

**Advanced GCE  
CHEMISTRY B (SALTERS)**

**F335 QP**

Unit F335: Chemistry by Design

**Specimen Paper**

Candidates answer on the question paper.

Time: 2 hours

Additional Materials:

Data Sheet for Chemistry B (Salters) (Inserted)  
Scientific calculator

Candidate  
Name

Centre  
Number

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Candidate  
Number

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**INSTRUCTIONS TO CANDIDATES**

- Write your name, Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do **not** write in the bar code.
- Do **not** write outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED.

**INFORMATION FOR CANDIDATES**

- The number of marks is given in brackets [] at the end of each question or part question.
-  Where you see this icon you will be awarded marks for the quality of written communication in your answer.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry B (Salters)* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **120**.

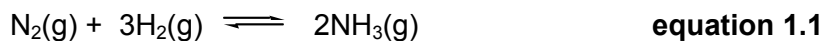
**FOR EXAMINER'S USE**

Qu.	Max.	Mark
1	24	
2	22	
3	29	
4	29	
5	16	
<b>TOTAL</b>	<b>120</b>	

This document consists of **19** printed pages, **1** blank page and a *Data Sheet for Chemistry B (Salters)*.

Answer **all** the questions.

- 1 Hydrogen is used to make ammonia, an important agricultural chemical.



Ammonia is used to make fertilisers.

- (a) (i) Suggest the cheapest source for the nitrogen gas used in **equation 1.1**.

..... [1]

- (ii) Ammonium nitrate,  $\text{NH}_4\text{NO}_3$ , is a fertiliser made from ammonia.

Calculate the percentage by mass of nitrogen in  $\text{NH}_4\text{NO}_3$ .

answer = .....% [2]

- (iii) Ammonium sulfate is another fertiliser.

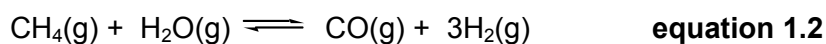
Write the formula of ammonium sulfate.

..... [1]

- (iv) Explain **one** advantage and **one** disadvantage of adding ammonium salts to the soil.

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

- (b) Hydrogen is produced industrially from methane by *steam reforming* as shown below.



- (i) Write an expression for  $K_c$  for the reaction in **equation 1.2**.

[2]

- (ii) At the temperature of the reaction,  $K_p = 292 \text{ mol}^2 \text{ dm}^{-6}$ . The concentrations of some of the gases present in an equilibrium mixture at this temperature were measured and are given in the table below.

gas	concentration/ $\text{mol dm}^{-3}$
$\text{CH}_4$	5.00
$\text{H}_2\text{O}$	5.00
$\text{H}_2$	12.0

Calculate the concentration of carbon monoxide under these conditions.

Give your answer to a **suitable** number of significant figures.

[CO] = .....  $\text{mol dm}^{-3}$  [3]

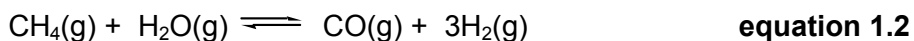
- (c) (i) Use Le Chatelier's principle to predict the effect of **decreasing** the pressure on the yield of hydrogen in **equation 1.2**.

.....  
 .....  
 .....  
 ..... [3]

- (ii) Suggest a reason why a pressure of around 30 atm is actually used for the process.

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

[Turn over



(d) The mixture of gases from the reaction in **equation 1.2** is mixed with more steam and passed over a hot iron catalyst. The carbon monoxide is converted to carbon dioxide.

(i) Write an equation for the reaction of carbon monoxide with steam.

[1]

(ii) Suggest **two** reasons why the carbon monoxide is **not** released into the atmosphere.

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

(e) (i) Predict the sign of  $\Delta S_{\text{sys}}$  for the forward reaction in **equation 1.2**. Explain your reasoning.

