OCR
Oxford Cambridge and RSA

Monday 15 June 2015 – Afternoon

A2 GCE CHEMISTRY B (SALTERS)

F335/01 Chemistry by Design

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry B (Salters)* (inserted)

Other materials required:
- Scientific calculator

Duration: 2 hours

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found inside this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.

  This means for example you should:
  – ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  – organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry B (Salters)* is provided as an Insert with this Question Paper.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **120**.
- This document consists of **28** pages. Any blank pages are indicated.

Answer **all** the questions.

1 Limestone, consisting mainly of calcium carbonate, $CaCO_3$, is a major constituent of some rocks.

(a) The action of heat on limestone forms calcium oxide that can be used for making cement.

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g) \qquad \Delta H = +180\,kJ\,mol^{-1} \qquad \textbf{equation 1.1}$$

State the bonding in $CO_2(g)$ and the bonding and structure in CaO(s).

.....

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

(b) Some entropy data for the compounds in **equation 1.1** are given below.

Compound	***S*/J mol^{-1} K^{-1}**
$CaCO_3(s)$	+93
CaO(s)	+40
$CO_2(g)$	+214

(i) Calculate a value of ΔS_{sys} for the reaction in **equation 1.1**.

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

(ii) Calculate the value of ΔS_{tot} at 298 K.

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

(iii) Calculate the temperature at which ΔS_{tot} for the reaction in **equation 1.1** is zero and comment on the significance of this temperature.

T = ... K

comment .....

.....

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

(c) When rainwater runs over limestone rocks, the reaction shown in **equation 1.2** takes place.

$$CaCO_3(s) + CO_2(aq) + H_2O(l) \rightleftharpoons Ca(HCO_3)_2(aq) \qquad \textbf{equation 1.2}$$

(i) Give the systematic name for $Ca(HCO_3)_2$.

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

(ii) Where does the CO_2 in **equation 1.2** come from?

.....

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

(iii) When water containing $Ca(HCO_3)_2$ is boiled, a reaction occurs and a precipitate of limescale is formed.

Use information from **equation 1.2** to suggest why this happens.

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

(d) Some data for the dissolving of calcium carbonate are given in the table below.

	Enthalpy change / kJ mol^{-1}
Lattice enthalpy of $CaCO_3(s)$	–2800
Enthalpy change of solution of $CaCO_3(s)$	–12
Enthalpy change of hydration of $Ca^{2+}(g)$	–1650

The enthalpy level diagram below is for the dissolving of calcium carbonate.

Label it with the species present on each energy level.

Use your diagram to calculate the enthalpy change of hydration of $CO_3^{2-}(g)$.

ΔH_{hyd} ($CO_3^{2-}(g)$) = ... kJ mol^{-1} **[4]**

[Total: 16]

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Question 2 begins on page 6

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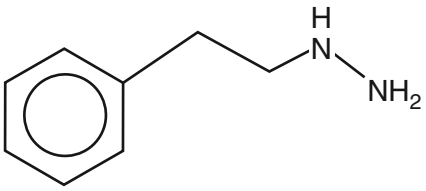
2 Phenelzine is an antidepressant drug.



phenelzine

(a) (i) Give the molecular formula of phenelzine.

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

(ii) Give and explain the H–N–H bond angle in phenelzine.

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

(b) Phenelzine is made by reacting hydrazine, H_2NNH_2, with a brominated hydrocarbon.

Suggest a skeletal formula for the brominated hydrocarbon.

[1]

(c) Benzene can either be represented as diagram **A** or diagram **B** below.

Explain, in terms of the reactions of benzene, why diagram **A** is often preferred.

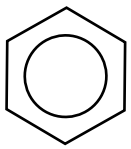

diagram A

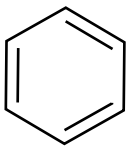

diagram B

In your answer you should make it clear how your points link together.

