THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

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

Thursday 18 June 2009
Morning

Duration: 2 hours

OCE/T69316

2854401

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.
- 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.
- This document consists of **20** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**19**	
2	**28**	
3	**21**	
4	**19**	
5	**33**	
TOTAL	**120**	

Answer **all** the questions.

1 Breathalysers are used to detect the ethanol in people's breath to see whether they are fit to drive a motor vehicle. Breathalysers work in various ways.

(a) Some breathalysers have a tube containing a solution of potassium dichromate(VI) and a silver nitrate catalyst in sulphuric acid. The subject's breath is bubbled through the solution. The colour difference (compared with that of a reference tube) is measured using a colorimeter.

(i) What colour does the dichromate go when it reacts with ethanol?

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

(ii) Name a possible organic product of this reaction.

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

(iii) Silver nitrate is **not** used in the laboratory when oxidising ethanol with dichromate(VI).

How are the laboratory conditions different?

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

(b) One type of roadside breathalyser contains an electrochemical cell. At one electrode, ethanol is oxidised and at the other, oxygen is reduced to water.

Complete and balance the half-equation for the reduction of oxygen to water.

$$O_2 + H^+ \rightarrow H_2O$$ **[2]**

(c) Back at the police station, an infrared spectrometer is used to measure the amount of ethanol in the breath more accurately.

Many such machines work by measuring the absorption at 2950 cm^{-1}.

Suggest:

- why this frequency is used and not another absorption in the infrared spectrum of ethanol;
- why vinegar (ethanoic acid) in breath might interfere;
- an absorption that ethanoic acid would give but ethanol would not, giving the bond responsible.

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

(d) Ethanol in the breath comes from ethanol in the bloodstream, and an equilibrium is set up in the lungs.

$$C_2H_5OH(blood) \rightleftharpoons C_2H_5OH(g) \qquad \textbf{equation 1.1}$$

For this equilibrium, $K_c = [C_2H_5OH(g)] / [C_2H_5OH(blood)]$

(i) At normal body temperature, $K_c = 4.35 \times 10^{-4}$.
In 2008, the legal limit for blood ethanol for a driver was 0.080 g per 100 cm^3 blood.
Calculate the breath ethanol concentration (in g per 100 cm^3 air) that corresponds to this figure.

breath ethanol concentration = ...g per 100 cm^3 air **[2]**

(ii) The process in **equation 1.1** is endothermic.

State and explain how the value of K_c changes with temperature.

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

(e) The blood ethanol concentration can be measured using gas-liquid chromatography. The blood sample is diluted with water and a standard amount of propan-1-ol is added. The ratio of the peak areas of ethanol : propan-1-ol gives the blood ethanol concentration.

(i) Draw the **skeletal** formula of propan-1-ol.

[1]

(ii) In g.l.c., ethanol is detected before propan-1-ol. Suggest why this is so.

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

(iii) The g.l.c. instrument has to be calibrated frequently. Suggest how this is done.

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

[Total: 19]

2 A crucial reaction in the manufacture of sulphuric acid involves the oxidation of sulphur dioxide to sulphur trioxide by oxygen in the air.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3 \qquad \Delta H = -197 \text{ kJ mol}^{-1} \qquad \textbf{equation 2.1}$$

A V_2O_5 catalyst is used.

(a) (i) Give the oxidation states of sulphur in SO_2, SO_3 and H_2SO_4.

SO_2 ..... SO_3 ..... H_2SO_4 ..... **[3]**

(ii) Give the systematic name of V_2O_5.

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

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

Describe and explain the effect of increasing the pressure on the **rate of formation** and the **yield** of sulphur trioxide in **equation 2.1**.

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

Quality of Written Communication **[1]**

(ii) In fact, a pressure of just above atmospheric is used.

Suggest an explanation for why a higher pressure is **not** used.