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

(ii) Use the entropy data given in the table below to calculate the value of  $\Delta S_{\text{sys}}$  (with the correct **sign**) for the forward reaction in **equation 1.2**.

compound	$S/\text{J K}^{-1} \text{mol}^{-1}$
$\text{CH}_4(\text{g})$	+186
$\text{H}_2\text{O}(\text{g})$	+189
$\text{CO}(\text{g})$	+198
$\text{H}_2(\text{g})$	+131

$\Delta S_{\text{sys}}$  .....  $\text{J K}^{-1} \text{mol}^{-1}$  [3]

(iii) At 500 K the value of  $\Delta S_{\text{tot}}$  for the forward reaction is  $-1784$ .

Calculate the value of  $\Delta S_{\text{tot}}$  at 1000 K.

Assume that  $\Delta S_{\text{sys}}$  does not change with temperature.

$\Delta S_{\text{tot}} =$  .....  $\text{J K}^{-1} \text{mol}^{-1}$  [2]

[Total: 24]

2 The pigment *chrome yellow* consists of lead chromate(VI),  $\text{PbCrO}_4$ . It is made by precipitation when solutions of lead nitrate and sodium chromate(VI) are mixed.

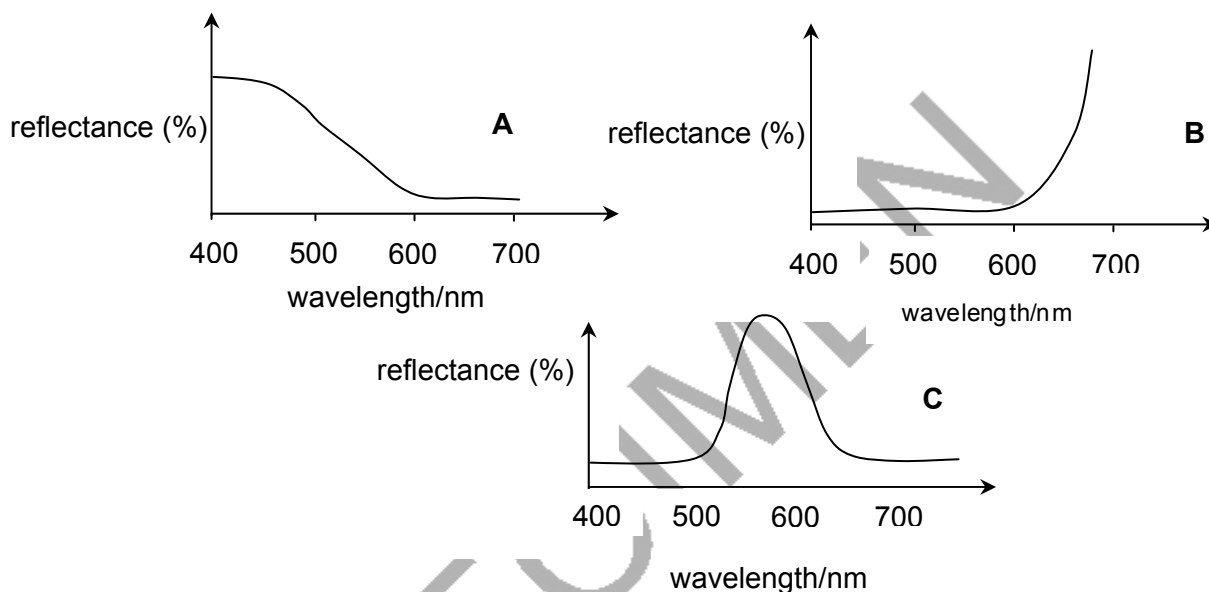
(a) Explain why (VI) is used to describe the  $\text{CrO}_4^{2-}$  ion.

..... [1]

(b) Write an **ionic** equation for the precipitation of lead chromate(VI), showing state symbols.

[2]

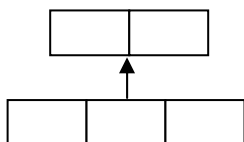
(c) Pigments can be identified by their visible reflectance spectra. The spectra of three pigments are shown below, lettered **A**, **B** and **C**.