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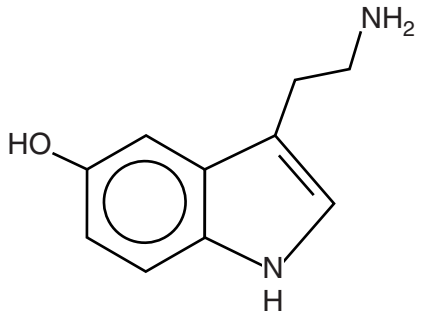
..... **[4]**

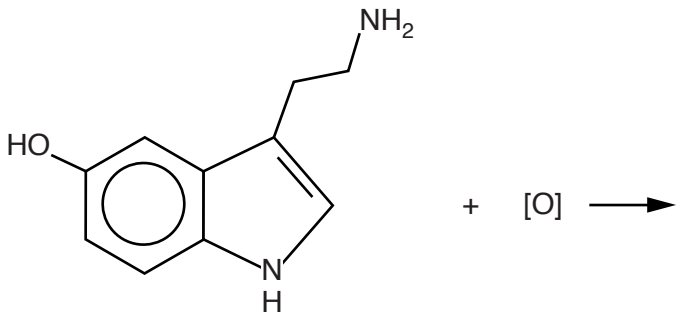
(d) Phenelzine acts as an antidepressant because it irreversibly inhibits an enzyme. This enzyme catalyses the reaction of serotonin with an oxidising agent. Serotonin controls human mood.



serotonin

Complete **equation 2.1** below for the enzyme-catalysed reaction in which the $–CH_2NH_2$ group is oxidised to –CHO.

[O] represents an atom of oxygen supplied by the oxidising agent.



equation 2.1

[2]

(e) Another inhibitor of the enzyme is 'moclobemide'. This inhibits the enzyme **reversibly**.

- Name the substrate of the enzyme.
- Explain how moclobemide inhibits the enzyme action.
- Describe how increasing the concentration of the substrate would affect the rate of the reaction in **equation 2.1** when moclobemide is present.

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

(f) Phenelzine is not coloured because it absorbs only in the ultraviolet.
Many aromatic compounds are coloured.

Explain, in terms of chromophores and energy levels, why these compounds are coloured whereas phenelzine is not.

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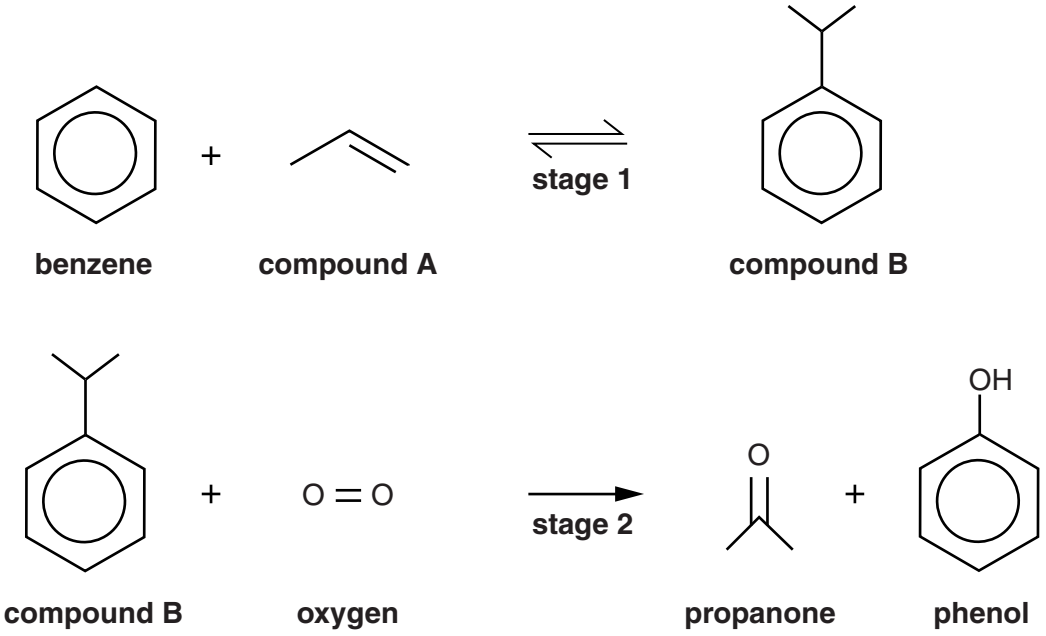
..... **[5]**

[Total: 20]

3 Propanone and phenol are useful organic compounds. They are both manufactured from benzene by the two-stage process shown below.