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

$$2SO_2 + O_2 \rightleftharpoons 2SO_3 \qquad \Delta H = -197 \text{ kJ mol}^{-1} \qquad \textbf{equation 2.1}$$

(c) (i) Write the expression for the equilibrium constant, K_p, for the reaction in **equation 2.1** in terms of partial pressures.

[2]

(ii) At 1100 K, $K_p = 1.3 \times 10^{-1}$ atm^{-1}.

The equilibrium partial pressures are:

SO_2	0.66 atm
O_2	0.33 atm

Calculate the partial pressure of sulphur trioxide at equilibrium at this temperature.

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

partial pressure of SO_3 = ... atm **[3]**

(d) (i) ΔS_{sys} for the reaction in **equation 2.1** is negative. Use equation 2.1 to explain why this is so.

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

$2SO_2 + O_2 \rightleftharpoons 2SO_3$ $\Delta H = -197$ kJ mol^{-1} **equation 2.1**

(ii) Use the data in the table to calculate a value for ΔS_{sys} for the reaction in **equation 2.1**.

substance	S/J K^{-1} mol^{-1}
SO_2	+249
SO_3	+256
O_2	+205

ΔS_{sys} = ... J K^{-1} mol^{-1} **[2]**

(iii) Use the expressions below to explain why you would expect the value of ΔS_{tot} for the reaction in **equation 2.1** to become more negative as the temperature increases.

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

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

(iv) Calculate the temperature at which ΔS_{tot} is zero.

temperature = ...K **[2]**

(e) The sulphur trioxide is turned into sulphuric acid.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3 \qquad \textbf{equation 2.1}$$

$$SO_3 + H_2O \rightarrow H_2SO_4 \qquad \textbf{equation 2.2}$$

Calculate the maximum mass of sulphuric acid (in kg) that could be made from 10 kg of sulphur dioxide.

A_r: S, 32; O, 16; H, 1.0

mass = ... kg **[2]**

[Total: 28]

3 Ion channels are small passageways that control the movement of electrically charged particles across a cell's membrane. Each channel allows only certain kinds of ion to flow through. Recent research has revealed details of how one such ion channel allows potassium ions, but not sodium ions, to pass through it.

(a) (i) Give the electron configurations, in terms of s and p electrons, of a sodium **ion** and a potassium **ion**.

sodium ion .....

potassium ion ..... **[2]**

(ii) Explain why potassium ions are larger than sodium ions and why they have a smaller charge density.

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

(b) The researchers found that barium ions passed through the potassium channels.

The relative surface charge density of an ion can be calculated by dividing its charge by the square of its radius.

(i) Complete the table by calculating the relative surface charge density for the barium ion.

ion	charge	radius/ nm	relative surface charge density $\left(\frac{\text{charge}}{\text{radius}^2}\right)$
potassium	+1	0.133	56.5
sodium	+1	0.098	104.1
barium	+2	0.134	

[1]

(ii) Use the table to decide whether **ion size** or **surface charge density** is more important in determining which ions can pass through the channels. Give your reasoning.

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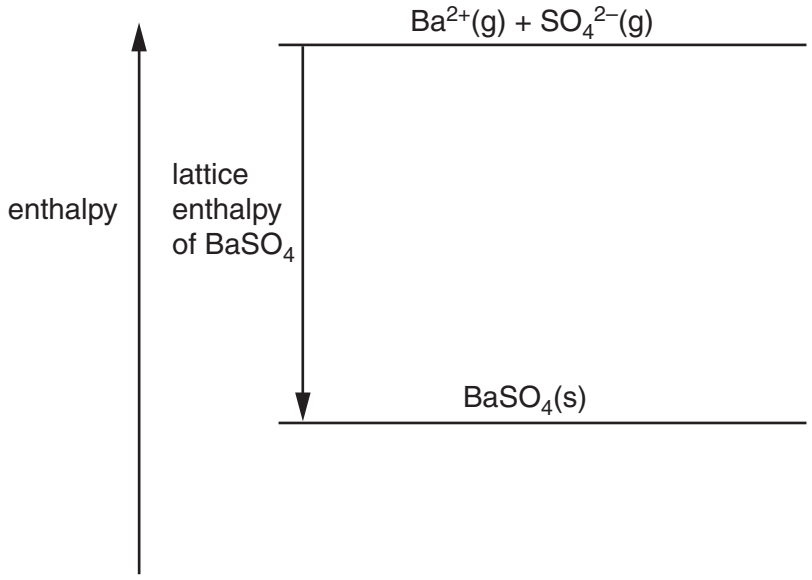
..... **[2]**