Suggest, with a reason, which is the reflectance spectrum of chrome yellow.

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

(d) The diagram below helps to explain the yellow colour of the chromate ion.



(i) Which electron sub-shell is shown in the diagram?

..... [1]

(ii) What causes the splitting of the orbitals within the sub-shell?

..... [1]

[Turn over

(e) A painting is being analysed. Four yellow pigments it might contain are shown below.

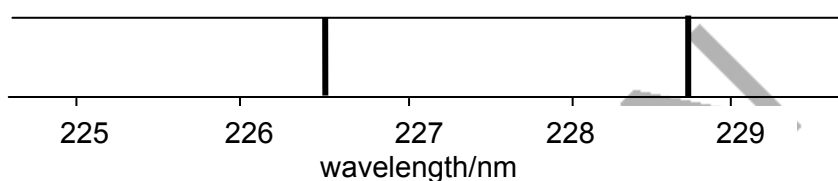
- barium yellow,  $\text{BaCrO}_4$
- cadmium yellow,  $\text{CdS}$
- orpiment,  $\text{As}_2\text{S}_3$
- yellow ochre, containing  $\text{Fe}_2\text{O}_3$

(i) Give the systematic name of the compound contained in yellow ochre.

..... [1]

(ii) One method of identifying pigments is to use atomic emission spectroscopy.

Part of a simplified atomic emission spectrum of the pigment is shown below.



Explain why the emissions occur at specific frequencies.

Include a diagram in your answer.

*In your answer, you should make clear how the observed effect depends on the explanation.*

.....  
 .....  
 .....

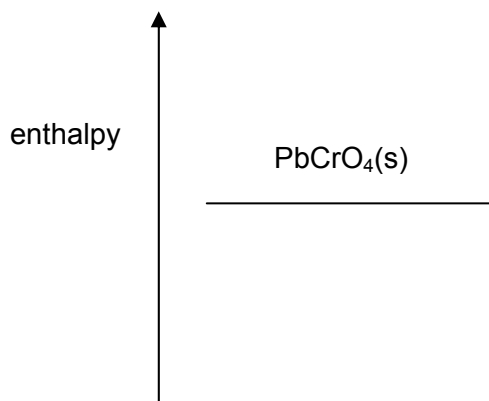
..... [4]

(iii) Use the data in the table below to identify the element and hence the **systematic name** of the pigment.

element	certain characteristic emissions/nm
Ba	233.5
Cd	228.8 226.5
As	228.8 235.0
Fe	238.2 239.7

element is ..... systematic name of pigment is ..... [2]

- (f) Lead chromate(VI) is insoluble because it has an enthalpy change of solution of  $+17 \text{ kJ mol}^{-1}$ . An estimate of the lattice enthalpy of lead chromate is  $-1000 \text{ kJ mol}^{-1}$ .
- (i) Complete the diagram to illustrate this by drawing and labelling suitable enthalpy levels and inserting the given values. Then use your diagram to calculate the sum of the enthalpy changes of hydration of the lead and chromate ions.



[3]

sum of enthalpy changes of hydration = .....  $\text{kJ mol}^{-1}$  [1]

- (ii) Explain, in terms of bonds broken and made, the endothermic nature of this dissolving process, naming the bonds involved.

*In your answer, you should use appropriate technical terms, spelled correctly.*

.....

.....

.....

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.....

