

IMPERIAL COLLEGE LONDON

**BSc and MSci DEGREES – JANUARY 2012, for Internal Students of the
Imperial College of Science, Technology and Medicine**

**This paper is also taken for the relevant examination for the
Associateship**

ADVANCED CHEMISTRY THEORY IIIA

Organic Chemistry

Tuesday 10th January 2012, 14:00-17:00

**PLEASE NOTE THAT IT IS DEPARTMENTAL POLICY THAT THESE
EXAM QUESTIONS MAY REQUIRE UNDERSTANDING OF ANY PRIOR
CORE COURSE.**

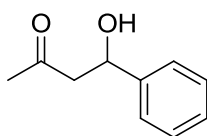
**USE A SEPARATE ANSWER BOOK FOR EACH QUESTION.
WRITE YOUR CANDIDATE NUMBER ON EACH ANSWER
BOOK.**

3.O11 – Synthesis Part 2

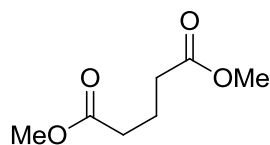
Answer **ALL** parts of this question.

- a) For each of the compounds **A** and **B** shown below, show a simplifying C-C bond disconnection. Identify the synthons implied by your disconnections, and write down the synthetic equivalents of the synthons.

(2 x 5 marks)



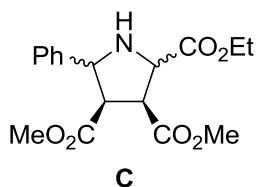
A



B

- b) Show how compound **C** below may be disconnected using a cycloaddition reaction. (Details of the synthesis of the cycloaddition starting materials are NOT required). Why do the two methyl esters have the *cis*-relative configuration in the product **C**?

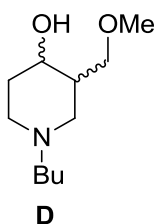
(5 marks)



C

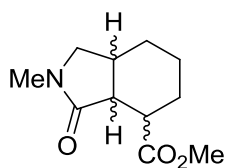
- c) Devise a synthesis of **EITHER** compound **D** OR compound **E** shown below. Your starting materials should have 5 carbons or fewer. Show clearly your retrosynthetic analysis, identifying synthons and synthetic equivalents where appropriate. Propose reagents for your forward synthesis where required and mention any possible issues of selectivity.

(10 marks)



D

(stereocontrol not required)



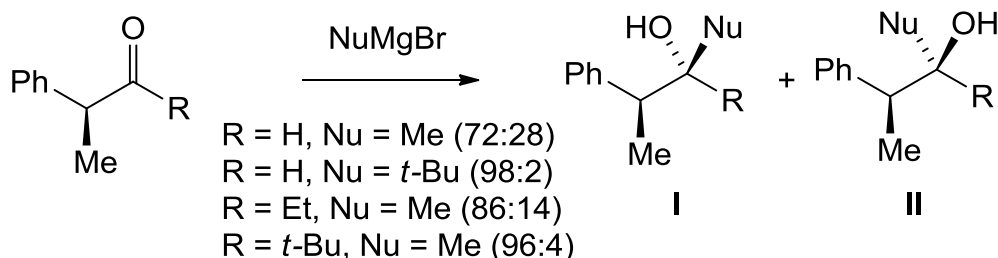
E

(stereocontrol not required)

3.O12 – An Introduction to Reaction Stereoelectronics

Answer **BOTH** part a) **AND** part b) of this question.

- a) Consider the following four reactions which involve the addition of Grignard reagents to α -chiral aldehydes and ketones. The ratios in parentheses are those of the two products.



- i) All these reactions give a major product having the same relative stereochemistry. Is the major product **I** or **II**? Why is it formed in preference to the other one?

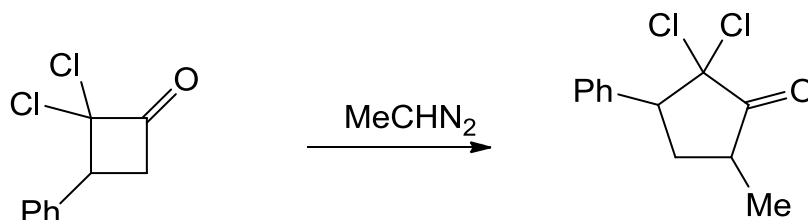
(7 marks)

- ii) Explain why the selectivity increases when both the size of nucleophile increases and the size of the R group increases.

