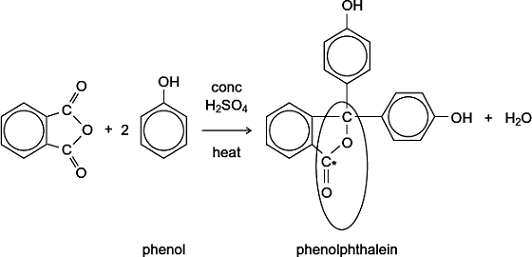
**(2)**

(d)     Complete the following equation for the reaction of one molecule of benzene-1,2-dicarboxylic anhydride (phthalic anhydride) with one molecule of methanol by drawing the structural formula of the single product



**(1)**

(e)     The indicator phenolphthalein is synthesised by reacting phthalic anhydride with phenol as shown in the following equation.



(i)      Name the functional group ringed in the structure of phenolphthalein.

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**(1)**

(ii)     Deduce the number of peaks in the 13C n.m.r. spectrum of phenolphthalein.

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**(1)**

(iii)     One of the carbon atoms in the structure of phenolphthalein shown above is labelled with an asterisk (\*).  
Use **Table 3** on the Data Sheet to suggest a range of δ values for the peak due to this carbon atom in the 13C n.m.r. spectrum of phenolphthalein.

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**(1)**

(f)      Phenolphthalein can be used as an indicator in some acid–alkali titrations.  
The pH range for phenolphthalein is 8.3 – 10.0

(i)      For **each** acid.alkali combination in the table below, put a tick () in the box if phenolphthalein could be used as an indicator.

|  |  |  |
| --- | --- | --- |
| **Acid** | **Alkali** | **Tick box** () |
| sulfuric acid | sodium hydroxide |  |
| hydrochloric acid | ammonia |  |
| ethanoic acid | potassium hydroxide |  |
| nitric acid | methylamine |  |

**(2)**

(ii)      In a titration, nitric acid is added from a burette to a solution of sodium hydroxide containing a few drops of phenolphthalein indicator.  
Give the colour **change** at the end-point.

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**(1)**

**(Total 21 marks)**

**Q18.**Describe how you could distinguish between the compounds in the following pairs using **one** simple test-tube reaction in each case.

For each pair, identify a reagent and state what you would observe when both compounds are tested separately with this reagent.

(a)



Reagent .........................................................................................................

Observation with **R**.........................................................................................

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Observation with **S**.........................................................................................

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**(3)**

(b)



Reagent .........................................................................................................

Observation with **T**.........................................................................................

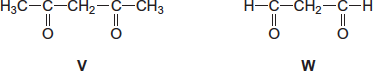
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Observation with **U**.........................................................................................

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**(3)**

(c)



Reagent .........................................................................................................

Observation with **V**.........................................................................................

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Observation with **W**........................................................................................

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**(3)**

**(Total 9 marks)**

**M1.**         (a)     Identity of **A**;  
ethane-1,2-diol **or** 1,2 dihydroxyethane **or** ethylene glycol **or** formula **(1)**

*N.B. Do NOT allow OHCH2CH2OH unless a correct name is also given*

          K2Cr2O7 / dilute H2SO4 **or** dilute HCl **or** K2Cr2O7 / H+

*N.B. Oxidising agent must be a reagent  
N.B. Do NOT allow concentrated H2SO4*

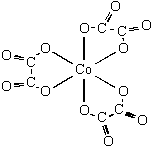
          Reflux **or** warm **or** heat **(1)**

*Ignore temperature if given  
N.B. If a temperature given on its own it must be at or below 200°C*

          Anion:  **(1)**

*N.B. Do NOT allow C2O42–N.B. Ignore lone pairs of electrons*

**4**

(b)     Structure : 

*correct co-ordination (1)  
bonding through six correct oxygen (1)*

*Score 2 or zero  
N.B. Not essential to show double bonds i.e. C=O in structure*

Explanation:  
Substitution produces more molecules or particles or more disorder **(1)**Entropy change is positive **(1)**

