

**ADVANCED GCE
CHEMISTRY (SALTERS)**

Chemistry by Design

THURSDAY 25 JANUARY 2007

2854/01

Afternoon

Time: 2 hours

Additional materials: Scientific calculator
Data Sheet for Chemistry (Salters) (Inserted)



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. ANSWERS WRITTEN ELSEWHERE WILL NOT BE MARKED.**

INFORMATION FOR CANDIDATES

- The number of marks for each question 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.
- A copy of the *Data Sheet for Chemistry (Salters)* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE

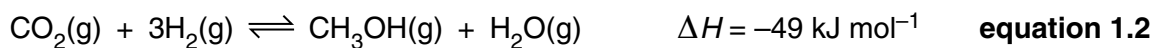
Qu.	Max.	Mark
1	31	
2	26	
3	20	
4	26	
5	17	
TOTAL	120	

This document consists of **20** printed pages and a *Data Sheet for Chemistry (Salters)*.

Answer **all** the questions.

- 1 Methanol is made by reacting 'synthesis gas'. Synthesis gas contains carbon monoxide, carbon dioxide and hydrogen.

The equations for the reactions are given below.



- (a) Draw a dot-cross diagram for methanol.

[2]

- (b) Synthesis gas is reacted using a catalyst at 100–200°C and 40–100 atm pressure.

- (i) Give and explain **two** reasons why a high pressure is used.

..... [4]

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- (ii) Explain why a higher temperature is **not** used.

..... [2]

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- (c) (i) Use the entropy data below to calculate the entropy change involved in the forward reaction in **equation 1.1**.

substance	$S/\text{J mol}^{-1} \text{K}^{-1}$
CO(g)	198
H ₂ (g)	131
CH ₃ OH(g)	240

$$\Delta S = \dots\dots\dots \text{J mol}^{-1} \text{K}^{-1} \quad [2]$$

- (ii) Comment on the sign of ΔS in terms of the numbers of molecules involved in **equation 1.1**.

.....

 [1]

- (d) (i) Write the equation for the equilibrium constant, K_p , for the reaction in **equation 1.1**.

[2]

- (ii) The data below show the composition of an equilibrium mixture at a certain temperature. Calculate a value for K_p at this temperature and give its units.

gas	partial pressure/atm
CH ₃ OH	90
CO	2.0
H ₂	2.0

$$K_p = \dots\dots\dots \text{units} \dots\dots\dots [2]$$

- (e) Methanol is used as a feedstock in a variety of industrial processes.

Explain the meaning of the term *feedstock*.

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

- (f) In industry, air is used to oxidise methanol to methanal, HCHO, using a catalyst.

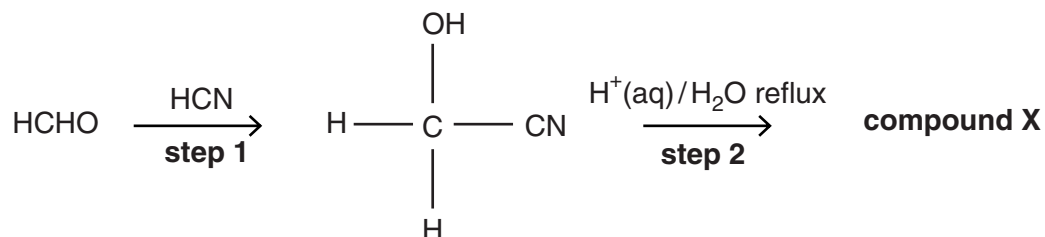
(i) Write a balanced chemical equation for this reaction.

[2]

(ii) Draw a **full** structural formula for methanal.

[1]

- (g) Methanal can be converted to a useful acid, **compound X**, in the laboratory by using the following sequence of reactions.



- (i) For the reaction in **step 1**, circle **two** words in the list below that describe the mechanism involved.

addition electrophilic elimination nucleophilic radical substitution [2]

- (ii) Use the reactions on your *Data Sheet* to predict a **full** structural formula and name for **compound X**.

name [3]