(3 marks)

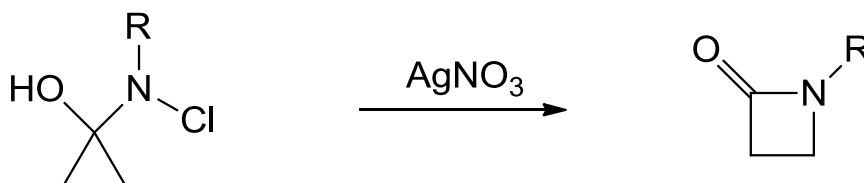
- b) Give a mechanism for **THREE** of the **FIVE** following transformations. Indicate all products and show any stereoelectronic control.

i)



(5 marks)

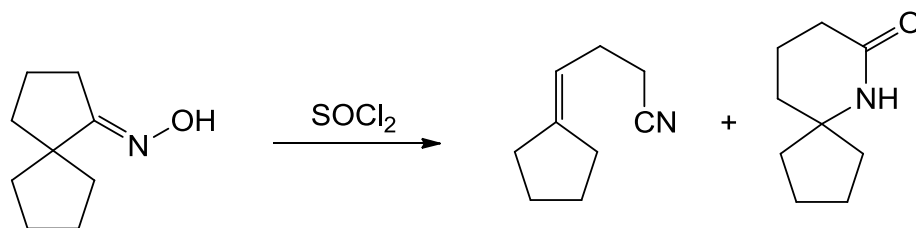
ii)



(5 marks)

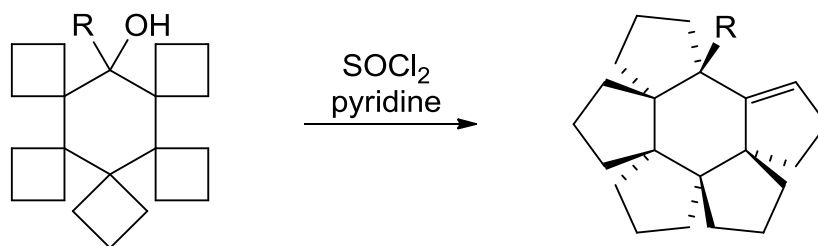
QUESTION CONTINUED OVERLEAF

iii)



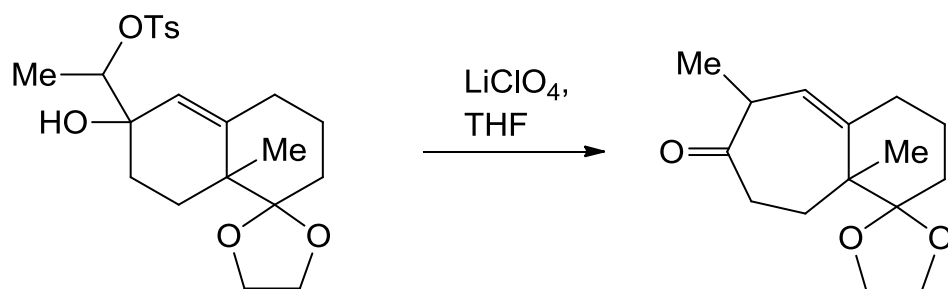
(5 marks)

iv)



(5 marks)

v)



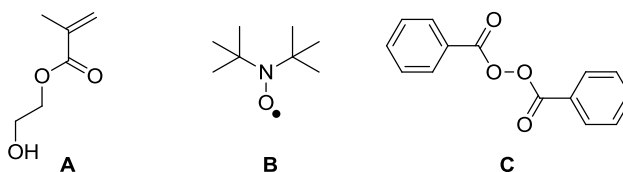
(5 marks)

3.O3 – Polymers – The Essential Guide

Answer **BOTH** part a) **AND** part b) of this question.