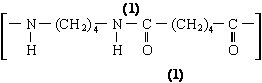
**4**

**[8]**

**M2.**(a)     1, 4-diaminobutane or butane -1, 4-diamine **(1)**A: BrCH2CH2Br **or** ClCH2CH2Cl **(1)**B: NC CH2CH2CN  
Step 1: Br2 or Cl2 **(1) (ignore aq)**Step 2: KCN **(1) (NOT HCN)**Step 3: H2 / Ni **or** LiAlH4 **or** Na / C2H5OH **(1) (NOT NaBH4)**Hydrogenation only for H2 / Ni, **or** nucleophilic addition only for LiAlH4**(1)**

*OR reduction or addition*

**7**

(b)     

QL hydrogen bonding **(1)**

Polarity of H-bonding shown or discussed **(1)**

**4**

(c)     Polyamides / peptide link can be hydrolysed **(1)**

*OR polyalkenes cannot be hydrolysed*

          QL OH– attacks peptide link or C+ **(1)** poly(ethene) non-polar **(1)**

**3**

**[14]**

**M3.**          (a)     Identity of **X**; 2-methylpropene **(1)**Absorption at 1650 cm–1 indicates an alkene present **(1)**

*OR a chemical answer e.g. Br2 (aq) brown to colourless*

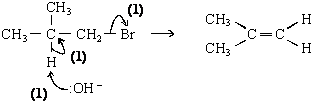
**2**

(b)     Reagents  
Step 1 KOH (allow NaOH) **(1)** alcoholic **(1)** warm **(1)**

*Only allow solvent and warm if reagent correct*

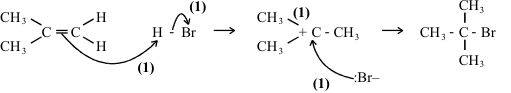
Step 2 HBr **(1)**

Mechanism:                    A → **X**

****

*Or a carbocation mechanism*

Mechanism                     **X** → B



**11**

(c)     A gives three peaks **(1)**B gives one peak **(1)**

*Allow one for “A has more peaks than B” when no number of peaks is given*

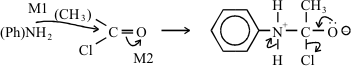
**2**

**[15]**

**M4.**          (a)     CH3COCl or (CH3CO)2O **(1)**

*AlCl3 or H2O or CH2SO4 loses this mark  
CH3COOH loses reagent and M3, M4 = max 3*

          nucleophilic addition–elimination **(1)**

****

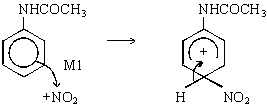
*M3: structure  
M4: 3 correct arrows  
Allow M1 for attack on CH3‑C+=O  
Penalise Cl– removing H+*

**6**

(b)     Conc HNO3 **(1)**Conc H2SO4 **(1)**HNO3 + 2 H2SO4 → NO2+ + H3O+ + 2 HSO4– **(2)  
         (or H2SO4 )             (or H2O + HSO4–)**

*HNO3 / H2SO4 scores 1  
Any 2*

          electrophilic substitution **(1)**

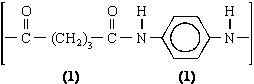
****

*M2 structure  
M3 arrow*

**6**

(c)     Sn **(or Fe)** / HCl or Ni / H2 **(1)**

*NOT LiAlH4 NaBH4*

**

**3**

**[15]**

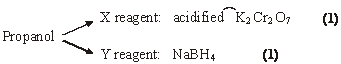
**M5.**          (a)     X contains > C=O **(1)**

*if X and Y reversed lose this mark but allow remaining max 6/7*

** X is CH3CH2COOH **(1)**

**** Y is CH3CH2CH2OH **(1)**

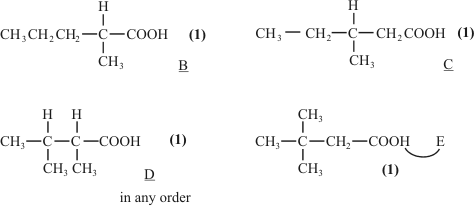
**** A is  **(1)**

****

Conc H2SO4 : catalyst **(1)**

**7**

(b)