(c) (i) Barium sulphate is only slightly soluble in water and the process is endothermic.

Complete the diagram below for the dissolving of barium sulphate, labelling the enthalpy levels and enthalpy changes involved.



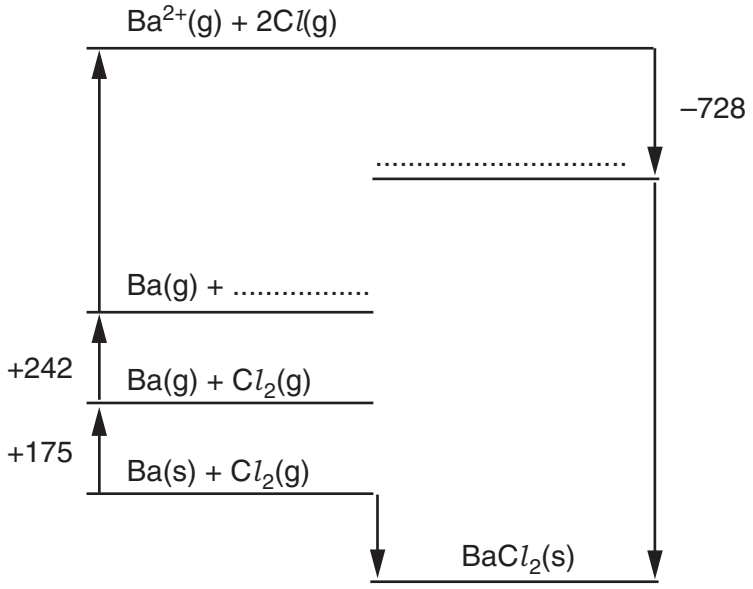
[5]

(ii) Barium ions are hydrated in solution. Draw a diagram of a hydrated barium ion showing charges and partial charges.

[2]

(d) The lattice enthalpy is one factor that determines the solubility of a salt. A partly completed Born-Haber cycle for barium chloride is given below.

(i) Write the missing formulae on the dotted lines in the Born-Haber cycle diagram.



[2]

	kJ mol^{-1}
first ionisation enthalpy of barium	+500
second ionisation enthalpy of barium	+1000
enthalpy change of formation of barium chloride	–512

(ii) Label the lattice enthalpy on your diagram. **[1]**

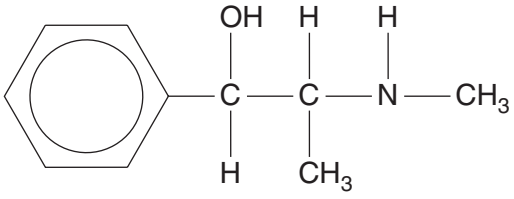
(iii) Use the data above to work out a value for the lattice enthalpy of barium chloride. Enthalpy change values shown on the diagram are in kJ units.

Show your working on the diagram.

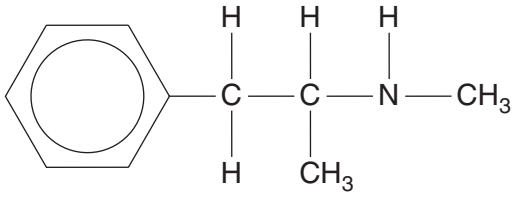
lattice enthalpy = ...kJ mol^{-1} **[3]**

[Total: 21]

4 The medicine ephedrine was used to clear blocked noses and as a slimming aid until it was found to have other effects. Methamphetamine can be made from ephedrine and can also be used as a slimming aid, though it is more often used as a 'social drug' with dangerous side-effects. The structures of these two compounds are shown below.



ephedrine



methamphetamine

(a) (i) Name the functional group that is present in ephedrine and **not** in methamphetamine.

