OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

CHEMISTRY (SALTERS) 2854

Chemistry by Design

Monday **26 JUNE 2006** Morning 2 hours

Candidates answer on the question paper.
Additional materials:
Data Sheet for Chemistry (Salters)
Scientific calculator

Candidate Name	Centre Number	Candidate Number

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 that 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 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 calculations.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**25**	
2	**18**	
3	**26**	
4	**30**	
5	**21**	
TOTAL	**120**	

This question paper consists of 18 printed pages and 2 blank pages.

Registered Charity Number: 1066969
[Turn over

Answer **all** the questions.

1 In a lightning flash, the following reaction occurs.

$$N_2 + O_2 \rightleftharpoons 2NO \qquad \Delta H = +180\,kJ\,mol^{-1} \qquad \textbf{equation 1.1}$$

(a) Give the oxidation states of nitrogen in N_2 and NO.

N_2 .....

NO ..... [2]

(b) **(i)** The high temperature of the lightning flash is necessary to get a reasonable yield of NO. Use your understanding of Le Chatelier's principle to explain the effect of increasing the temperature on the **equilibrium position** of **equation 1.1**.

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..... [3]

(ii) The temperature of the air outside the lightning flash is very much lower. This means that the equilibrium reverses very slowly. Explain why reactions go more **slowly** at lower temperatures.

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..... [2]

(c) The value of K_p for **equation 1.1** is 1.0×10^{-5} at 1500 K.

(i) Write the expression for K_p in terms of the partial pressures of the gases involved.

[2]

(ii) Calculate the partial pressure of NO in an equilibrium mixture at this temperature, assuming that $pO_2 = 0.20$ atm and $pN_2 = 0.80$ atm.

pNO = ... atm [2]

(d) Some countries use the reaction shown in **equation 1.1** for making nitrogen monoxide by generating sparks in air. Suggest a commodity that must be cheap in these countries.

..... [1]

(e) The reaction in **equation 1.1** is one of the few ways in which nitrogen gas in the atmosphere is turned into its compounds in nature.

Suggest one other **natural** method in which nitrogen gas is turned into its compounds.

.....

..... [1]

(f) Another method by which nitrogen gas is made into a compound is the Haber process.

(i) Give the pressure that is used in a modern Haber process plant.

..... [1]

(ii) Suggest **one** safety aspect and **one** cost implication of working at this pressure.

safety .....

.....

cost .....

..... [2]

(g) Nitrogen is hard to turn into its compounds because of the nature of its bonding. Use an electron dot-cross diagram to show the bonding within N_2 and suggest why nitrogen is unreactive.

.....

..... [3]

(h) Why is it important for us that nitrogen compounds reach the soil?

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..... [2]

(i) A white solid can be purified from solution in the soil. It has a high melting point and dissolves readily in water to give a solution that conducts electricity. Name the type of bonding in this compound and explain how this accounts for the properties described.

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..... [4]

[Total: 25]

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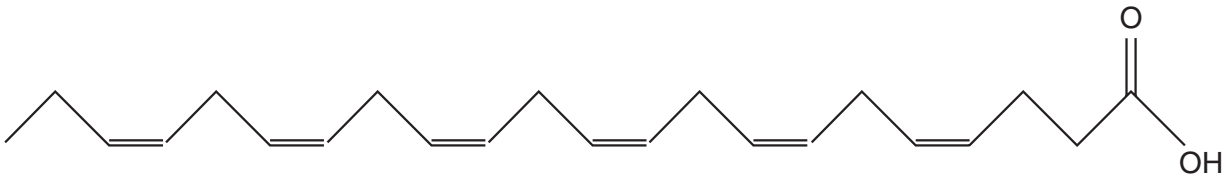
2 Cod liver oil is thought to be especially beneficial as a foodstuff because it contains 'omega-3' fatty acids. These are thought to lessen the likelihood of heart disease.

One such acid is docosahexaenoic acid, DHA.



DHA

(a) Deduce the molecular formula of DHA.

..... [2]

(b) This acid is described as 'omega-3' because its first alkene group starts three carbon atoms from the non-carboxylic end. 'Omega-6' acids are also involved in nutrition. Draw the skeletal formula of an omega-6 acid that has eight carbon atoms.

[2]

(c) The amount of unsaturation in a fat or oil is measured by its 'iodine number', the number of grams of iodine that will react with 100 g of the substance.

(i) Complete the equation below to show how iodine reacts with part of an unsaturated chain.

[2]

(ii) What colour change would be seen when an unsaturated fat or oil is shaken with a solution of iodine in a suitable solvent?

..... [1]

(iii) Calculate the iodine number of **DHA**.

M_r: DHA, 328; A_r: I, 127

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

iodine number = ... g [3]

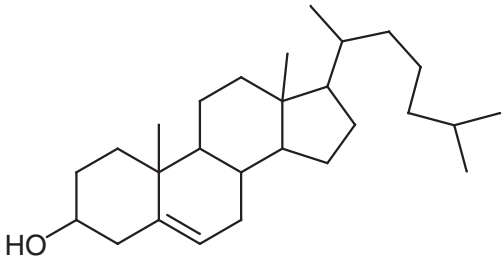
(d) DHA is described as *cis-cis*. Suggest what this term means.

.....

.....

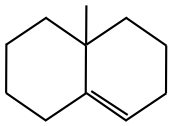
..... [2]

(e) Omega-3 acids are thought to be important in reducing the build-up of cholesterol in blood vessels. The structure of cholesterol is shown below.



cholesterol

Cholesterol forms esters with carboxylic acids in the body. Complete the skeletal formula below to show the ester group. Represent the carbon chain of the carboxylic acid by 'R'.



part of the cholesterol structure

[2]

(f) Suggest why cholesterol has low solubility in water. Describe the partition equilibrium that occurs when a small amount of **cholesterol** is distributed between octan-1-ol and water.

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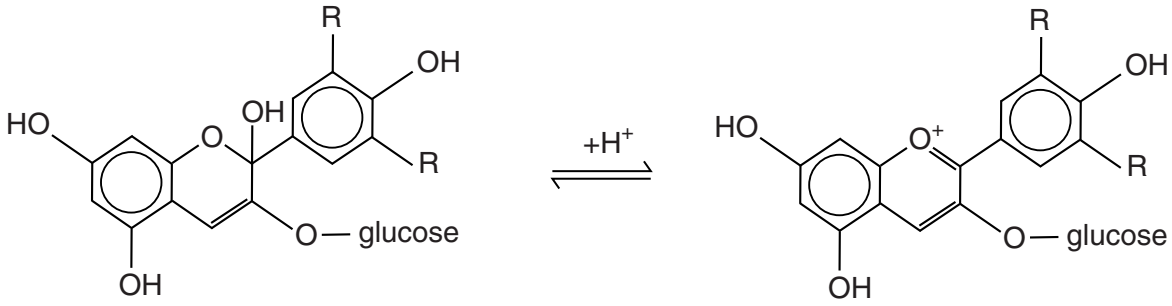
..... [4]

[Total: 18]

3 Anthocyanins give the red and purple colours to many fruits. Their colour can be changed by varying the pH.

The structure of one such anthocyanin, the natural red dye in cranberries, is shown below with its acid and alkaline forms.



form A **form B**

(a) Say, giving reasons, which form is present at low pH.

.....

..... [1]

(b) **(i)** Classify the type of hydroxyl group that is shown in both **form A** and **form B**.

..... [1]

(ii) Describe a laboratory test for the type of hydroxyl group described in **(i)**.

.....

..... [2]

(c) **(i)** Draw an electron dot-cross diagram to illustrate the electron pairs round the oxygen atom represented by 

Show the outer electron shell only.

[3]

(ii) Suggest and explain a value for the bond angle in 

.....

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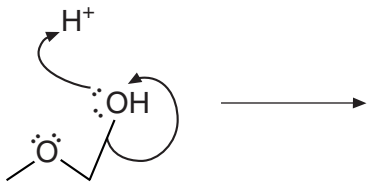
..... [3]

(d) The mechanism of the reaction of **form A** with H^+ is partially shown below.



A 'curly arrow' represents the movement of a pair of electrons.

(i) Add another 'curly arrow' to the structure to complete the mechanism and show the products of the reaction. [3]

(ii) Underline the **two** words below that best describe the mechanism.

addition **electrophilic** **elimination** **nucleophilic** **substitution** [2]

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

Form B is coloured while **form A** absorbs in the ultra-violet. Explain this by considering the difference in their structures and how this affects the electronic energy levels in the molecules.

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..... [4]

Quality of Written Communication [1]

(f) A chemist wishes to modify the chromophore of **form B** by substituting an $-NO_2$ group on to one of its aromatic rings.

(i) What difference in the properties of **form B** might be noticed as a result of this modification of the chromophore?

..... [1]

(ii) Give the reagents and conditions that are needed to nitrate **benzene**.

.....

..... [3]

(iii) Classify the **type** of reagent which carries out nitration.

..... [1]

(iv) Name the product when one $-NO_2$ group is substituted on to benzene.

..... [1]

[Total: 26]

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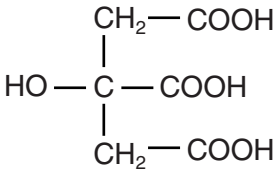
4 Citric acid is present in lemon juice and is responsible for the sharp taste. It is also present in the sweet 'sherbet' together with sodium hydrogencarbonate and sugar.



citric acid, $C_6H_8O_7$

(a) The reaction that occurs between citric acid and sodium hydrogencarbonate when a small amount of water is added is shown below.

$$C_6H_8O_7(s) + 3NaHCO_3(s) \longrightarrow Na_3C_6H_5O_7(s) + 3CO_2(g) + 3H_2O(l)$$ **equation 4.1**

(i) Explain, in terms of its structure, why one mole of citric acid reacts with **three** moles of sodium hydrogencarbonate.

.....

..... [1]

(ii) Suggest what is responsible for the 'fizzy' taste of sherbet.

..... [1]

(b) **(i)** Use the data in the table to calculate a value for ΔS_{sys} for the reaction in **equation 4.1**. **Give a sign with your answer.**

compound	S / J K^{-1} mol^{-1}
$C_6H_8O_7(s)$	+200
$NaHCO_3(s)$	+100
$Na_3C_6H_5O_7(s)$	+200
$CO_2(g)$	+210
$H_2O(l)$	+70

$$C_6H_8O_7(s) + 3NaHCO_3(s) \longrightarrow Na_3C_6H_5O_7(s) + 3CO_2(g) + 3H_2O(l)$$

equation 4.1

ΔS_{sys} = ... J K^{-1} mol^{-1} [3]

(ii) Explain how the sign of your answer could be predicted from **equation 4.1**.

.....

..... [2]

(iii) Given that $\Delta H = +70\,\text{kJ mol}^{-1}$ for the reaction in **equation 4.1**, calculate a value for ΔS_{total} at 298 K, **giving the sign and the correct units**.

$$\Delta S_{\text{total}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}} \qquad \Delta S_{\text{surr}} = -\frac{\Delta H}{T}$$

ΔS_{total} = ... [3]

(iv) What does the sign of ΔS_{total} suggest about the reaction in **equation 4.1**?

.....

..... [1]

(c) In aqueous solution, citric acid can be regarded as reacting by losing one proton only, so that it can be represented as HA.

$$HA \rightleftharpoons H^+ + A^- \qquad \textbf{equation 4.2}$$

Use **equation 4.2** to explain the meaning of the term *weak* when applied to acids.

.....

..... [1]

(d) K_a for citric acid in **equation 4.2** is $7.5 \times 10^{-4}\,\text{mol dm}^{-3}$.

(i) Write the expression for K_a using **equation 4.2**.

[2]

(ii) Calculate the pH of a $0.010\,\text{mol dm}^{-3}$ solution of citric acid.

pH = ... [2]

(e) Many foods that contain citric acid also have sodium citrate added as an 'acidity regulator'. This means that the mixture acts as a buffer solution.

$$HA \rightleftharpoons H^+ + A^- \qquad \textbf{equation 4.2}$$

(i) Use **equation 4.2** to explain how a buffer solution containing HA and A^- works.

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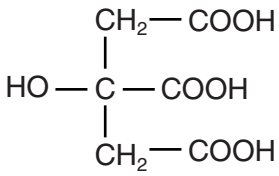
..... [3]

(ii) Calculate the pH of a buffer solution that contains 0.010 mol dm^{-3} citric acid and 0.020 mol dm^{-3} sodium citrate.

(K_a for citric acid in **equation 4.2** is 7.5×10^{-4} mol dm^{-3})

pH = ... [3]



citric acid, $C_6H_8O_7$

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

The mass spectrum, infrared spectrum and proton n.m.r. spectrum of citric acid are studied by a student. Describe and explain **one** important feature from each spectrum that would be characteristic of citric acid.

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..... [6]

Quality of Written Communication [2]

[Total: 30]

5 The pigment *chrome yellow* consists of lead chromate(VI), $PbCrO_4$. 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 CrO_4^{2-} ion.

..... [1]

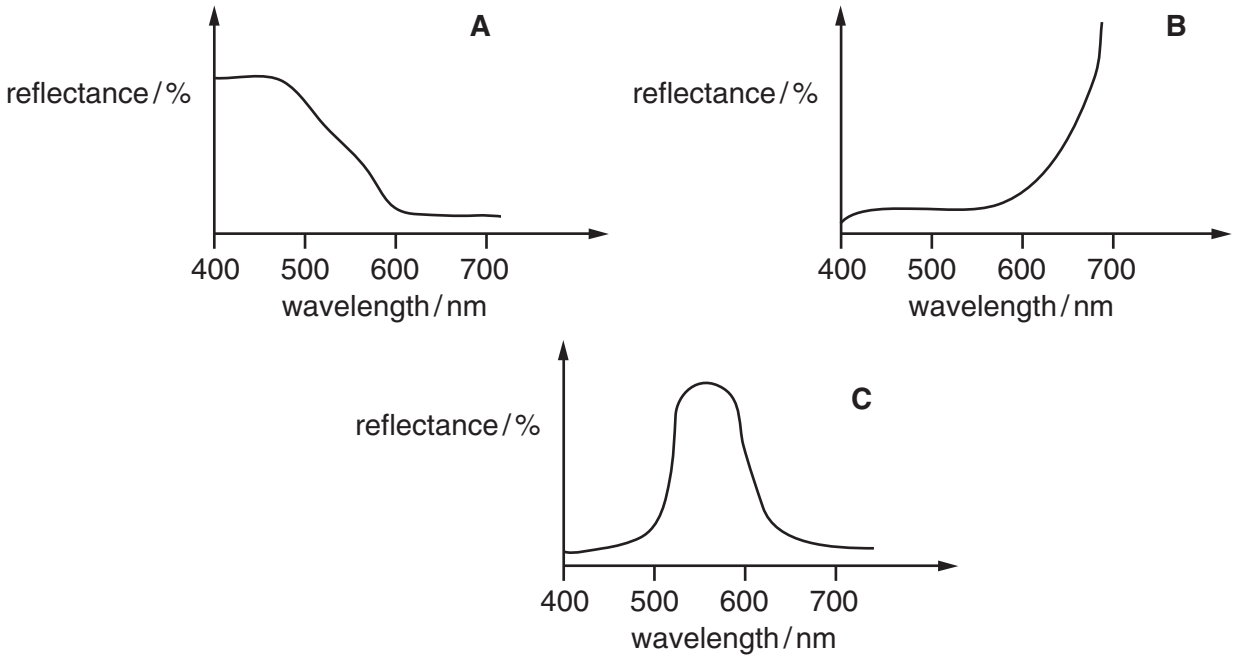
(b) Write an **ionic** equation for the precipitation of lead chromate(VI), showing state symbols.

[2]

(c) Different yellow shades can be obtained by mixing the solutions in different concentrations and at different temperatures. Circle the term in the list below that best describes the reason for the **differences in shades of colour** that are formed.

acid-base **ligand exchange** **polymorphism** **precipitation** **redox** [1]

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



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

.....

.....

..... [2]

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

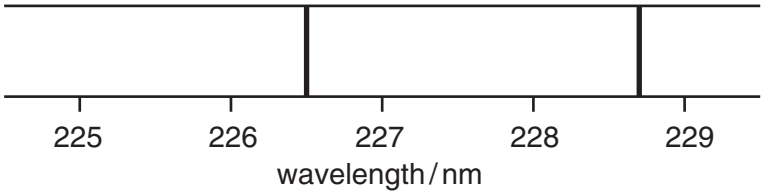
- barium yellow, $BaCrO_4$
- cadmium yellow, CdS
- orpiment, As_2S_3
- yellow ochre, containing Fe_2O_3

(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.

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.....

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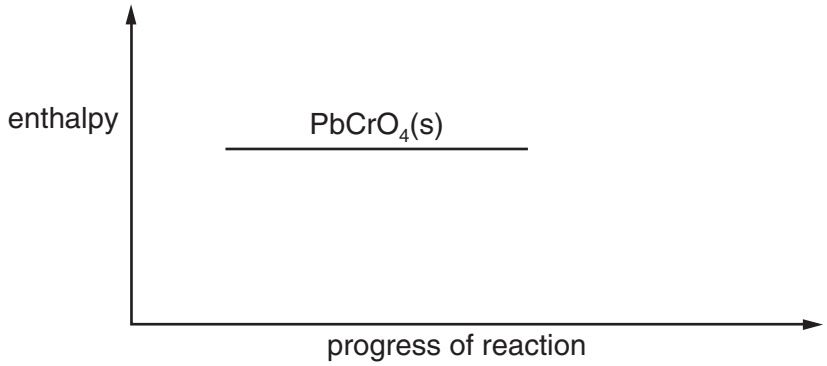
..... [4]

(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 a large positive enthalpy change of solution. Complete the diagram to illustrate this by drawing and labelling a suitable enthalpy level.



[2]

(g) The solubility products for two insoluble chromates are given below.

lead chromate(VI) $2.5 \times 10^{-14}\,mol^2\,dm^{-6}$

barium chromate(VI) $2.1 \times 10^{-10}\,mol^2\,dm^{-6}$

(i) Give the expression for the solubility product of **lead** chromate.

K_{sp} =

[2]

(ii) Solutions are mixed so that the concentrations of lead ions and chromate(VI) ions are both 1×10^{-4} mol dm^{-3}. Calculate whether a precipitate will form.

[2]

(iii) A solution containing 1×10^{-4} mol dm^{-3} lead nitrate and 1×10^{-4} mol dm^{-3} barium nitrate is added drop by drop to a solution containing 1×10^{-4} mol dm^{-3} sodium chromate(VI). What will precipitate first and why?

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..... [2]

[Total: 21]

END OF QUESTION PAPER