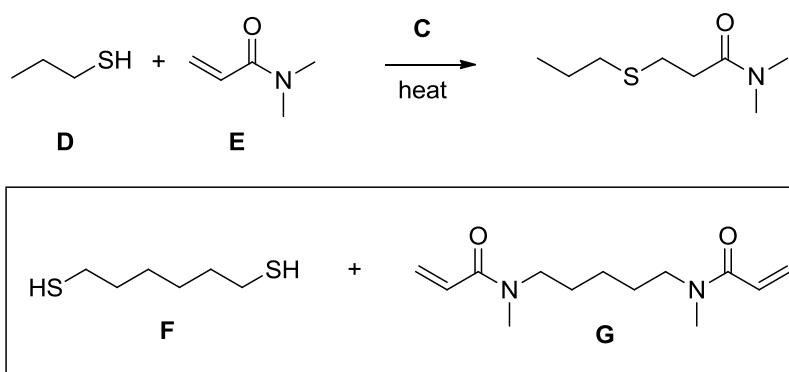
a) Answer **ALL** parts of this question.

- i) Identify three chain transfer processes that occur in free radical polymerisation.
(3 marks)
- ii) Describe in mechanistic detail the initiation, propagation and termination steps of a controlled nitroxide-mediated polymerisation of 2-hydroxyethyl methacrylate (**A**).
Use **B** as your nitroxide agent and benzoyl peroxide (**C**) as your initiator.
(7 marks)



b) Answer any **FIVE** of the **EIGHT** questions (i) – (viii)

The conjugate addition of a thiol to an α,β -unsaturated carbonyl compound can proceed via a radical mechanism initiated by benzoyl peroxide **C**. An example is shown for thiol **D** and Michael acceptor **E**. With difunctional thiols and difunctional Michael acceptors (**F** and **G**) linear polymers are formed. **Hint**: treat the thiols in these reactions as radical chain transfer agents.



QUESTION CONTINUED OVERLEAF

- i) Write down the repeat unit of the polymer derived from monomers **F** and **G**.
(3 marks)
- ii) Provide mechanistic details for the initiation and propagation reaction in the polymerisation of monomers **F** and **G**.
(3 marks)
- iii) Provide mechanistic details for a termination reaction in the polymerisation of monomers **F** and **G**.
(3 marks)
- iv) Is the polymerisation of monomers **F** and **G** a chain growth or a step growth polymerisation? Justify your choice.
(3 marks)
- v) What effect would an increase of the amount of thiol **F** have on the number average molecular weight (M_n) of the polymer product? Explain.
(3 marks)
- vi) Without any thiol **F** present, what polymer structure (repeat units) would you form? Explain.
(3 marks)
- vii) Draw the molecular structure of the product you would form when you react **B**, **F** and **G** in a molar ratio of 2:1:1.
(3 marks)
- viii) What would be the consequence on polymer properties if the dithiol **F** were replaced by a trithiol compound?
(3 marks)

3.O4 – Introduction to Physical Organic Chemistry

Answer part a) and **EITHER** part b) **OR** part c) of this question.

a) Answer **ALL** parts of this question.

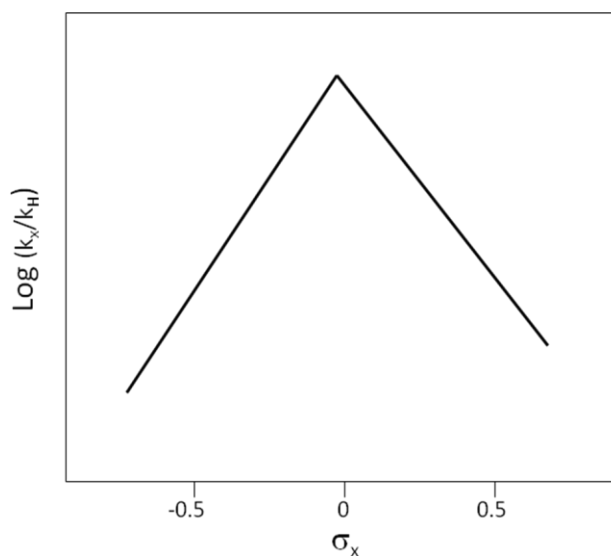
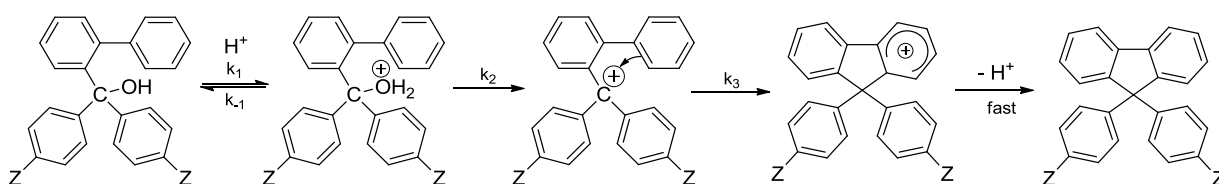
The Friedel Crafts alkylation reaction shown below, was observed to have the nonlinear Hammett plot shown below.