**4**

(c)             3.1 – 3.9 **(1)**

****   2.1 – 2.6 **(1)**

a: quartet **(1)**  3 adjacent H **(1)**

b: triplet **(1)**  2 adjacent H **(1)**

**6**

(d)     3269 cm–1 OH  alcohol **(1)**

**** G is  (1)

**2**

**Notes**

(a)     first mark for C=O stated or shown in **X**

*Ignore wrong names*

**Y** CH3CH2CH2OH  
allow C3H7 in **A** if **Y** correct or vice versa  
Allow **(1)** for **A** if correct conseq to wrong **X** and **Y**

          other oxidising agents: acidified KMnO4; Tollens; Fehlings

          other reducing agents: LiAlH4; Na/ethanol; Ni/H2; Zn or Sn or Fe/HCl

(b)     give **(1)** for carboxylic acid stated or COOH shown in each suggestion  
**(1)** for correct **E**any 2 out of 3 for **B**, **C** or **D**allow C3H7 for either the **B** or **D** shown on the mark scheme  
i.e. a correct structure labelled **B**, **C** or **D** or **E** will gain 2.

(c)     protons a – *quartet* must be correct to score *3 adjacent H* mark. Same for b

(d)     allow **(1)** for any OH (alcohol) shown correctly in any structure – ignore extra functional groups. Structure must be completely correct to gain second mark

**[19]**

          Organic points

(1)     Curly arrows: must show movement of a pair of electrons,  
i.e. from bond to atom or from lp to atom / space  
e.g.



(2)     Structures

penalise sticks (i.e. ) once per paper



Penalise once per paper

          allow CH3– or –CH3 or  or CH3    or   H3C–

**M6.**         (a)     (i)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Reagent | Tollens | Fehlings or Benedicts | K2Cr2O7/H+  or acidified | KMnO4/H+ | I2/NaOH |
| Propanal | silver (mirror) | red ppt or goes red *(not red solution)* | goes green | goes colourless | No reaction |
| Propanone | no reaction | no reaction | no reaction | no reaction | Yellow (ppt) |

*(penalise incomplete reagent e.g. K*2*Cr*2*O*7 *or Cr*2*O*72–*/H*+ *then mark on)*

**3**

(ii)     propanal 3 peaks

*ignore splitting even if wrong*

**1**

propanone 1 peak

**1**

(b)     **X** is CH3CH2COOH or propanoic acid  if both name and formula given,  
                                                             both must be correct, but

**1**

**Y** is CH3CH(OH)CH3 or propan-2-ol     allow propanol with correct formula

**1**

**Mark the type of reaction and reagent/condition independently.  
The reagent must be correct or close to score condition**

Step 1        Oxidation

         K2Cr2O7/H+ or other oxidation methods as above  
allow Cr2O72–H+ if penalised above (ecf)  
reflux (not Tollens/Fehlings) or heat or warm

**1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Step 2 | reduction or nucleophilic addition | reduction or nucleophilic addition | reduction or hydrogenation | **1** |
|  | NaBH4 | LiAlH4 | H2 | **1** |
|  | in (m)ethanol or water or ether or dry | ether or dry | Ni / Pt etc | **1** |

Step 3        esterification or (nucleophilic) addition-elimination or condensation

**1**

(conc) H2SO4 or HCl

**1**

warm (allow without acid reagent if **X** and **Y** given as reagents)

**1**

or reflux or heat

**1**

**[15]**

**M7.**          (a)     ethyl benzene

**1**

chloroethane or bromoethane (*or ethene and hydrogen chloride/bromide*)

**1**

aluminium chloride/bromide or iron(III) chloride /bromide or iron +  
chorine/bromine

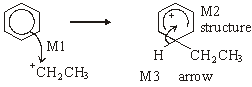
**1**

CH3CH2Cl + AlCl3 → CH3CH2+ + AlCl4–

**1**

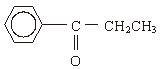
electrophilic substitution

**1**

****

**3**

(b)



