

→ PMS

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

CHEMISTRY (SALTERS)
Chemistry by Design

2854

Tuesday **28 JUNE 2005** Morning 2 hours

Candidates answer on the question paper.

Additional materials:

Data Sheet for Chemistry (Salters)

Scientific calculator

Candidate Name	Centre Number	Candidate Number									
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TIME 2 hours

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [] at the end of each question or part question.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use a scientific calculator.
- You may use the *Data Sheet for Chemistry (Salters)*.
- You are advised to show all the steps in any calculations.

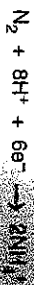
FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	16	
2	22	
3	38	
4	20	
5	24	
TOTAL	120	

This question paper consists of 15 printed pages and 1 blank page.

Answer all the questions.

1 Ammonium ions and ammonia are formed in the soil by several processes. These include fixation of atmospheric nitrogen in the root nodules of certain plants and mineralisation of organic nitrogen.

(a) The half-equation for the fixation of nitrogen in root nodules is shown below.



equation 1.1

(i) Give the oxidation states of nitrogen in



..... [2]



..... [2]

(ii) The half-reaction in equation 1.1 is called a reduction. Explain why.

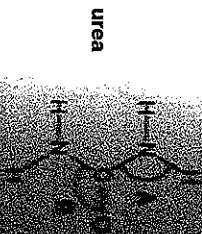
..... [1]

(iii) Draw a dot-cross diagram for the ammonium ion, showing the outer electron shells only.

..... [1]

(b) Urea is an organic nitrogen-containing compound that is found in the soil. Its formula is shown below.

[2]



(i) Give the values of the bond angles A, B and C in the urea molecule.

A [2]

(ii) Urea is slowly hydrolysed in the soil according to the equation for the hydrolysis.



urea

[2]

(c) The rate equation for the reaction in (b) (ii) can be represented as shown below.

$$\text{rate} = k[\text{CO}(\text{NH}_2)_2]$$

(i) What name is given to the term k in a rate equation?

..... [1]

(ii) What effect does raising the temperature have on the value of k ?

..... [1]

(d) Nitrogen forms several oxides. One of these, NO_2 , fits the acid-base trend of oxides across a period in the Periodic Table.

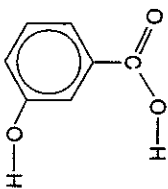
What can you predict about the acid-base character of NO_2 from the position of nitrogen in the Periodic Table? Explain your prediction.

..... [1]

..... [1]

(e) Another organic compound found in soil is 3-hydroxybenzoic acid.

..... [2]



3-hydroxybenzoic acid

(i) What name is given to a hydroxyl group attached to a benzene ring?

..... [1]

(ii) Give the structural formula of the salt formed when 3-hydroxybenzoic acid reacts with sodium hydroxide solution. Show ionic charges.

[2]

[Total: 16]

2 Antifreeze solution is added to car radiators in winter to stop the water freezing and expanding, which can crack the cylinder block. Early antifreeze solutions contained methanol, CH_3OH , which tended to evaporate. Then ethane-1,2-diol, $\text{HO}-\text{CH}_2-\text{CH}_2-\text{OH}$, was used in antifreeze solutions as it has a higher boiling point. Both are very poisonous, however.

(a) Theory shows that 8 moles of solute are needed to lower the freezing point of 1 kg of water to -15°C .

Compare the masses of methanol and ethane-1,2-diol which need to be dissolved in 1 kg of water to lower the freezing point to -15°C .
 A_r : C, 12; O, 16; H, 1.0

[3]

(b) Water expands when it freezes because ice has an 'open' structure in which the molecules are held together by hydrogen bonds.

Draw a diagram to show three water molecules held in this open structure. Show partial charges.

[4]

(c) Methanol reacts in the eye to form methanal which causes blindness.

(i) Draw a full structural formula for methanal.

[1]

(ii) Classify the type of reaction by which methanol is converted to methanal.

[1]

(iii) Use the Data Sheet to write down the formula of a reagent that would convert methanal back to methanol in the laboratory.

[1]

(d) Ethane-1,2-diol is poisonous because it is oxidised in the body to ethanedioic acid, $\text{C}_2\text{H}_2\text{O}_4$. Draw the full structural formula of ethanedioic acid.

[2]

(e) Ethanedioic acid removes vital calcium ions from solution in the bloodstream. It reacts to precipitate out calcium ethanedioate.

K_{sp} for calcium ethanedioate, CaC_2O_4 , is $2.3 \times 10^{-9} \text{ mol}^2 \text{ dm}^{-6}$ at 298 K.

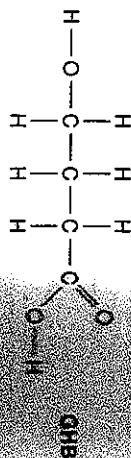
(i) Write an expression for K_{sp} for calcium ethanedioate.

[2]

(ii) Calculate the concentration of calcium ions in a saturated solution of calcium ethanedioate.

calcium ion concentration = mol dm^{-3} [3]

3 The substance GHB was originally designed for use in anorexia pills. However, other drug-related uses were found for the substance and its sale was restricted in 2003. GHB stands for gamma-hydroxybutyric acid, an old name for the structure shown below.



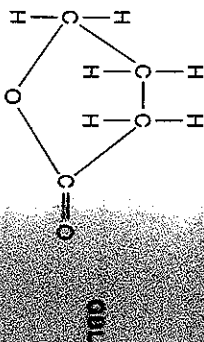
(a) (i) Name the two functional groups in GHB.

.....[2]

(ii) Give the systematic name for GHB.

.....[2]

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



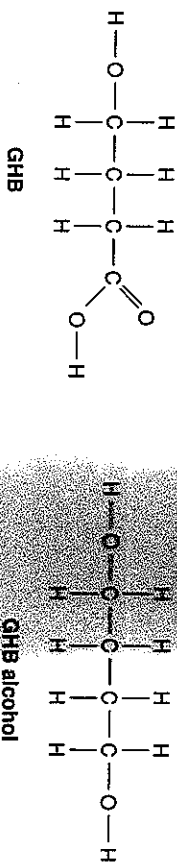
(i) Name the functional group in GBL.

.....[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.



(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 forces involved.

.....

.....

.....

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

.....[3]

(iv) Give the reagents and conditions for making an organic acid from an alcohol in the laboratory.

.....[3]

.....[3]

4 Ammonia is a very important chemical. Large quantities are produced in Britain every year.

(a) Give one reason why it is important to make ammonia.

When ammonia is manufactured, hydrogen is needed as part of the feedstock.

(b) Name the gas that forms the rest of the feedstock for making ammonia.

(c) The hydrogen feedstock is produced from methane by steam reforming as shown below.



equation 4.1

(i) Write an expression for K_p for the reaction in equation 4.1.

(ii) At the temperature of the reaction, $K_p = 292 \text{ atm}^{-2}$. The partial pressures of some of the gases present in an equilibrium mixture at this temperature are given in the table.

gas	partial pressure/atm
CH ₄	5.00
H ₂ O	5.00
H ₂	12.0

Calculate the partial pressure of carbon monoxide under these conditions. Give your answer to a suitable number of significant figures.

$P_{\text{CO}} = \dots \dots \dots \text{ atm}$ [3]

(d) (i) Use Le Chatelier's principle to predict the effect of decreasing the total pressure on the yield of hydrogen in equation 4.1.

..... [3]

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

..... [1]

(e) The mixture of gases from the reaction in equation 4.1 is mixed with more steam and passed over a hot iron catalyst. The carbon monoxide is converted to carbon dioxide.

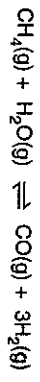
(i) Write an equation for the reaction of carbon monoxide with steam.

[2]

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

..... [2]

(f) (i) Predict the sign of $\Delta S_{\text{sys}}^\ominus$ for the forward reaction in equation 4.1. Explain your reasoning.



equation 4.1

..... [2]

(ii) Use the entropy data given in the table below to calculate the value of $\Delta S_{\text{sys}}^\ominus$ (with the correct sign) for the forward reaction in equation 4.1.

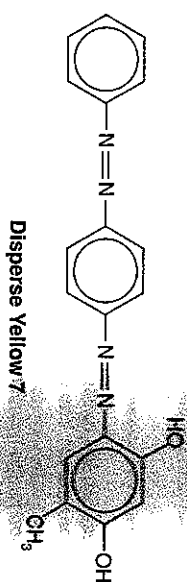
compound	$S^\ominus / \text{J K}^{-1} \text{ mol}^{-1}$
CH ₄ (g)	+186
H ₂ O(g)	+189
CO(g)	+198
H ₂ (g)	+131

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

[Total: 20]

Turn over

5 The dye *Disperse Yellow 7* dyes polyesters but not cotton.



- (a) How many carbon and hydrogen atoms are there in a molecule of *Disperse Yellow 7*?
carbon atoms
hydrogen atoms [2]
- (b) Why does a yellow substance look yellow?
.....
..... [2]

- (c) The dye molecule has delocalised electrons.
..... [2]

- (i) Explain what is meant by the term *delocalisation*.
.....
..... [2]
- (ii) Over which parts of the molecule does the delocalisation occur?
..... [2]

- (iii) Over which parts of the molecule does the delocalisation occur?
..... [3]

- (ii) The answer to part (i) describes the *chromophore* of the molecule. Increasing the length of the chromophore in a dye molecule decreases the frequency of the light absorbed. Suggest an explanation for this in terms of energy levels.
.....
.....

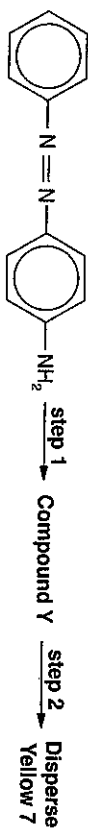
- (d) (i) Suggest the reagents and conditions that might be used to substitute another CH_3 group into one of the aromatic rings in *Disperse Yellow 7*.
..... [2]

- (ii) Explain why this is described as a *substitution* reaction.
..... [3]

- (iii) Circle a word in the list below that describes the mechanism of this substitution reaction.
..... [2]

electrophilic radical nucleophilic [1]

- (e) *Disperse Yellow 7* can be made by the following route.



- (i) In **step 1**, the amine group is reacted with cold nitrous acid. Name the **type** of compound that is formed (**compound Y**).
..... [1]

- (ii) In **step 2**, **compound Y** is coupled with another reagent. Draw the structure of this reagent.
..... [2]