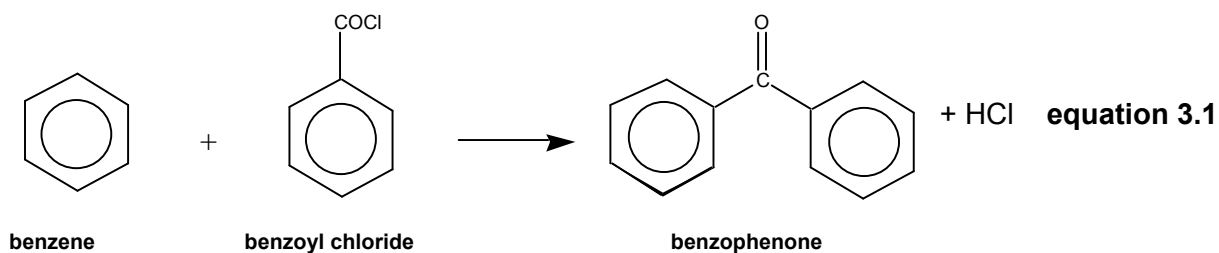
.....

[4]

[Total: 22]

[Turn over]

- 3 The compound benzophenone is used in cosmetics and as a sunscreen. It can be prepared in the laboratory by the following reaction in the presence of an aluminium chloride catalyst.



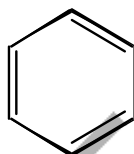
- (a) (i) Draw the **full structural formula** for the acyl chloride group in **benzoyl chloride**.

[1]

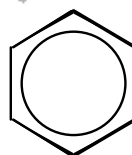
- (ii) Name the **reaction mechanism** by which benzene reacts in **equation 3.1**.

[2]

- (b) An alternative way of representing the structure of **benzene** is shown as **representation 1** below.



representation 1



representation 2

Give reasons why **representation 2** is sometimes preferred. Give **one** reason in terms of the shape of the molecule and **one** reason in terms of its chemical properties.

shape.....

.....

chemical properties .....

..... [2]



- (c) Sunscreens absorb ultraviolet radiation.

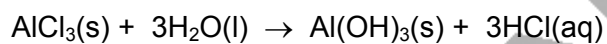
Explain, in terms of electronic energy levels, why a substance such as benzophenone absorbs in the ultraviolet but is not coloured.

*In your answer, you should make clear how your explanation links with what is observed.*

.....  
.....  
.....  
.....  
.....

[5]

- (d) The most effective way of removing the aluminium chloride at the end of the reaction is to hydrolyse it with water and to run it to waste.

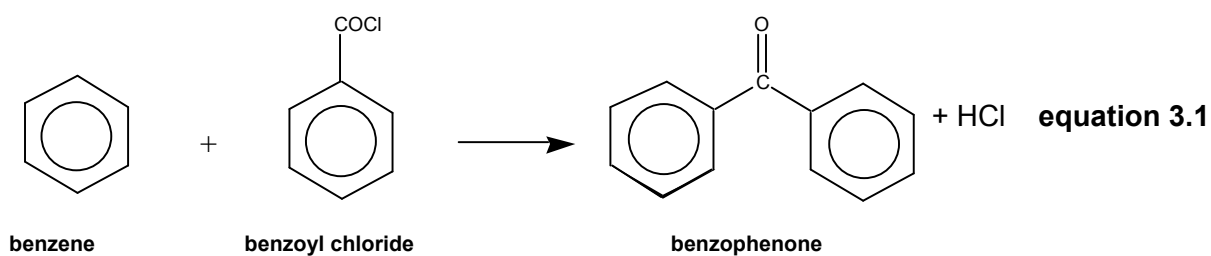


In the 1980s, benzophenone was made industrially by this method. Suggest and explain **two** reasons why this could lead to environmental hazards.

.....  
.....  
.....  
.....  
.....  
.....

[4]

[Turn over



(e) More recently, benzophenone has been prepared using another metal catalyst and a solvent that is an ionic liquid. A very high percentage yield is achieved and the catalyst and the solvent can be recycled.

(i) Explain the meaning of the term *ionic liquid*.