**1**

CH3CH2COCl / propanoyl chloride or (CH3CH2CO)2O / propanoic  
anhydride

**1**

NaBH4 or LiAlH4 or H2/Ni (*not Sn/Fe with HCl*)

**1**

**[11]**

**M8.**          (a)     CH3COCl  +  AlCl3  →  CH3O  +  AlCl   
                                        (1)                        equation (1)

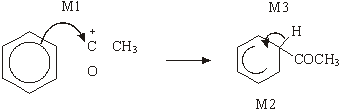
**2**

penalise wrong alkyl group once at first error  
position of + on electrophile can be on O or C or outside [ ]  
penalise wrong curly arrow in the equation or lone pair on AlCl3 else ignore

Electrophilic substitution

*NOT F/C acylation*

**1**

****

*horseshoe must not extend beyond C2 to C6 but can be smaller*

*+ not too close to C1*

*M3 arrow into hexagon unless Kekule*

*allow M3 arrow independent of M2 structure*

M1 arrow from within hexagon to C or to + on C

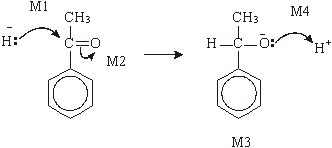
+ must be on C of 

**3**

(b)     Nucleophilic addition

*NOT reduction*

**1**

****

*M2 not allowed independent, but can allow M1 for attack of H– on C+ formed*

**4**

          1–phenylethan(–1–)ol        or (1–hydroxyethyl)benzene

**l**

(c)     dehydration or elimination

**1**

(conc) H2SO4 or (conc) H3PO4

*allow dilute and Al2O3*

*Do not allow iron oxides*

**1**

**[14]**

**M9.**          Acidified potassium dichromate(VI)

**1**

Turns green with propan-2-ol and propanal

**1**

No reaction with hexene and 1-bromopropane

**1**

Tollens with propan-2-ol and propanal

**1**

only propanal gives silver mirror

**1**

Bromine water

**1**

Decolourised by hexane

**1**

No reaction with 1-bromopropane

**1**

Warm NaOH followed by acidified AgNO3

**1**

White ppt with 1-bromopropane

**1**

**[10]**

**M10.**          **H**                                   CH3CN or ethanenitrile

**1**

**S**                                   CH3CH2NH2 or ethylamine 1Step 1 KCN

**1**

                                      aq/alcoholic

**1**

Step 2                           H2

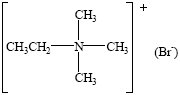
**1**

                                      Ni

**1**

**W**                                   secondary amine

**1**



**1**

                                      nucleophilic substitution

**1**

**[9]**

**M11.**

|  |  |
| --- | --- |
| **Mark Range** | The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates’ QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question  **Descriptor** an answer will be expected to meet most of the criteria in the level descriptor |
| 4-5 | –    claims supported by an appropriate range of evidence  –    good use of information or ideas about chemistry, going beyond those given in the question  –    argument well structured with minimal repetition or irrelevant points  –    accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling |
| 2-3 | –    claims partially supported by evidence  –    good use of information or ideas about chemistry given in the question but limited beyond this  –    the argument shows some attempt at structure  –    the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling |
| 0-1 | –    valid points but not clearly linked to an argument structure  –    limited use of information or ideas about chemistry  –    unstructured  –    errors in spelling, punctuation and grammar or lack of fluency |

(a)     (i)      Mr of C6H5NH2 = 93    Mr of CH3COCl = 78.5  
total Mr of reagents = 264.5

**1**

% atom economy =  × 100 QWC

**1**

=  × 100 = 51.0 %

**1**

(ii)     expected yield =  × 0.5 × 135 = 7.26 kg

**1**

% yield =  × 100 = 74.1 %

**1**

(iii)     Although yield appears satisfactory (74%) % atom economy  
is only 51% QWC

