



ADVANCED GCE
CHEMISTRY (SALTERS)
 Chemistry by Design

2854/01

Candidates answer on the question paper
 A calculator may be used for this paper

OCR Supplied Materials:

- *Data Sheet for Chemistry (Salters)*
 (Inserted)

Other Materials Required:

- Scientific calculator

Friday 23 January 2009
Morning

Duration: 2 hours



Candidate
Forename

Candidate
Surname

Centre Number

Candidate Number

INSTRUCTIONS TO CANDIDATES

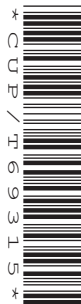
- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [] at the end of each question or part question.
- The total number of marks for this paper is **120**.
- 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.
- This document consists of **16** pages. Any blank pages are indicated.

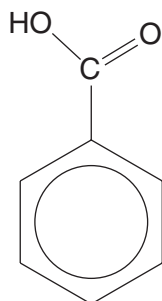
FOR EXAMINER'S USE

Qu.	Max.	Mark
1	27	
2	17	
3	22	
4	29	
5	25	
TOTAL	120	



Answer **all** the questions.

- 1 Benzoic acid is a food preservative as it inhibits the metabolism of bacteria. It is often added to foods as its salt, sodium benzoate.

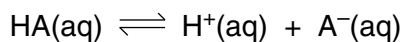


benzoic acid

- (a) Draw the formula of sodium benzoate.

[1]

- (b) Benzoic acid is a weak acid. Weak acids in aqueous solution are often represented by **equation 1.1**.



equation 1.1

- (i) Write the expression for K_a for **equation 1.1**.

$$K_a =$$

[1]

- (ii) For benzoic acid, $K_a = 6.3 \times 10^{-5} \text{ mol dm}^{-3}$.

Calculate the pH of a $0.010 \text{ mol dm}^{-3}$ solution of benzoic acid.

pH = [2]

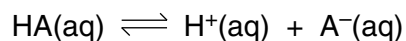
- (iii) In food science books, it is stated that 'sodium benzoate is not used in a preservative unless the pH is below 3.6'.

Calculate the ratio of [benzoic acid]:[sodium benzoate] in a solution at pH 3.6.

ratio = [3]

- (c) A mixture of sodium benzoate and benzoic acid will act as a buffer solution which helps food preservation.

- (i) Use **equation 1.1** to explain how a buffer solution works.



equation 1.1

..... [3]

- (ii) Food can be spoiled by enzyme-catalysed reactions.
Suggest why the presence of a buffer solution helps preserve food by preventing enzymic reactions.

..... [2]

(d) There are concerns over the use of benzoic acid in drinks. It reacts with vitamin C to form very small quantities of toxic benzene. Vitamin C is said to produce hydroxyl (OH) radicals that cause this reaction.

(i) Draw a dot-cross diagram for the hydroxyl radical and explain why it is called a radical.

explanation [3]

(ii) Write a balanced equation for the decomposition of benzoic acid. One of the two products is benzene.

[2]

(iii) Suggest the role of the OH radical in this reaction.

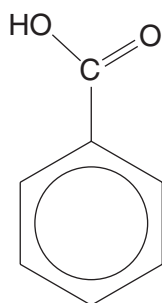
..... [1]

(iv) **Benzene** can be detected by mass spectrometry. The mass spectrum has peaks at 78 and 51. Give the formulae of the ions corresponding to these peaks.

A_r : C, 12; H, 1.0

78 51 [3]

- (e) Methyl benzoate is an ester formed from benzoic acid and is used as a food flavouring.



benzoic acid

Draw the structure of methyl benzoate, showing the **full structural** formula of the **ester link**.

[2]

- (f) Methyl benzoate can be made in the laboratory by heating benzoic acid under reflux with **two** other substances.

- (i) Name these other substances.

.....

..... [2]

- (ii) Draw a labelled diagram of the apparatus you would use to heat these substances under reflux.