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

(ii) If the percentage yield were 100%, calculate the maximum mass of benzophenone that could be produced from 10 kg of **benzene**.

answer = ..... kg [2]

(iii) Calculate the atom economy of the reaction in **equation 3.1**.

answer = ..... % [2]

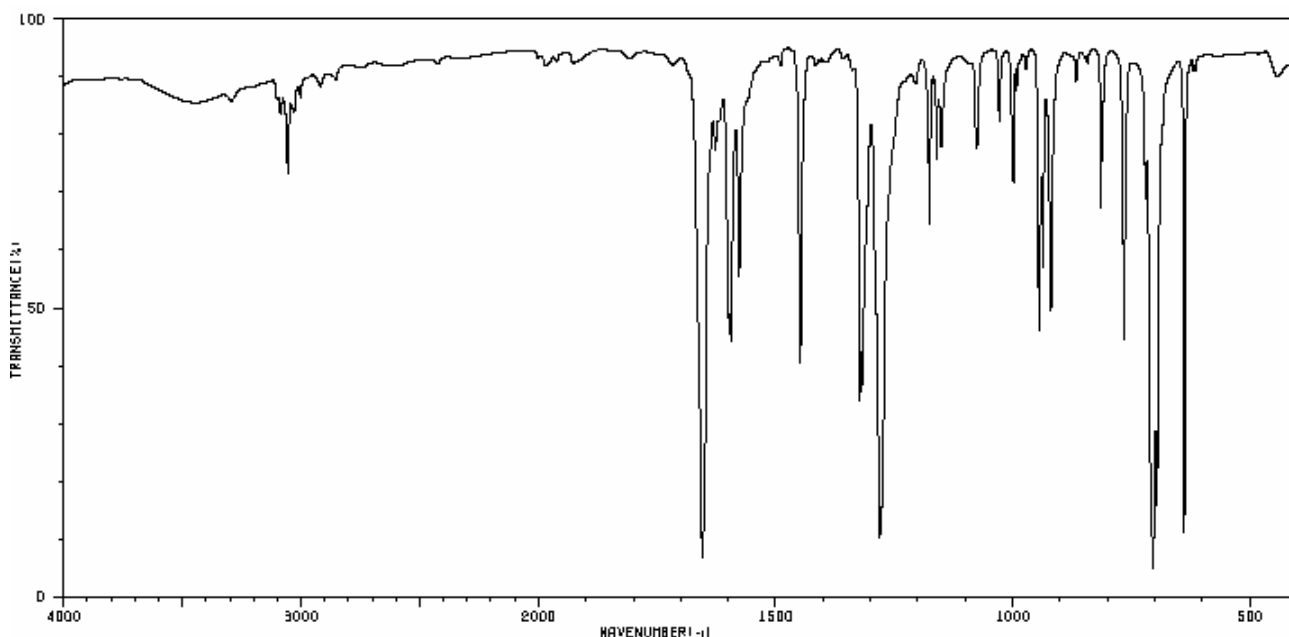
(iv) Explain the importance to society and the environment of using the modern method of making benzophenone.

.....  
 .....  
 .....  
 .....  
 ..... [4]

- (v) The ionic liquid contains the  $\text{PF}_6^-$  ion. Draw a 'dot-and-cross' diagram for this ion and give a word that describes its shape.

shape ..... [3]

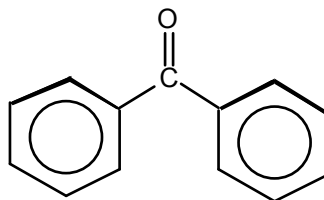
- (f) A chemist wished to confirm the identity of a sample of benzophenone by recording its infrared and proton NMR spectra. The infrared spectrum is shown below.



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- (i) Use the *Data Sheet* to select one absorption in the spectrum that is characteristic of benzophenone. Label this absorption with the bond that causes it. [1]
- (ii) The proton NMR spectrum of benzophenone contains three signals in the ratio 2 : 2 : 1.

Mark on the structure below all the protons in each environment, lettering the environments **a**, **b** and **c**.