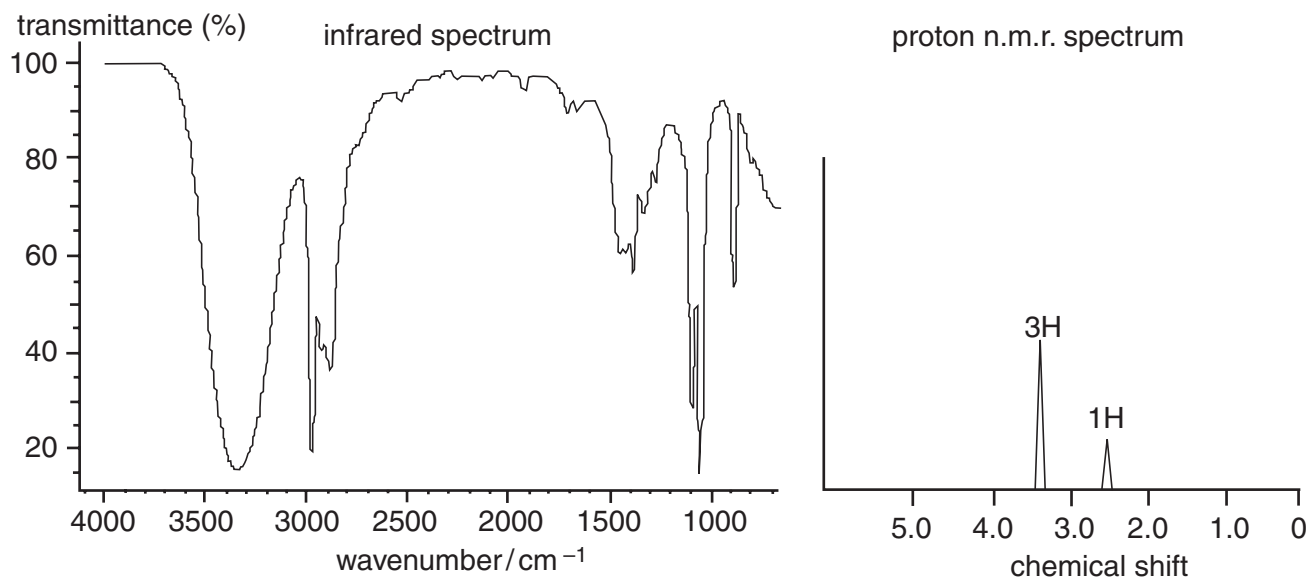
- (h) In this question, two marks are available for the quality of the use and organisation of scientific terms.

Shown below are the infrared and proton n.m.r. spectra of **compound Y** that is known to be one of:

methanol, methanal or methanoic acid.

Give **two** pieces of evidence from the **infrared** spectrum to identify the compound.

Give **two** pieces of evidence from the **n.m.r.** spectrum that confirm your identification.



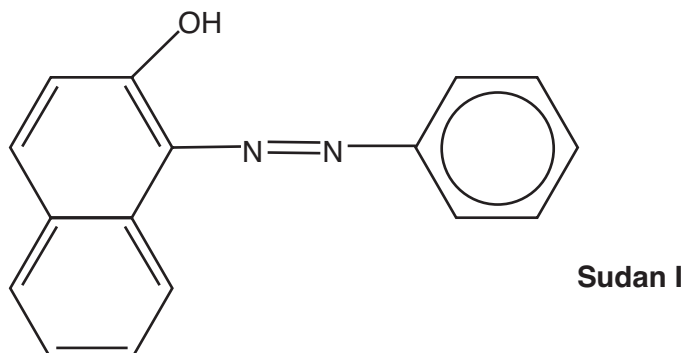
..... [5]

Quality of Written Communication [2]

[Total: 31]

- 2 In 2005, food shops cleared their shelves of items containing *Sudan I*. This orange azo dye had been used illegally to colour sauces in many food products. The dye is thought to cause cancer in humans.

The structure of Sudan I is shown below.



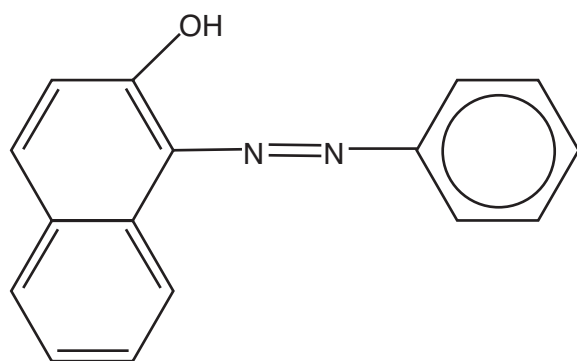
- (a) Circle the azo group in Sudan I. [1]

- (b) Describe a test for the phenol group.