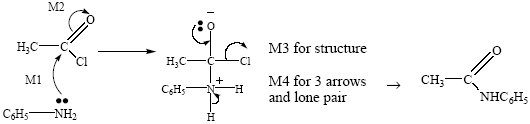
**1**

nearly half of the material produced is waste and must be  
disposed of QWC

**1**

(b)     (nucleophilic) addition-elimination

**1**

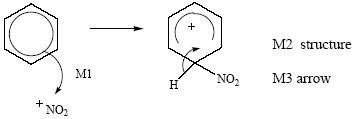
****

QWC (2)

**4**

(c)     HNO3 + 2H2SO4 → NO2+ + H3O+ + 2HSO4–

**1**

****

**3**

**[16]**

**M12.**          (a)     **J** (acid) amide

*not peptide, not N-substituted amide*

**1**

**K** (secondary) amine or amino

*penalise primary or tertiary  
allow N-substituted amine*

**1**

(b)     (δ =) 3.1-3.9

**1**

doublet **OR** duplet

*Not 3.7 – 4.1*

*Not secondary  
name required not the number 2*

**1**

(c)     (i)      Solvent must be proton-free

**OR** CHCl3 has protons or has H or gives a peak

**1**

(ii)     CDCl3 is polar **OR** CCl4 is non-polar

**1**

(d)     11 **OR** eleven

**1**

(e)     (i)      Si(CH3)4 **OR** SiC4H12

*ignore TMS*

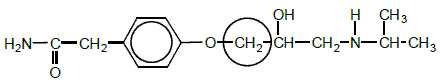
**1**

(ii)     a single number or a range within 21-25

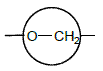
*penalise anything outside this range*

**1**

(iii)



*allow ring around the C only and also allow*

**

**1**

(f)      (i)      NaBH4

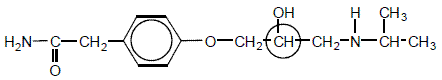
*ignore name if formula correct*

*ignore solvent*

*allow LiAlH4   Zn/HCl   Sn/HCl   H2/Ni   H2/Pt*

**1**

(ii)



*allow ring around the C only*

**1**

(iii)     (plane) polarised light **OR** light in a polarimeter

**1**

polarised light is not rotated or is unaffected

*penalise bent/diffracted/deflected/reflected*

*Not just solution is optically inactive*

**1**

(iv)    **adv** cheaper medicine due to cost or difficulty of separation or  
both can lower blood pressure

**OR** more effective/beneficial with a reason

*or no need to separate*

**1**

**disadv** may be side effects from one enantiomer in the mixture or  
only half the product works or one enantiomer may be  
ineffective or double dose required

**1**

**[16]**

**M13.**          (i)      More absorption/less transmittance of infrared radiation  
by it/water vapour

***OR*** broader absorption by OH

***OR*** less absorption/more transmittance of infrared radiation  
       by carbon dioxide

*Must be comparative*

*This may be described and must not be contradictory*

*Credit answers which refer correctly to “transmittance”*

*(more absorption = less transmittance)*

**1**

(ii)      **M1**    CO2 contains C=O (stated like this or in words or strongly  
implied) OR is O=C=O

**M2    depends on correct M1**

***OR*** expected absorption/peak (for C=O) is missing

***OR*** expected absorption/peak (for C=O) is shifted to 2300 (cm–1)

***OR*** asymmetric stretching is occurring (due to C=O)

*If M1 and M2 not scored, give one mark for either*

*No absorption/peak at 1700 (cm–1)/1715 (cm–1)*

*OR no absorption in the range 1680 – 1750 (cm–1)*

*Ignore “carbon-oxygen bonds”, “C-O bonds”*

*Ignore reference to other absorptions*

*For M2*

*Allow “dip” OR “spike” OR “low transmittance” as alternatives for absorption.*

**2**

**[3]**

**M14.**          (a)     (i)      Single reagent

If wrong single reagent, CE = zero

Incomplete single reagent (e.g. carbonate) or wrong formula (e.g.NaCO3) loses reagent mark, but mark on

For “no reaction” allow “nothing”

Different reagents

If different tests on E and F; both reagents and any follow  
on chemistry must be correct for first (reagent) mark.  
Reagent must react: i.e. not allow Tollens on G (ketone) – no reaction.  
Second and third marks are for correct observations.  
i.e. for different tests on E and F, if one reagent is correct and one wrong, can score max 1 for correct observation with correct reagent.