[2]

[Total: 27]

2 Triesters of glycerol are used as the binding medium for oil paints. Analysis of old paintings enables scientists to work out which oil has been used.

(a) The oils are usually triesters made from glycerol (propane-1,2,3-triol) and unsaturated carboxylic acids.

(i) Draw the **full structural formula** of a triester. Use 'R' to represent the side-chains of the carboxylic acids.

(ii) Explain what is meant by an *unsaturated* carboxylic acid. [2]

..... [1]

(iii) How would you test a sample of an oil for unsaturation?

test

result [2]

(iv) Explain why **unsaturated** oils are used as the medium for oil paints.

.....

..... [2]

(b) One analysis method for the identification of oils involves gas-liquid chromatography.

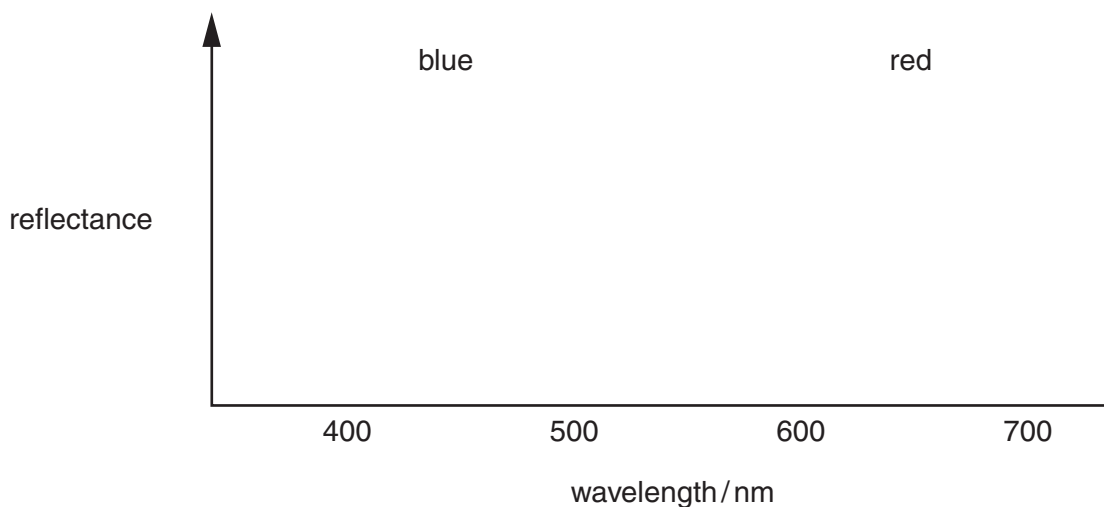
Gas-liquid chromatography has a stationary phase and a mobile phase. Describe the constituents of each of these phases.

stationary phase

.....

mobile phase [3]

- (c) The pigments present in a paint can be identified by their reflectance spectra. On the axes below, sketch a possible shape for the reflectance spectrum of an orange pigment.



[2]

- (d) Atomic emission spectra can also be used to identify the pigments.

Draw a labelled diagram and explain how different elements in a pigment each produce a **unique** atomic emission spectrum.

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..... [5]

[Total: 17]

3 Lead-acid batteries are used in cars to store electricity.

During discharging the reaction at the positive electrode is the conversion of PbO_2 to lead sulphate, PbSO_4 . At the negative electrode metallic lead is converted to lead sulphate. The reactions at each electrode are reversed during charging. The electrolyte is sulphuric acid.

(a) (i) Give the systematic name of PbO_2 .

..... [1]

(ii) Explain how the formula PbO_2 fits into a pattern in the Periodic Table.

.....

.....

..... [2]

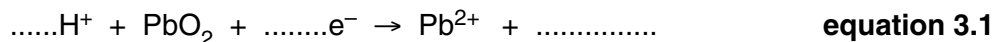
(iii) Another oxide of lead is PbO .

Give the **outer** electron subshells for Pb and Pb^{2+} (e.g. phosphorus is $3s^2 3p^3$).

Pb

Pb^{2+} [3]

(b) The incomplete half-equation for the reaction at one electrode is given below.



(i) Complete the half-equation for this discharge reaction. [2]

(ii) Give the source of the H^+ ions.

..... [1]

(iii) Name the process occurring in **equation 3.1**, giving a reason.

.....

..... [2]

(iv) When the battery is **discharging** this electrode is positive. Explain why.

.....

..... [1]

(v) Suggest a half-equation for the reaction at the **other** electrode when the battery is **charging**.

[1]

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

PbO is a yellow ionic solid, insoluble in water.

Suggest **two** other physical properties for PbO.

Explain these properties in terms of the ionic structure of PbO.

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..... [4]

Quality of Written Communication [1]

- (d) PbO is a basic oxide.

(i) Write an equation for a reaction of PbO that illustrates that it is basic.

[2]

- (ii) Does the basic nature of PbO fit with the trend for oxides across a period?
Explain your answer.

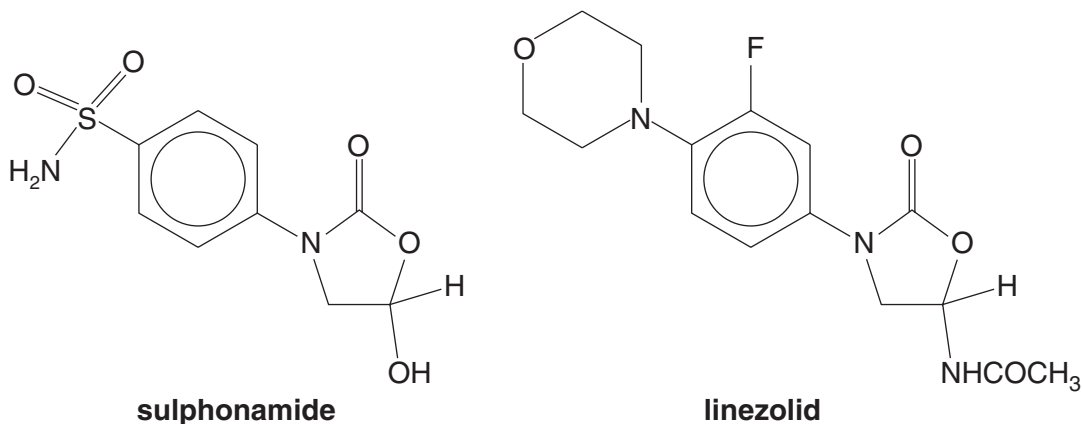
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..... [2]

[Total: 22]

- 4 In the 1980s, compounds called oxazolidinones were discovered to be antibacterials. One of the first was based on sulphonamide. From this, linezolid was developed as a very effective antibacterial compound in 1996.



- (a) Circle **one** chiral carbon atom in **sulphonamide**. [1]

- (b) (i) Name the functional group -NHCO- and draw the **full structural formula** for the -NHCOCH_3 group in linezolid.

name

[2]

- (ii) Give the **formula** and **name** of a reagent that is used to make the -NHCOCH_3 group from the corresponding amine.

..... [2]

- (iii) An -OH group cannot be directly substituted by an -NH_2 group. A synthesis route involving two substitution reactions can be used.

Give details of these reactions below by indicating the intermediate functional group. Write reagents and conditions on the arrows.



[4]

- (c) By comparing the structures of the two antibacterial compounds, sulphonamide and linezolid, draw a circle round the *pharmacophore* on the structure of **linezolid** above. Suggest how this accounts for their antibacterial properties.

.....

.....

..... [3]

O=C1NC(CO)O1CC(=O)N[C@@H]1CCNC1=O

Describe and explain **two** ways in which the contribution of these parts to the **infrared spectra** of the molecules would be **similar**.

Describe and explain **two** ways in which the contribution of these parts to the **proton nmr spectra** of the molecules would be **different**.

..... [8]

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- (e) Linezolid has a fluorine atom on its benzene ring.

A student suggested that fluorobenzene could be made from benzene in a similar way to bromobenzene.

- (i) Suggest the reagents and conditions that might be tried to make fluorobenzene, C_6H_5F .

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

- (ii) This reaction is described as electrophilic substitution.

Explain the meaning of the term *electrophile*.

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

- (iii) What feature of the bonding in benzene causes it to undergo substitution reactions rather than addition?

..... [1]

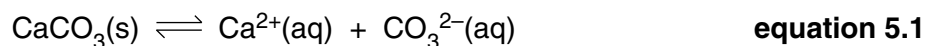
- (iv) The reaction of fluorine with benzene actually forms C_6F_{12} .
Suggest an equation for the reaction that occurs.

[1]

[Total: 29]

5 It is important to sea creatures with shells that calcium carbonate does not dissolve in water.

(a) The solubility product of calcium carbonate, CaCO_3 , is $5.0 \times 10^{-9} \text{ mol}^2 \text{ dm}^{-6}$ at 298 K.



(i) Write the expression for this solubility product in terms of concentrations.

$$K_{\text{sp}} =$$

[1]

(ii) The concentrations of calcium ions and carbonate ions are equal in a solution of calcium carbonate.

Calculate the maximum concentration of calcium carbonate (in g dm^{-3}) that will form when it dissolves at 298 K.

A_r : Ca, 40; C, 12; O, 16

maximum concentration = g dm^{-3} [3]

(b) (i) Use the data in the table below to calculate the entropy change of the system for the dissolving of calcium carbonate as shown in **equation 5.1**.

	$S / \text{J mol}^{-1} \text{ K}^{-1}$
$\text{Ca}^{2+}(\text{aq})$	-55.1
$\text{CO}_3^{2-}(\text{aq})$	-56.8
$\text{CaCO}_3(\text{s})$	+92.9

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

(ii) Explain why many dissolving processes have a positive value for ΔS_{sys} .

.....

 [2]

- (iii) The unusual value of ΔS_{sys} for calcium carbonate occurs because of the strong hydration of the ions.

Explain why calcium ions are strongly hydrated in solution and how this affects the entropy change of solution.

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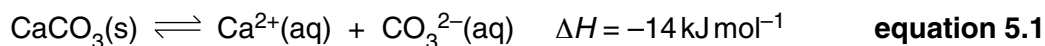
..... [4]

- (c) Calculate the total entropy change of solution for calcium carbonate at 298 K.

$$\Delta S_{\text{tot}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}}; \quad \Delta S_{\text{surr}} = \frac{-\Delta H}{T}; \quad \Delta H = -14 \text{ kJ mol}^{-1}$$

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

- (d) Temperatures are much lower at the bottom of the oceans than at the top. Use Le Chatelier's Principle to explain how you would expect the solubility of calcium carbonate to differ at lower temperatures.



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..... [4]

- (e) The pH of a sample of ocean water is 8.1.
In order to calculate the hydroxide ion concentration of this water sample, it is necessary to know that $K_w = 1 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$.

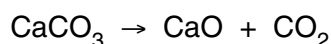
- (i) Write the expression for K_w .

$$K_w = \text{.....} \quad [1]$$

- (ii) Calculate the **hydroxide** ion concentration in a solution where the pH is 8.1.

$$[\text{OH}^-] = \text{..... mol dm}^{-3} \quad [2]$$

- (f) Large quantities of calcium carbonate are heated industrially to form calcium oxide.



- (i) Suggest an environmental impact that this process might have.

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

- (ii) Calculate the mass of carbon dioxide (in tonnes) that would be formed by heating 1.0 tonne of calcium carbonate.

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

A_r : Ca, 40; C, 12; O, 16; 1 tonne = 10^6 g

$$\text{mass of CO}_2 = \text{..... tonnes} \quad [3]$$

[Total: 25]

END OF QUESTION PAPER