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

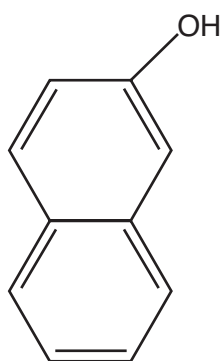
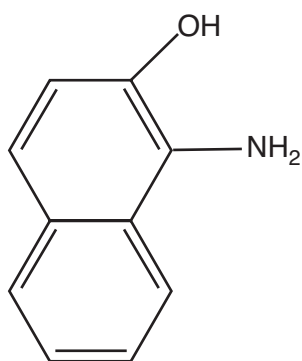
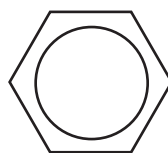
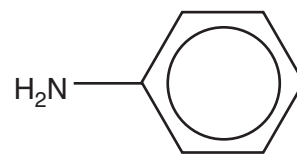
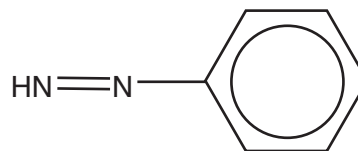
- (c) Give the molecular formula of Sudan I.

..... [2]



Sudan I

- (d) From the compounds **A** to **E**, given below, choose **two** that could be starting materials for the synthesis of Sudan I.

**A****B****C****D****E**

compounds and [2]

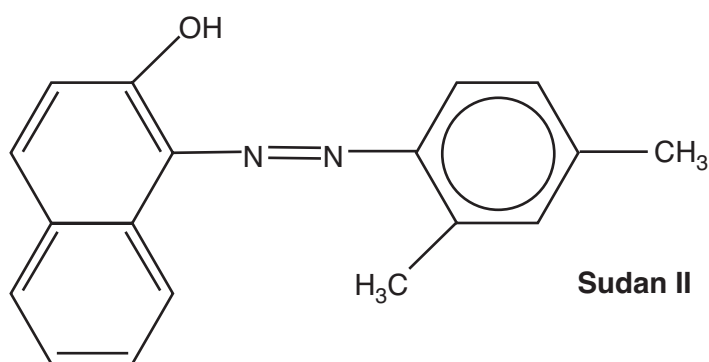
- (e) The cancer-inducing nature of azo dyes is thought to be caused by reduction of the dye in the body to the corresponding amines.

Choose the letters of **two** amines from the compounds in (d) and name **one** of them.

first amine name

second amine [3]

- (f) *Sudan II*, a related compound, has the structure shown below and is an orange dye.



- (i) Give the reagents and conditions that would be used to substitute methyl groups on to the benzene ring.

.....

 [3]

- (ii) Name the **type** of substitution that is occurring in (i).

..... [1]

- (iii) What name is given to the part of the structure of a dye that is responsible for the colour?

..... [1]

- (iv) Explain, in terms of electron energy levels, the reasons why Sudan II is orange.

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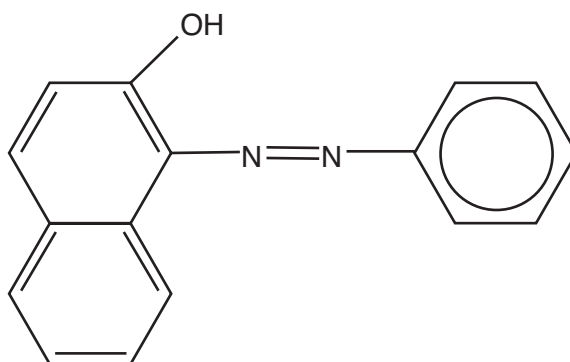
 [4]

(g) Sudan dyes are legitimately used to colour oils and waxes.

(i) Draw the general structure of a triglyceride oil showing:

- the ester groups as full structural formulae;
- long side chains as skeletal formulae with at least six carbon atoms.

[3]



Sudan I

(ii) The main intermolecular forces in Sudan I are instantaneous dipole-induced dipole. Suggest why Sudan I is more soluble in a triglyceride oil than in water.

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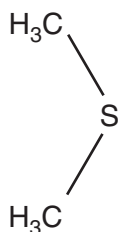
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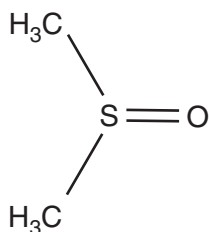
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[Total: 26]

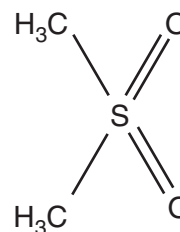
- 3 Seaweed and marine algae produce the gas dimethylsulphide, DMS. In the atmosphere this is oxidised to two other compounds whose structures are shown below.



DMS
dimethyl sulphide



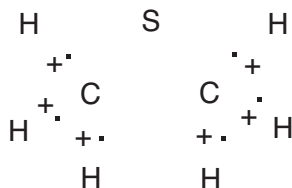
DMSO
dimethylsulphoxide



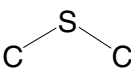
MSM
methylsulphonylmethane

DMSO is used as an industrial solvent and occasionally as a medicine. MSM is marketed as a medicine to provide sulphur to build body protein.