(a) (i) Name compound **A**.

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

(ii) The reaction in **stage 1** is described as a *Friedel-Crafts* reaction.

Give **one** similarity and **one** difference between this reaction and most other Friedel-Crafts reactions. Give your answer in terms of the **reactants** and **products**.

Similarity .....

.....

Difference .....

.....

[2]

(b) **Stage 1** is carried out at 250 °C and 30 atmospheres pressure in the gas phase. The reaction is exothermic.

(i) Describe and explain the effect of increased pressure on the reaction in **stage 1**. Answer in terms of the equilibrium yield and rate.

In your answer, you should relate your explanation to the equation for the reaction.

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

(ii) Describe and explain the effect (if any) of increasing the temperature on the **equilibrium constant** for **stage 1**.

Suggest why a temperature lower than 250 °C is **not** used.

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

(iii) What is the atom economy of the whole process (stages **1** and **2** taken together)?

Explain why this is beneficial to the environment.

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

(c) Propanone is used to make 'methyl methacrylate' which is an important monomer for making 'acrylic' polymers. The process is outlined below.

$(CH_3)_2CO \rightarrow (CH_3)_2C(OH)CN \rightarrow CH_2=C(CH_3)CONH_2 \rightarrow CH_2=C(CH_3)COOCH_3$

propanone **compound C** **compound D** **methyl methacrylate**

(i) Name compound **C** and give a reagent for its formation from propanone.

Name .....

Reagent .....
[2]

(ii) Name **two** functional groups in compound **D**.

.....

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

(iii) Suggest a reagent that would react with compound **D** to give methyl methacrylate and ammonia.

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

(iv) Suggest, with a reason, the **type** of polymerisation that methyl methacrylate undergoes.

Give the **full** structural formula of the repeat unit of the polymer.

Type of polymerisation and reason .....

.....

.....

Repeat unit

[2]

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Question 3 continues on page 14

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(d) Phenol, C_6H_5OH, can be chlorinated. The resulting compounds are used to make antiseptic medicines.

(i) Name the mechanism of the reaction between phenol and chlorine.

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

(ii) Give the **molecular** formula of a monosubstituted chlorophenol (i.e. a molecule of phenol with one chlorine atom substituted for a hydrogen on the ring).

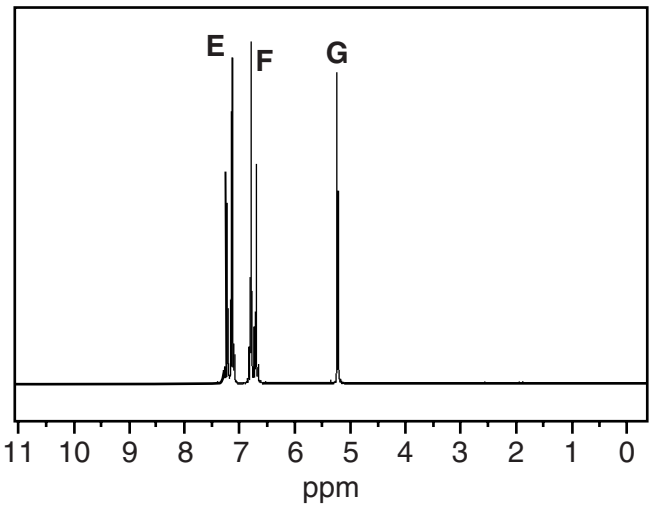
..... **[1]**

(iii) There are several monosubstituted chlorophenol isomers.

Give the total number of isomers.

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

(e) The proton NMR spectrum of one monosubstituted chlorophenol is given below.



(i) Explain why there are three peaks in the spectrum.

.....

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

(ii) Draw the structure of the monosubstituted chlorophenol which produces this spectrum.

[1]

(iii) Label the relevant protons on the structure in part **(ii)** with **E**, **F** and **G** to correspond to the three peaks. **[2]**

(iv) Explain why peaks **E** and **F** are doublets.