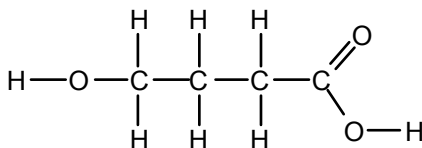
benzophenone

[2]

[Total: 29]

[Turn over

- 4 The substance GHB was originally designed for use in sleeping pills. However, other drug-abuse issues were identified with the substance and its sale was restricted in 2003. GHB stands for hydroxybutyric acid, an old name for the structure shown below.



GHB

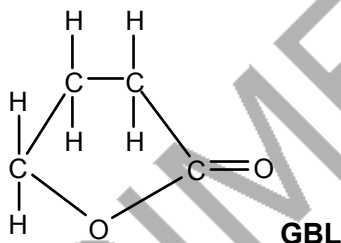
- (a) (i) Name the **two** functional groups in GHB.

..... [2]

- (ii) Give the systematic name for GHB.

..... [2]

- (b) A substance known as GBL is converted into GHB in the body. The structure of GBL is shown below.



GBL

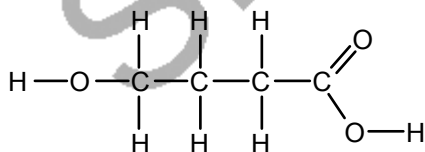
- (i) Name the functional group in GBL.

..... [1]

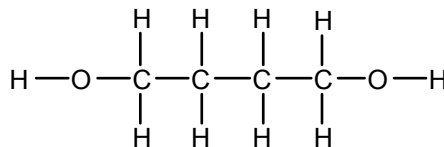
- (ii) Name the **type** of reaction by which GBL forms GHB in the body.

..... [1]

- (c) A molecule that has the same effect on the body as GHB is called 'GHB alcohol'. Its structure is shown below, together with the structure of GHB.



GHB



GHB alcohol

- (i) On the molecule of **GHB** above, draw a ring round the largest part of the molecule that could be the *pharmacophore*.

[1]

- (ii) Suggest why both of these molecules are able to bind to the same receptor site in the body. Name the intermolecular bonds involved.

.....  
.....  
..... [3]

- (d) Chemists are constantly seeking new medicines, starting from known pharmacophores.

- (i) Name a modern technique that allows chemists to view the possible ways in which a molecule can bind on to a receptor site.

..... [1]

- (ii) Suggest how chemists might justify continuing to manufacture GHB when it has been implicated as a 'date-rape' drug.

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

Question 4 continues on the next page.

[Turn over

(e) GHB is a weak acid. Weak acids can be represented as HA.

(i) Write an equation to show how a weak acid HA behaves when dissolved in water.

[1]

(ii) Use ions and molecules from this equation to explain the meaning of the term *conjugate base*.

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

(iii) Write an expression for the acidity constant  $K_a$  of an acid HA.

[1]

(iv) A  $0.10 \text{ mol dm}^{-3}$  solution of GHB has a pH of 2.9.

Calculate the value of  $K_a$  for GHB and give its units.

$K_a = \dots \dots \dots$  units  $\dots \dots \dots$  . [4]

(v) State one simplifying assumption that you made when carrying out your calculation in (iii).

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

(f) A mixture of GHB and its sodium salt acts as a buffer solution.

(i) Explain the meaning of the term *buffer solution* and explain why buffer solutions are found in our bodies.

.....  
.....  
.....  
.....  
.....  
.....  
..... [5]

(ii) Calculate the pH of a buffer solution containing equal amounts of GHB and its sodium salt.

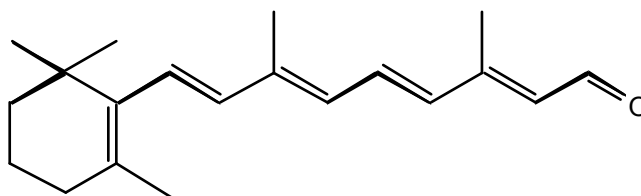
pH = ..... [2]

[Total: 29]

SPECIMEN

[Turn over

- 5 The rod cells in the retina at the back of the eye contain an alcohol called retinol which is responsible for their sensitivity to light. Retinol is oxidised by an enzyme-catalysed reaction to the aldehyde retinal.