- (a) (i) Complete the dot-cross diagram for **DMS** to show the outer shell electrons around the sulphur atom.



[2]

- (ii) Suggest a value for the  bond angle in DMS. Explain how you arrived at your answer.

angle

explanation

.....

[3]

(b) DMSO is liquid at room temperature. It is used as a solvent because it can dissolve non-polar solutes but it is also very soluble in water.

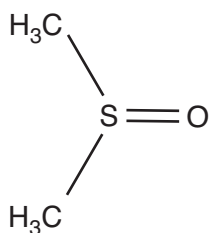
(i) DMSO has a relatively small dipole. One reason is that the S=O bond is not very polar. Explain why this is so.

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

(ii) Some molecules have strongly polar bonds but still have little or no overall dipole. Suggest why.

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

(iii) One molecule of DMSO forms hydrogen bonds with two molecules of water. Complete the diagram below to illustrate this, showing lone pairs and partial charges.



[4]

(c) DMSO is toxic in all but very small doses. MSM does not show this characteristic and thus is a better choice as a dietary supplement to help the body build protein.

(i) Suggest why sulphur atoms are important in protein structures.

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

(ii) MSM, $(\text{CH}_3)_2\text{SO}_2$, can be made from dimethylsulphide by oxidation using hydrogen peroxide, H_2O_2 .

Suggest an equation for this reaction.

[2]

(iii) Suggest the formula of another compound that chemists might investigate as an improvement to MSM.

[1]

(d) Global warming will increase the surface temperature of the oceans and thus encourage the growth of the marine algae that produce DMS. Water can absorb more thermal energy for the same rise in temperature than other liquids.

What name is given to this property and how can its higher value for water be explained in terms of bonding?

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..... [3]

[Total: 20]

4 DMS is oxidised in the atmosphere to sulphur dioxide. It is estimated that, at certain times of the year, 25% of the SO₂ over Europe is generated in this way.

(a) (i) Suggest and explain another source of SO₂ caused by human activity.

.....

 [2]

(ii) Name the type of pollution caused by SO₂ and give **two** ways that this causes damage to the environment.

.....

 [3]

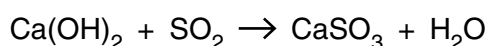
(b) Sulphur dioxide can be removed from waste gases using cheap basic materials, such as calcium oxide or calcium hydroxide.

(i) How does the position of calcium in the Periodic Table allow the basic nature of its oxide to be predicted?

.....
 [1]

(ii) Calculate the mass of calcium hydroxide that will react with 15 000 dm³ of sulphur dioxide at room temperature and pressure.

Give your answer in **kg** to **an appropriate number** of significant figures.



A_r: Ca, 40; S, 32; O, 16; H, 1.0.

1.0 mole of molecules of a gas at room temperature and pressure occupies 24 dm³.

mass of calcium hydroxide = **kg** [3]

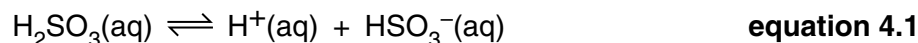
(c) Sulphur dioxide dissolves in water to form H_2SO_3 , a weak acid.

(i) H_2SO_3 is often known as sulphurous acid.

Complete the **systematic** name of H_2SO_3 .

sulphuric(.....) **acid** [1]

(ii) Sulphurous acid reacts with water to give the products as shown.



Which part of this equation shows that aqueous sulphurous acid is:

acidic

a weak acid [2]

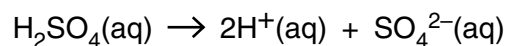
(iii) Write the expression for the acidity constant, K_a , for **equation 4.1**.

[2]

(iv) Calculate the pH of a 0.10 mol dm^{-3} solution of sulphurous acid, given that $K_a = 1.5 \times 10^{-2} \text{ mol dm}^{-3}$.

pH = [2]

(v) Sulphurous acid is a reducing agent. It is oxidised to sulphuric acid, H_2SO_4 .
 H_2SO_4 ionises in water.



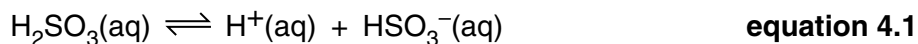
Calculate the pH of a 0.10 mol dm^{-3} solution of H_2SO_4 .

pH = [2]

(d) Sulphurous acid is used as a preservative in foods.

(i) In this question, one mark is available for the quality of spelling, punctuation and grammar.