.....

.....

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

(f) The compound I*Cl* reacts with phenol. One of the products is a monosubstituted phenol.

Suggest the structure of this product and suggest why this product is formed.

Structure

Reason .....

.....

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

[Total: 29]

4 Calcium carbide, CaC_2, can be made by reacting calcium oxide with carbon at high temperatures.

(a) Write a possible equation for the formation of calcium carbide from calcium oxide, CaO.

[1]

(b) Calcium carbide is heated with nitrogen under pressure. Calcium cyanamide is formed.

$$CaC_2 + N_2 \rightarrow CaCN_2 + C$$

Calcium cyanamide is used as a fertiliser because it reacts with water to give ammonia, NH_3.

(i) Suggest an equation for the reaction of calcium cyanamide with water.

[2]

(ii) The formation of calcium cyanamide is an example of 'nitrogen fixation' as it converts atmospheric nitrogen to its compounds.

Suggest and explain why there are not many nitrogen fixation reactions.

.....

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

(iii) Explain why nitrogen fixation is important for plants.

.....

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

(iv) Calculate the percentage by mass of nitrogen in calcium cyanamide.

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

Percentage = ... % **[2]**

(c) Ammonia reacts with oxygen to form NO in the presence of a platinum catalyst at 850 °C.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$$

(i) Give the oxidation states of nitrogen in NH_3 and NO.

NH_3 ..... NO ..... **[1]**

(ii) Give the systematic name of NO.

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

(iii) A mixture of 50 cm^3 of ammonia and 50 cm^3 of oxygen is allowed to reach equilibrium. The total volume is then 105 cm^3. All volumes are measured at the same temperature (above 100 °C) and pressure.

Calculate the percentage of ammonia that has been converted to NO.

Percentage = ... % **[2]**

(iv) At room temperature, a sample of NO immediately turns brown when released into the air.

Explain why this happens.

.....

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

(d) Calcium carbide has been used as a source of ethyne, C_2H_2, because it reacts with water as shown below.

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$$

(i) Suggest the **full** structural formula for ethyne, showing a bond angle in the molecule with its value.

[2]

(ii) Ethyne can be polymerised in the presence of a catalyst to give cycloocta-1,3,5,7-tetraene.

Draw a **skeletal** formula for cycloocta-1,3,5,7-tetraene.

[2]

(iii) A molecule of cycloocta-1,3,5,7-tetraene does **not** have delocalised electrons.

Suggest the **skeletal** formula of the compound formed when cycloocta-1,3,5,7-tetraene reacts with excess bromine.

[1]

(e) The ethyne produced by the method in **(d)** is often contaminated with phosphane, PH_3. Phosphane is produced when calcium phosphide (an impurity in the calcium carbide) reacts with water.

(i) Give the formula of calcium phosphide.

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

(ii) Draw a *'dot-and-cross'* diagram for phosphane, PH_3.

Show outer shell electrons only.

[1]

(iii) Unlike ammonia, phosphane, PH_3, is not very soluble in water.

Explain this difference in solubility.

Answer in terms of intermolecular bonding and the differences between P and N atoms.

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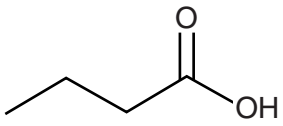
..... **[4]**

[Total: 24]

5 Butanoic acid (often called 'butyric acid') is a foul-smelling liquid that has been used by anti-whaling protesters to throw on board whaling ships.



butanoic acid

(a) 'Isobutyric acid' is an isomer of butanoic acid.

Give the systematic name of isobutyric acid.

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

(b) 'Butyric' means 'buttery'. Butanoic acid is formed by hydrolysis when butter turns rancid (sour).

(i) Butter consists mainly of triesters of propane-1,2,3-triol.

Draw the **full** structural formula of a triester molecule that hydrolyses to give three molecules of butanoic acid.

[2]

(ii) Explain why this triester is an example of a *saturated* fat.

.....

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

(c) Butanoic acid is soluble in water and its K_a value is 1.51×10^{-5} mol dm^{-3}.