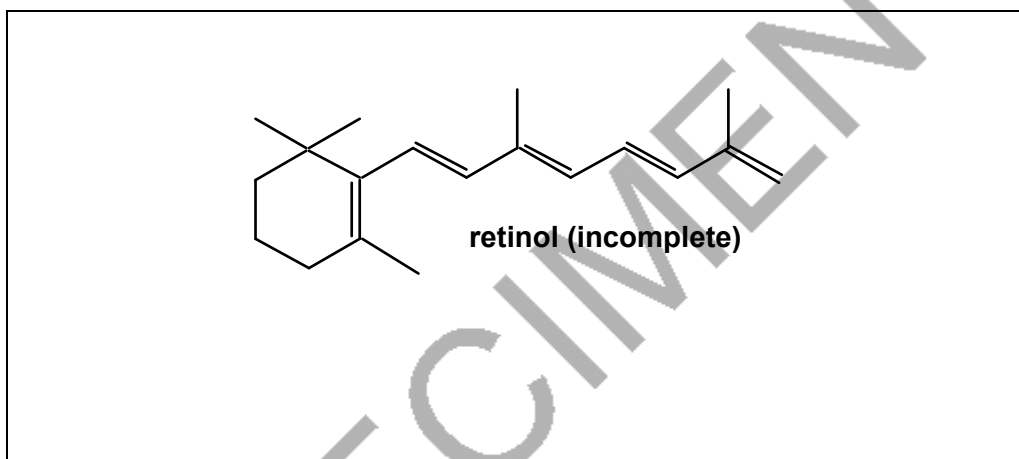


retinal

- (a) (i) Deduce the molecular formula of **retinal** from its skeletal formula above.

..... [1]

- (ii) Suggest the structure of the alcohol **retinol** by completing the skeletal formula below.



retinol (incomplete)

[2]

- (iii) Name a functional group which is present in **both** retinol and retinal.

..... [1]

- (b) (i) What reagents and conditions could be used to convert an alcohol to an aldehyde in a laboratory?

.....  
 .....  
 ..... [3]

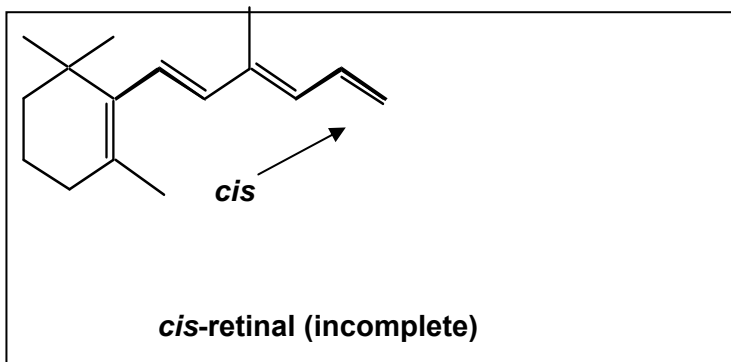
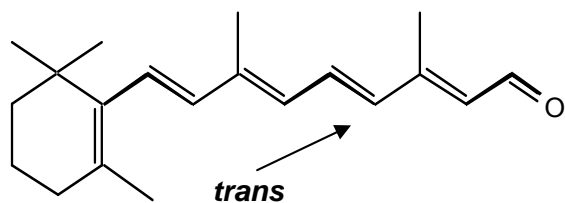
- (ii) How many moles of hydrogen molecules would you expect to react with one mole of **retinol**?

..... [1]



(c) When light shines on the rod cells, an enzyme-catalysed reaction occurs. This changes the arrangement around the double bond from *trans* to *cis*, as indicated in the structure below.