Hydrogensulphites (HSO_3^-) are added to foods with sulphurous acid as an ‘acidity regulator’. This is because an aqueous mixture of H_2SO_3 and HSO_3^- acts as a buffer solution.



Explain the meaning of the term *buffer solution* and explain how a buffer solution based on **equation 4.1** works.

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..... [5]

Quality of Written Communication [1]

(ii) Calculate the pH of a buffer solution where $[\text{H}_2\text{SO}_3] = 0.0010 \text{ mol dm}^{-3}$ and $[\text{HSO}_3^-] = 0.0020 \text{ mol dm}^{-3}$. $K_a = 1.5 \times 10^{-2} \text{ mol dm}^{-3}$.

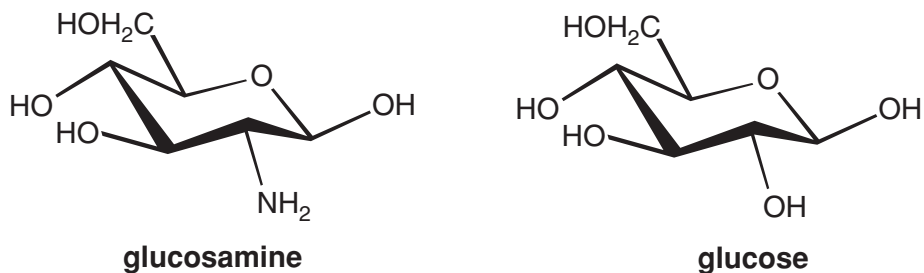
$$K_a = [\text{H}^+] \times [\text{salt}] / [\text{acid}]$$

pH = [2]

[Total: 26]

5 Glucosamine is marketed as a medicine that will help keep human joints healthy.

Its structure is related to glucose as shown below.



(a) (i) On the **glucosamine** structure above, circle a *primary alcohol* group. [1]

(ii) On the **glucose** structure, circle **all** the **chiral carbon** atoms. [2]

(iii) Glucose is a cyclic compound but **not** an arene. Give **one** reason why glucose is not classed as an arene.

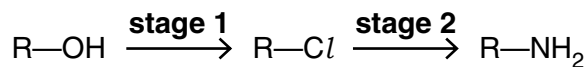
.....
 [1]

(b) Glucosamine is usually sold as the chloride salt. Identify the functional group that will form a chloride. Write an equation for this functional group reacting with hydrochloric acid. Indicate the ionic nature of the product.

[3]

- (c) Glucose and glucosamine differ in that glucosamine has an amine group replacing an alcohol group.

In the laboratory it is possible to convert an alcohol to an amine in two stages. These stages are shown below.



- (i) Give the name of the **type** of compound represented by R-Cl.

..... [1]

- (ii) Give the reagent for **stage 1**.

..... [1]

- (iii) Give the reagents and conditions for **stage 2**.

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

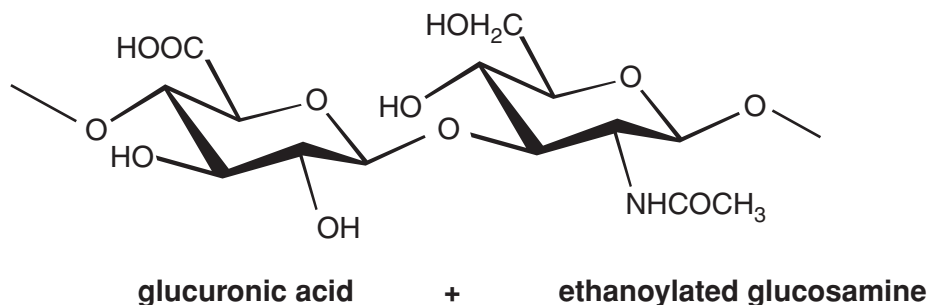
- (iv) Both **stage 1** and **stage 2** proceed by the same reaction mechanism.

Name this mechanism.

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

- (d) In the body, glucosamine is ethanoylated and combines with glucuronic acid to give the polymer *hyaluronan*. Hyaluronan is widespread in the body, especially around joints. For this reason, glucosamine is taken as a dietary supplement by some people to keep their joints healthy.

The repeating structure of hyaluronan is shown below.



- (i) By what **type** of polymerisation is hyaluronan formed?
 [1]
- (ii) By what **type** of reaction could glucuronic acid be made from glucose?
 [1]
- (iii) Name the functional group -NHCO- in hyaluronan.
 [1]
- (iv) Name a laboratory reagent that would convert the -NH_2 group in glucosamine into -NHCOCH_3 .
 [1]

[Total: 17]

END OF QUESTION PAPER

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