(i) Complete the equation for the ionisation of butanoic acid in water.

$$C_4H_8O_2(aq) \rightleftharpoons$$

[1]

(ii) Explain, in terms of a property of butanoic acid, why an equilibrium sign is used in the equation in **(i)**.

.....

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

(iii) Pure butanoic acid does not react with solid calcium carbonate.

Suggest why pure butanoic acid does not react.

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

(iv) When butanoic acid is partially neutralised by sodium hydroxide, a buffer solution is formed.

Explain how the particles in the solution account for its buffering action.

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

(d) In answering this part, you will need the following data.

$K_a = 1.51 \times 10^{-5}\,\text{mol}\,\text{dm}^{-3}$ $K_w = 1.00 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$

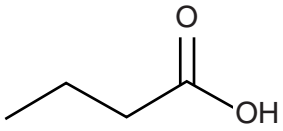
(i) Calculate the pH of a $0.0200\,\text{mol}\,\text{dm}^{-3}$ solution of butanoic acid.

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

(ii) $30.0\,\text{cm}^3$ of $0.0200\,\text{mol}\,\text{dm}^{-3}$ sodium hydroxide are added to $25.0\,\text{cm}^3$ of $0.0200\,\text{mol}\,\text{dm}^{-3}$ butanoic acid.

Calculate the pH of the resulting solution.

pH = ... **[3]**



butanoic acid

(e) Esters of butanoic acid are used as food flavourings.
Methyl butanoate, for example, smells and tastes of pineapples.

(i) Draw the **skeletal** formula of methyl butanoate.

[1]

(ii) Methyl butanoate can be made in the laboratory by a one-step reaction using an acyl chloride.

Give the structure of the acyl chloride.

[1]

(iii) Name the types of intermolecular bonding in methyl butanoate.

Explain whether the ester has a higher or a lower boiling point than butanoic acid.

In your answer you should use appropriate technical terms, spelled correctly.

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

(f) Fats also become rancid when they are oxidised. A mechanism for such a reaction is shown below. R represents an alkyl group.

$$R–CH_2–CH_2– + {}^{\bullet}OH \rightarrow R–C^{\bullet}H–CH_2– + H_2O \qquad \textbf{equation 5.1}$$

$$R–C^{\bullet}H–CH_2– + O_2 \rightarrow R–CH(OO^{\bullet})–CH_2– \qquad \textbf{equation 5.2}$$

$$R–CH(OO^{\bullet})–CH_2– + R–CH_2–CH_2– \rightarrow R–CH(OOH)–CH_2– + R–C^{\bullet}H–CH_2– \qquad \textbf{equation 5.3}$$

$$R–CH(OOH)–CH_2– \rightarrow R–CH(O^{\bullet})–CH_2– + {}^{\bullet}OH \qquad \textbf{equation 5.4}$$

$$R–CH(O^{\bullet})–CH_2– \rightarrow R–CHO + C^{\bullet}H_2– \qquad \textbf{equation 5.5}$$

(i) Use a '*dot-and-cross*' diagram to explain why ${}^{\bullet}OH$ is described as a *radical*.

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

(ii) In **equation 5.1** a C–H bond is broken in a CH_2 group.

Complete the diagram to indicate the movement of electrons in this process.

C–H

[1]

(iii) Name the **type** of bond breaking in **(ii)**.

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

(iv) Classify **equations 5.1** to **5.5** as initiation, propagation or termination by ticking the appropriate boxes in the table below.

Equation	Initiation	Propagation	Termination
5.1			
5.2			
5.3			
5.4			
5.5			

[2]

(v) The reactions in **equations 5.2** and **5.3** make a chain reaction.

Give the overall equation for this chain reaction.

[1]

(vi) The molecule R–CHO formed in **equation 5.5** is one of the rancid products produced by oxidation.

Name the functional group in this molecule.

This functional group has laboratory reactions that involve colour changes. Describe **one** of these reactions.

Name of functional group .....

Reagent and conditions for reaction .....

.....

.....

Final colour .....

.....

[2]

[Total: 31]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin.