

Carbonyl group

Question Paper

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Carbonyl group-Lower functional group level
Booklet	Question Paper

Time Allowed: 47 minutes

Score: /39

Percentage: /100

Grade Boundaries:

1. Grignard reagents are formed readily by iodoalkanes. This question concerns the conversion of a ketone, pentan-2-one, to a tertiary alcohol using a Grignard reagent.

Table 5.1 summarises the volatilities and hazards of the reagents and the organic product.

Table 5.1

substance	volatility	hazard
iodoethane	moderate	flammable; toxic; respiratory irritant
ethoxyethane	high	flammable; harmful
magnesium turnings	non-volatile	flammable
pentan-2-one	low	flammable; harmful
product alcohol	very low	flammable; irritant

- (a) (i) What are the **two** most important safety measures to guard against the hazards of these materials? You can assume that the experimenters are wearing gloves, eye protection and lab coats.

.....

 [2]

- (ii) The day before the experiment anhydrous calcium chloride is added to the iodoethane, sodium wire is added to the ethoxyethane and the glassware is left in an oven.

Suggest the single purpose of these three precautions.

.....
 [1]

Step one

1.50g of magnesium turnings is added to a pear-shaped flask with an equimolar quantity of iodoethane and 20 cm³ of ethoxyethane.

Table 5.2 gives some physical properties of the reagents and the organic product.

Table 5.2

substance	formula	molar mass /g mol ⁻¹	density /g cm ⁻³	solubility in water	boiling point /°C
iodoethane	C ₂ H ₅ I	156	1.93	slightly soluble	72
ethoxyethane	C ₂ H ₅ OC ₂ H ₅	74	0.713	slightly soluble	35
magnesium turnings	Mg	24.3	1.74	insoluble	1110
pentan-2-one	C ₅ H ₁₀ O	86	0.814	slightly soluble	102
product alcohol			0.823	slightly soluble	143

(b) (i) Calculate the amount, in mol, of magnesium used.

amount = mol [1]

(ii) Calculate the volume of iodoethane required to react with the magnesium.

volume = cm³ [2]

(iii) Suggest the role of the ethoxyethane.

..... [1]

Step two

A crystal of iodine is added to the mixture from **step one** to activate the magnesium, and this mixture is refluxed.

(c) (i) Suggest why elevated temperatures and long periods of time are required for reactions such as this.

.....

 [2]

(ii) Give the structural formula of the Grignard reagent that is the product of **step two**.

..... [1]

Step three

The mixture from **step two** is allowed to cool and 6.0 cm^3 of pentan-2-one is added dropwise. The mixture is then gently heated under reflux.

- (d) (i) Draw the structure of the product of the reaction between the Grignard reagent and pentan-2-one which is present at the end of **step three**.

[1]

- (ii) Show with a calculation that the Grignard reagent is in excess. Assume that the reaction between magnesium and iodoethane in **step two** had 100% yield. Use your answer to **(b)(i)**.

[2]

Step four

The mixture from **step three** is cooled using an ice bath, and then 25 cm^3 of 4 mol dm^{-3} hydrochloric acid is slowly added.

- (e) (i) Draw the structure of the tertiary alcohol produced by the reaction with dilute hydrochloric acid.

[1]

- (ii) What organic by-product results from the addition of the hydrochloric acid?

..... [1]

- (iii) Suggest why the mixture is cooled before adding the hydrochloric acid.

.....
..... [1]

Step five

The mixture from **step four** is added to a separating funnel. The lower aqueous layer is separated and shaken successively with two 10 cm³ portions of ethoxyethane, retaining the ethoxyethane extracts and combining them with the original ethoxyethane layer.

- (f) (i) Using the data in Table 5.2, explain why the ethoxyethane forms a layer above the aqueous layer.

.....
..... [2]

- (ii) Suggest the purpose of shaking the aqueous layer with ethoxyethane.

.....
..... [1]

Step six

The combined ethoxyethane layer is washed successively with 20 cm³ of

1. water,
2. saturated sodium hydrogencarbonate solution,
3. 1 mol dm⁻³ aqueous sodium thiosulfate,
4. saturated sodium chloride solution.

- (g) The water and the three aqueous solutions used to wash the ethoxyethane layer are each intended to remove a particular impurity, either by dissolving or by chemical reaction followed by dissolving.

Suggest the impurity removed in each step.

1. water
2. saturated sodium hydrogencarbonate
3. sodium thiosulfate
4. saturated sodium chloride [4]

Step seven

The ethoxyethane layer is allowed to stand over anhydrous magnesium sulfate.

(h) What is the purpose of the anhydrous magnesium sulfate?

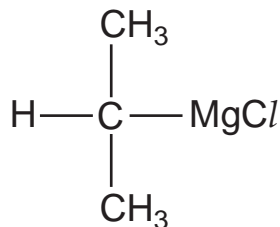
..... [1]

(i) Using the data in Table 5.2, describe how you would obtain a pure sample of the product alcohol.

.....
.....
..... [2]

[Total: 26]

2. (a) Grignard reagents are commonly used in synthesis to create carbon-carbon bonds. The structure is shown of the Grignard reagent formed from the reaction of 2-chloropropane and magnesium. Show the dipole on the relevant bond to carbon.



[1]

- (b) Which three of the following terms describe a Grignard reagent? Circle the three correct answers.

reducing agent

acid

oxidising agent

base

electrophile

nucleophile

[3]

- (c) The Grignard reagent from part (a) reacts with ethanal.

- (i) Draw the structure of the organic product of this reaction.

[1]

- (ii) Identify any chiral carbon atoms in the product with an asterisk (*). [1]

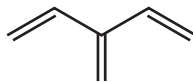
- (iii) Name this organic product.

..... [1]

- (d) Solvents that are employed for Grignard chemistry need to be rigorously dried. By considering the dipole on the O–H bonds in water, suggest what organic product results from getting the Grignard compound in part (a) wet.

[1]

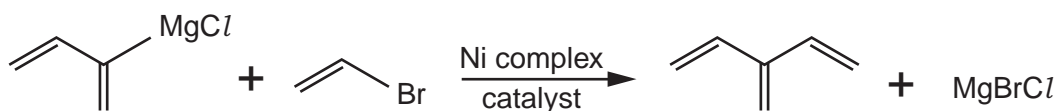
- (e) Recent research (*Angewandte Chemie International Edition*, 2009) has produced the first practical synthesis of dendralenes. Dendralenes are acyclic conjugated polyalkenes. An example is shown.



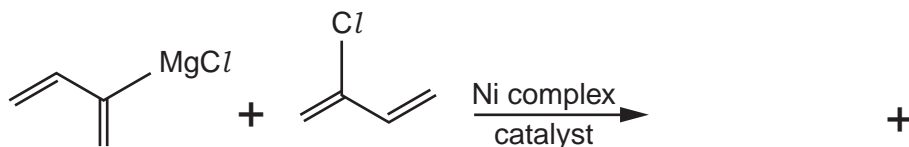
- (i) What is the molecular formula of this compound?

.....[1]

- (ii) The breakthrough was the discovery of the nickel complex that catalysed the process. An example of their dendralene synthesis is shown.



Complete the equation below by inserting the skeletal formula of the organic product and the formula of the inorganic product.



[2]

- (iii) The Grignard reagent from part (e)(ii) can also react with 1,1-dichloroethene in the presence of the nickel complex catalyst. Draw the skeletal formula of the dendralene product.

[2]

[Total: 13]