i) Explain its shape based on the scheme shown.

(3 marks)

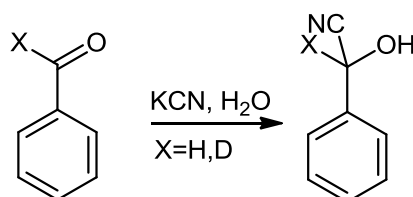
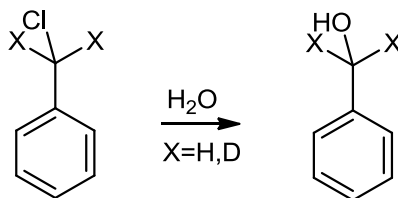
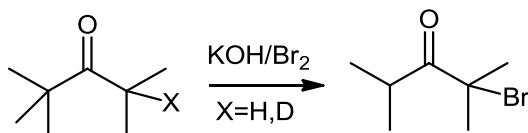
ii) Is the approximate magnitude of ρ for both sides of the plot likely to be greater or less than one? Explain your answer.

(3 marks)



QUESTION CONTINUED OVERLEAF

- iii) The following three reactions below exhibit either primary, secondary or inverse kinetic isotope effects.



A. For all three reactions, state which kinetic isotope effect will occur.

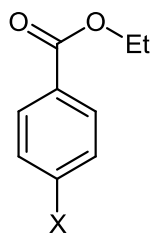
(3 marks)

B. Predict an approximate $k_{\text{H}}/k_{\text{D}}$ value for each type of kinetic isotope effect.

(3 marks)

- iv) Answer **ALL** parts of this question.

A. Provide a mechanism for the specific base catalysed hydrolysis of the substituted ethyl benzoate ester below.



(3 marks)

B. Identify the rate determining step, and estimate a ρ value from a Hammett plot of the hydrolysis reaction rates of a series of X substituents.

(3 marks)

C. What is the effect on the reaction rate when the base concentration is varied at constant pH?

(1 mark)

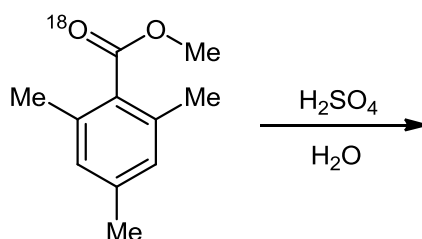
QUESTION CONTINUED OVERLEAF

b) Answer **ALL** parts of this question.

- i) The nucleophilic substitution of chlorodiphenylmethane with ethanol can occur by either S_N1 or S_N2 mechanism, depending on the choice of substituent on the phenyl groups. How would the entropy of activation differ between the two mechanisms? (2 marks)
- ii) What effect would the choice of solvent have on the rate of reaction in both cases? (1 mark)
- iii) Sketch the expected non-linear Hammett plot for the reaction. (3 marks)

c) Answer **ALL** parts of this question.

The acid catalysed hydrolysis of methyl mesitoate, shown below, labelled with ^{18}O in the carbonyl oxygen provides mesitoic acid with no loss of the ^{18}O label.



- i) Draw the two possible mechanisms (unimolecular or bimolecular acyl-oxy cleavage). (4 marks)
- ii) Is this observation above consistent with the unimolecular acyl-oxy or bimolecular acyl-oxy cleavage mechanism? Explain your reasoning. (2 marks)