(i) Suggest the structure of *cis*-retinal by completing the skeletal formula below.



[2]

(ii) Why are the *cis* and *trans* isomers of a compound not identical?

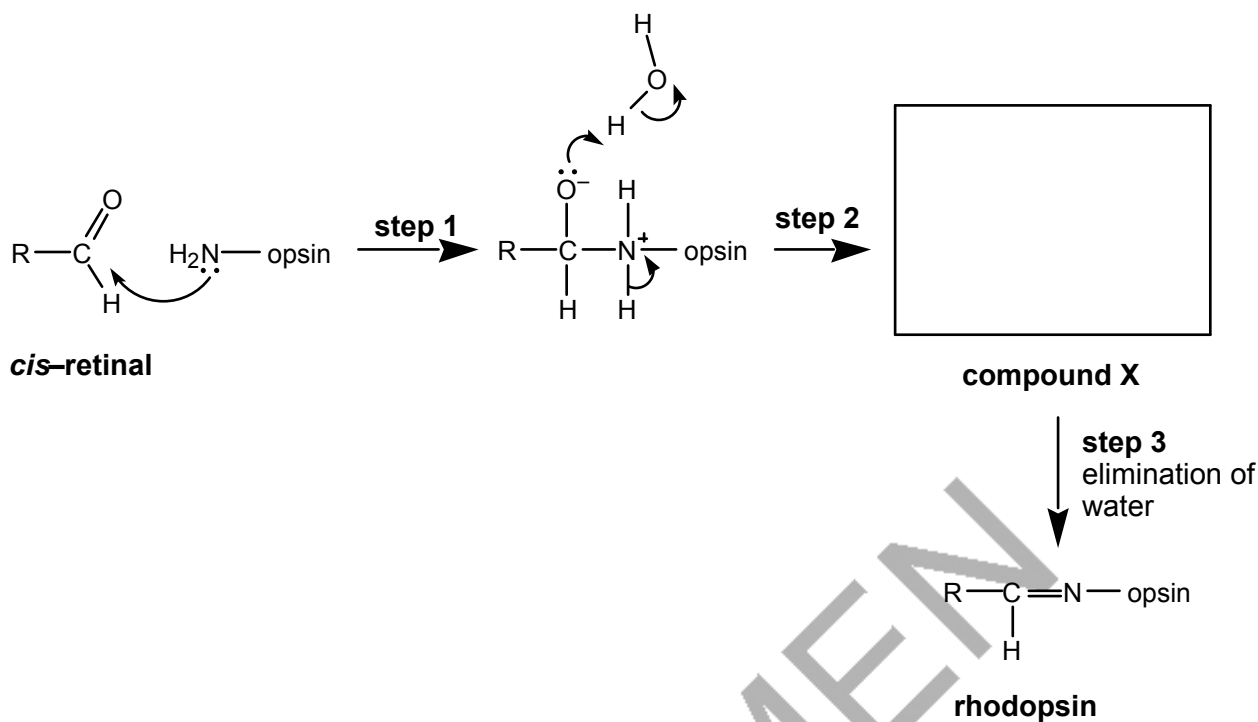
.....

..... [1]

SPECIMEN

[Turn over

- (d) The *cis*-retinal binds to the protein **opsin** to form **rhodopsin**. Part of the mechanism of this reaction is shown below.



- (i) Name the functional group on opsin which is reacting with the aldehyde group on *cis*-retinal.  
..... [1]
- (ii) Name the **type of reaction mechanism** which starts in **step 1** and is completed in **step 2**.  
..... [2]
- (iii) Draw a 'curly arrow' on the *cis*-retinal molecule to complete the electron movements that occur in **step 1**.  
..... [1]
- (iv) Deduce a structure for **compound X** and draw it in the box above.  
..... [1]

[Total: 16]

Paper Total [120]

END OF QUESTION PAPER

SPECIMEN

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*Sources*

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