PCl5 PCl3

SOCl2

**1**

**E** ester

Na2CO3/NaHCO3 named carbonate

metal e.g.Mg

no reaction

no reaction

named indicator

no effect

No reaction

**1**

**F** acid

Na2CO3/NaHCO3 named carbonate

Effervescence or CO2

metal e.g.Mg

Effervescence or H2

named indicator

acid colour

*fumes*

**1**

(ii)     Single reagent

If wrong single reagent, CE = zero  
Incomplete single reagent (e.g. carbonate) or wrong  
formula (e.g.NaCO3) loses reagent mark, but mark on  
**For “no reaction” allow “nothing”**

Different reagents

If different tests on E and F; **both** reagents and any  
follow on chemistry must be correct for first (reagent) mark.  
Reagent must react: i.e. not allow Tollens on  
G (ketone) – no reaction.  
Second and third marks are for correct observations.

**1**

**i.e. for different tests on E and F, if one reagent is correct  
and one wrong, can score max 1 for correct observation  
with correct reagent.**

**G** ketone

AgNO3

no reaction

Na2CO3/NaHCO3 named carbonate

water

no reaction

named indicator

no effect

Named alcohol

no reaction

Named amine or ammonia

no reaction

**1**

**H** Acyl chloride

AgNO3

(white) ppt

Na2CO3/NaHCO3 named carbonate

Effervescence or CO2 or fumes or exothermic

water

fumes

named indicator

acid colour

Named alcohol

Smell or fumes

Named amine or ammonia

fumes

**1**

*Allow iodoform test or Brady’s reagent (2,4,dnph) test (both positive for G)*

(iii)     Single reagent

If wrong single reagent, CE = zero  
Incomplete single reagent (e.g. carbonate) or wrong  
formula (e.g.NaCO3) loses reagent mark, but mark on

For “no reaction” allow “nothing”

Different reagents

If different tests on E and F; **both** reagents and any follow  
on chemistry must be correct for first (reagent) mark.

Reagent must react: i.e. not allow Tollens on  
G (ketone) – no reaction.

Second and third marks are for correct observations.

i.e. for different tests on E and F, if one reagent is correct  
and one wrong, can score max 1 for correct observation  
with correct reagent.

**1**

**J** Primary alcohol

K2Cr2O7/ H+

goes green

KMnO4/ H+

decolourised / goes brown

Lucas test (ZnCl2/HCl)

*Penalise missing H+ but mark on*

**1**

**K** Tertiary alcohol

K2Cr2O7/ H+

No reaction

KMnO4/ H+

no reaction

Lucas test (ZnCl2/HCl)

Rapid cloudiness

**1**

*If uses subsequent tests e.g. Tollens/Fehlings, test must be on product of oxidation*

(b)     (i)      3,3-dimethylbutan-1-ol

*Allow 3,3-dimethyl-1-butanol*

**1**

4

**1**

Triplet on three

**1**

(ii)     2-methylpentan-2-ol

*Allow 2-methyl-2-pentanol*

**1**

5

**1**

Singlet or one or no splitting

**1**

**[15]**

**M15.**(a)     **If 2 stage test for one compound, award no marks for that compound, eg no mark for ROH or RX to alkene then Br2 test. If reagent is wrong or missing, no mark for that test; if wrong but close/incomplete, lose reagent mark but can award for correct observation. In each test, penalise each example of wrong chemistry, eg AgClr2**

propan-1-ol

acidifiedpotassiumdichromate

sodium

Named acid + conc H2SO4

named acyl chloride

PCl5

M1

**1**

(orange) turns green

effervescence

Sweet smell

Sweet smell /misty fumes

Misty fumes

M2

**1**

propanal

add Tollens or Fehlings / Benedicts

acidifiedpotassiumdichromate

Bradys or 2,4-dnph

*if dichromate used for alcohol cannot be used for aldehyde*

M3

**1**

Tollens: silver mirror or Fehlings/ Benedicts: red ppt

(orange) turns green

Yellow or orange ppt

M4

**1**

propanoic acid

Named carbonate/ hydrogencarbonate

water and UI (paper)