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

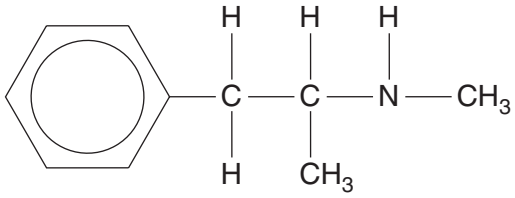
(ii) Name the **type** of reaction by which ephedrine could be turned into methamphetamine.

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

(iii) On the structures above, circle **all** the chiral centres in ephedrine **and** methamphetamine. **[2]**

(b) (i) Methamphetamine is often used as its chloride salt. This can be made from methamphetamine by reacting it with hydrochloric acid.

Add to the diagram below to show the structure of the chloride salt of methamphetamine, showing ionic charges.



[2]

(ii) Explain, in terms of intermolecular forces, why this salt is soluble in water, whereas methamphetamine is not.

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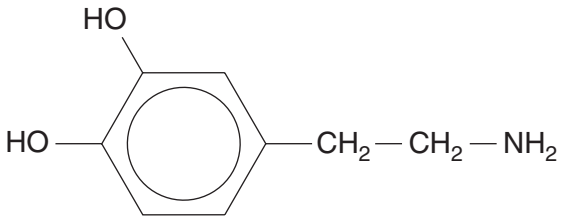
..... **[4]**

(iii) Name a reagent that would convert the salt back to methamphetamine.

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

(c) Dopamine is a chemical that is produced in the brain. Methamphetamine is thought to work by competitively inhibiting dopamine uptake.

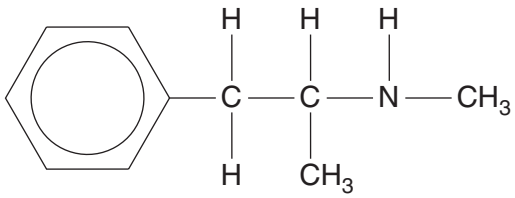


dopamine

What name is given to OH groups attached to a benzene ring?

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

(d) **(i)** If **methamphetamine** is a competitive inhibitor for a site which binds **dopamine**, suggest the part of the methamphetamine molecule that is most likely to bind to the site. Circle this part on the **methamphetamine** structure below.



methamphetamine

[1]

(ii) Only one enantiomer of methamphetamine is found to be active. Explain this in terms of the binding of the molecule to the site.

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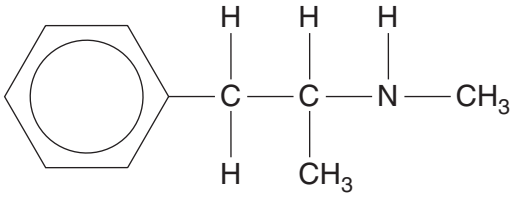
..... **[2]**



methamphetamine

(e) Mass spectrometry is used to identify methamphetamine.

(i) What is the mass of the molecular ion of methamphetamine?

A_r: C,12; H, 1.0; O, 16; N, 14

mass of molecular ion = ... **[1]**

(ii) A fragment at mass 58 is also important in identifying methamphetamine.
Suggest the formula of this fragment.

[1]

(f) In the proton nmr spectrum of methamphetamine there is a peak labelled '2H' arising from the **side-chain**.

Circle the part of the methamphetamine structure above that gives rise to the '2H' peak from the side-chain. Explain your choice.

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

[Total: 19]

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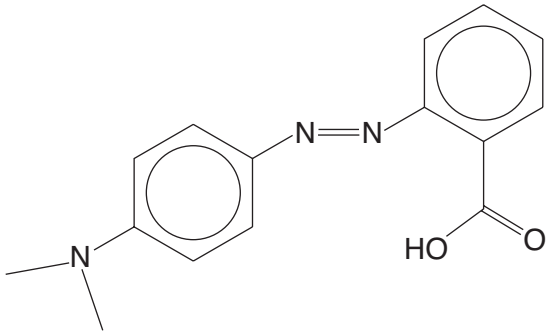
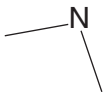
TURN OVER FOR QUESTION 5

5 The azo dye methyl red is used as an indicator in pH titrations.



methyl red

(a) (i) Draw the structural formula of the part of the molecule shown as 

[1]

(ii) Name **two** functional groups (apart from the arene rings) in the molecule.

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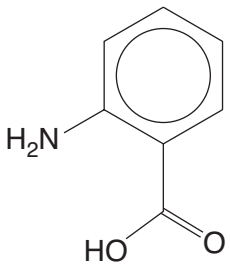
..... **[2]**

(b) **Compound A**, shown below, can be diazotised as part of the synthesis of methyl red.



compound A

(i) Draw the structure of the diazonium ion formed from **compound A**.

[1]

(ii) Draw the structure of a compound that will react with this diazonium ion to form methyl red.

[1]

(iii) What name is given to the substitution reaction when the diazonium ions react to form dyes?

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

(iv) Classify the reaction mechanism of this reaction.

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

(c) Electrons are delocalised over a large part of the methyl red structure and this part is called the chromophore.

(i) Explain where delocalised electrons come from in a benzene ring and how they are arranged relative to the atoms in the ring.

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

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

Methyl red is coloured whereas benzene is not.

Explain this in terms of electron energy levels and frequencies of radiation.

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..... **[6]**

Quality of Written Communication **[2]**

(d) A scientist wishes to substitute a CH_3CO group on to a benzene ring.

(i) Give the systematic name of the group and draw a structural formula to show it attached to a benzene ring.

name .....

formula

[2]

(ii) Give the reagents and conditions that the scientist would use for this reaction.

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

(iii) What name is given to this electrophilic substitution reaction of a CH_3CO group on to a benzene ring?

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

(iv) The CH_3CO group can be substituted on to a methyl red molecule causing a colour change.

Suggest a reason for this in terms of the chromophore.

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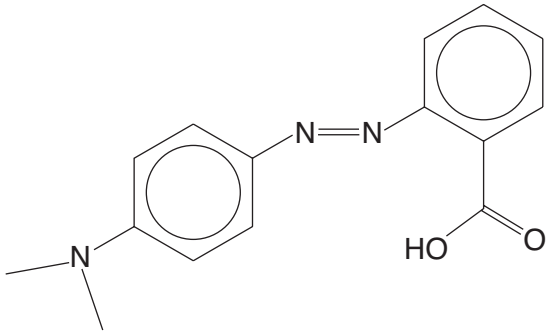
..... **[2]**

THIS QUESTION CONTINUES ON THE NEXT PAGE



methyl red

(e) Methyl red turns into a yellow form when alkali is added. The reaction can be summarised as **equation 5.1** below.

$$HIn \rightleftharpoons H^+ + In^- \qquad \textbf{equation 5.1}$$

(i) Which of 'HIn' and 'In^-' is yellow? Explain why.

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

(ii) Select the group on the methyl red molecule that reacts with alkali and write an equation for its reaction with hydroxide ions.

[2]

(f) For **equation 5.1**

$$K_a = \frac{[H^+]\,[In^-]}{[HIn]} = 7.9 \times 10^{-6} \text{ mol dm}^{-3}$$

Calculate the pH at which the red form and the yellow form are present in equal concentrations.

pH = ... **[2]**

[Total: 33]

END OF QUESTION PAPER