Named alcohol + conc H2SO4

sodium or magnesium

PCl5

*if sodium used for alcohol cannot be used for acid*

M5

**1**

effervescence

orange/red

Sweet smell

effervescence

Misty fumes

*if PCl5 used for alcohol cannot be used for acid*

M6

**1**

1-chloro propane

NaOH then acidified AgNO3

AgNO3

*If acidification missed after NaOH,no mark here but allow mark for observation*

M7

**1**

white ppt

white ppt

M8

**1**

(b)      oxidation (of alcohol by oxygen in air)

M1

**1**

absorption at 1680 -1750 (due to C=O)

*Must refer to the spectrum*

M2

**1**

comparison of polarity of molecules or correct imf statement:propanone is less polar OR propan-2-ol is more polarOR propanone has dipole-dipole forcesOR propan-2-ol has hydrogen bonding

M3

**1**

about attraction to stationary phase or solubility in moving phasePropan-2-ol has greater affinity for stationary phase or vice versaOR propanone is more soluble in solvent/moving phase or vice versa

M4

**1**

**[12]**

**M16.**(a)     CH3COCl   +   AlCl3    CH3CO+   +   AlCl4–

*Allow RHS as *

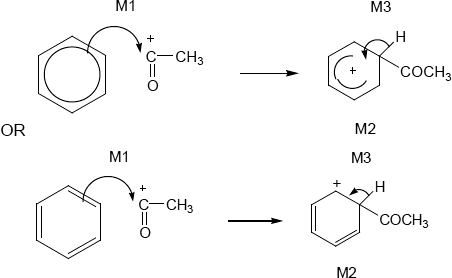
*Allow + on C or O in equation but + must be on C in mechanism below*

*Ignore curly arrows in equation even if wrong.*

**1**

AlCl4– + H+  AlCl3 + HCl

**1**

****

*• M1 arrow from within hexagon*

*to C or to + on C*

*• + must be on C of RCO in mechanism*

*• + in intermediate not too close to C1*

*• gap in horseshoe must be centred approximately around C1*

*• M3 arrow into hexagon unless Kekule*

*• allow M3 arrow independent of M2 structure*

*• ignore base removing H for M3*

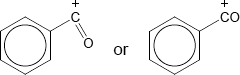
*•* ***NO*** *mark for name of mechanism*

**3**

Phenylethanone             ignore 1 in name, penalise other numbers

*Note: this is the sixth marking point in (a)*

**1**

(b)

*+ must be on C*

*But allow [C6H5CO]+*

**1**

(c)     M1 about electrons

methyl group has (positive) inductive effect OR increases electron density on   
benzene ring OR pushes electrons OR is electron releasing

*Ignore reference to delocalisation*

**1**

M2 about attraction

electrophile attracted more

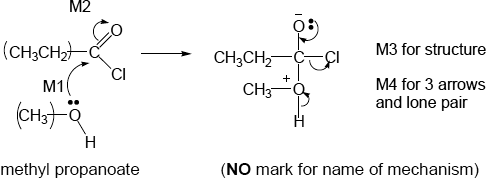
or benzene ring better nucleophile

*Allow intermediate ion stabilised*

***M2 only awarded after correct or close M1***

**1**

**[9]**

**M17.**(a)

*•         M2 not allowed independent of M1, but allow M1 for correct          attack on C+*

*•         + rather than δ+ on C=O loses M2*

*•         If Cl lost with C=O breaking, max1 for M1*

*•         M3 for correct structure with charges but lp on O          is part of M4*

*•         only allow M4 after correct/very close M3*

*•         ignore Cl – removing H+*

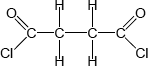
**4**

**1**

(b)     (i)      pentane-1,5-diol

*Second ‘e’ and numbers needed*

*Allow 1,5-pentanediol but this is not IUPAC name*

(ii)

*Must show ALL bonds*

**1**

(iii)     All three marks are independent

M1 (base or alkaline) Hydrolysis   (allow close spelling)

**1**

*Allow (nucleophilic) addition-elimination or saponification*

M2 δ+ C in polyester

**1**

M3 reacts with OH– or hydroxide ion

**1**

*Not reacts with NaOH*

**1**

(c)     (i)

*Allow CH3COOH or CH3CO2H*

**1**

(ii)     (nucleophilic) addition-elimination

*Both addition and elimination needed and in that order*

OR

(nucleophilic) addition followed by elimination

*Do* ***not*** *allow electrophilic addition-elimination / esterification*

*Ignore acylation*

**1**

(iii)     any **two** from: ethanoic anhydride is

•         less corrosive

•         less vulnerable to hydrolysis

•         less dangerous to use,

•         less violent/exothermic/vigorous reaction OR more controllable rxn

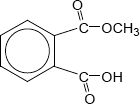
•         does not produce toxic/corrosive/harmful fumes (of HCl) OR does not  
produce HCl

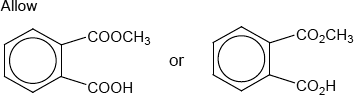
•         less volatile

***NOT*** *COST*

*List principle beyond two answers*

**2**

(d)



**1**

(e)     (i)      ester

*Do* ***not*** *allow ether*

*Ignore functional group/linkage/bond*

**1**

(ii)     12 or twelve (peaks)

**1**

(iii)     160 – 185

*Allow a number or range within these limits*

*Penalize extra ranges given*

*Ignore units*

**1**

|  |  |  |
| --- | --- | --- |
| (f)     (i)      sulfuric acid | sodium hydroxide |  |
| hydrochloric acid | ammonia | X or blank |
| ethanoic acid | potassium hydroxide |  |
| nitric acid | methylamine | X or blank |

*4 correct       scores 2*

*3 correct       scores 1*

*2 or 1 correct   scores 0*

**2**

(ii)     Pink to colourless

*Allow ‘red’ OR ‘purple’ OR ‘magenta’ instead of ‘pink’*

*Do* ***not*** *allow ‘clear’ instead of ‘colourless’*

**1**

**[21]**

**M18.**In each section

•        If wrong or no reagent given, no marks for any observations;

•        Penalise incomplete reagent or incorrect formula – but mark observations

•        Mark each observation independently

•        Allow *no reaction* for no change / no observable reaction in all three parts, but not *none* or *nothing*

•        Q says **one test**. If two tests are given, score zero

(a)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | K2Cr2O7 / H+ | KMnO4 / H+ | Lucas test (ZnCl2 / HCl) |

**1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **R**  Primary alcohol | (Orange) goes green Penalise wrong starting colour | (purple) goes colourless / decolourises allow goes brown | No cloudiness |

**1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **S**  Tertiary alcohol | no change / no observable reaction | no change / no observable reaction | Rapid cloudiness |

**1**

*Allow acidified potassium manganate and acidified potassium dichromate without oxidation numbers*

(b)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Na2CO3 / NaHCO3 named carbonate | metal eg Mg | named indicator |

*PCl5      PCl3*

*SOCl2*

*Named alcohol + HCl / H2SO4*

**1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **T**  ester | no change / no observable reaction | no change / no observable reaction | no effect |

*no change / no observable reaction*

**1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **U**  Acid | Effervescence or (CO2) gas formed | Effervescence or (H2) gas formed | acid colour |

*Fumes / (HCl) gas formed*

*Sweet smell*

**1**

(c)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | Fehling’s / Benedict’s | Tollens’ / [Ag(NH3)2]+ | |  |  | | --- | --- | |  | K2Cr2O7/ H+ | |

*I2 / NaOH*

**1**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **V**  Ketone | no change / no observable reaction | |  |  | | --- | --- | |  | no change / no observable reaction | | |  |  | | --- | --- | |  | no change / no observable reaction | |

*Yellow ppt*

**1**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **W**  aldehyde | Red ppt | Silver mirror | |  |  | | --- | --- | |  | (Orange) goes green Penalise wrong starting colour | |

*no change / no observable reaction*

**1**

**[9]**