Autumns Examinations 2011-2012

Exam Code(s) 0MB, 1BE, 1BG, 1BM, 1BO, 1BPM, 1BV
Exam(s) 1st Engineering, 1st Medicine, 1st Science
Module Code(s) CH111
Module(s) Engineering and Medical Chemistry

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Instructions: Answer five questions of which not more than two may be chosen from any one section.
Separate answers books for Sections A, B and C are not required

Duration 3 hrs
Number of pages 5 (including this front page)
School Chemistry

Requirements Graph paper, mathematical tables
Marks All questions carry equal marks; breakdown of marks is as shown.
Section A

1. (a) What is a heterogeneous catalyst? Using an example explain in detail how a heterogeneous catalyst functions. [6 marks]

(b) The gas N₂O₅ decomposes at 55°C as follows:

\[ 2\text{N}_2\text{O}_5 \rightarrow 4\text{NO}_2 + \text{O}_2 \]

The following time-course data were obtained for this reaction:

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>[N₂O₅] (molL⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0200</td>
</tr>
<tr>
<td>100</td>
<td>0.0169</td>
</tr>
<tr>
<td>300</td>
<td>0.0120</td>
</tr>
<tr>
<td>500</td>
<td>0.0086</td>
</tr>
<tr>
<td>700</td>
<td>0.0061</td>
</tr>
</tbody>
</table>

(i) Use the data to determine whether the reaction is zero or first order. [4 marks]

(ii) Determine the rate constant \((k)\) for the reaction. [4 marks]

(iii) Calculate the rate of the reaction when \([\text{N}_2\text{O}_5] = 0.0130\ \text{molL}^{-1}\). [3 marks]

(iv) Calculate the half-life of the reaction. [3 marks]

(NB Graph paper is available)

2. (a) Describe the principal fundamental particles from which atoms are constructed and explain how any one of them was discovered. [5 marks]

(b) Explain what is meant by an orbital and how a 2pₓ and a 3s orbital are related to each other. [5 marks]

(c) Explain what is meant by Le Chatelier’s Principle and how it might be used to determine the temperature conditions for maximum conversion of reactants to products in the following reaction (\(\Delta H = -206.1\ \text{kJmol}^{-1}\)):

\[ \text{CO}(g) + 3\text{H}_2(g) \rightleftharpoons \text{CH}_4(g) + \text{H}_2\text{O}(g) \]

[5 marks]

(d) Explain briefly how magnetic resonance imaging (MRI) is used to investigate internal problems in the body. [5 marks]
3. (a) The Solvay method for the manufacture of sodium carbonate (Na₂CO₃) is a two-stage process involving the following reactions:

\[
\text{NaCl} + \text{NH}_3 + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{NH}_4\text{Cl} + \text{NaHCO}_3
\]
\[
2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O}
\]

(i) What volume of NH₃ (at STP) would be required to process 1 tonne (1000 kg) of NaCl? [4 marks]

(ii) What mass of Na₂CO₃ would be formed from the same amount of NaCl? [3 marks]

(iii) What mass of NH₄Cl would be formed as a by-product in producing 500 kg of Na₂CO₃? [3 marks]

[1 mole of gas occupies 22.4 L at STP]

(b) The burning of ethanol (CH₃CH₂OH) produces carbon dioxide and water:

\[
\text{CH}_3\text{CH}_2\text{OH}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)
\]

Use the following data to determine the standard free energy change (\(\Delta G^\circ\)) for the reaction:

<table>
<thead>
<tr>
<th></th>
<th>(\Delta H^\circ_f) (kJmol⁻¹)</th>
<th>(S^\circ) (Jmol⁻¹K⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₃CH₂OH(l)</td>
<td>-277.6</td>
<td>160.7</td>
</tr>
<tr>
<td>H₂O(l)</td>
<td>-285.8</td>
<td>69.9</td>
</tr>
<tr>
<td>CO₂(g)</td>
<td>-393.5</td>
<td>213.6</td>
</tr>
<tr>
<td>O₂(g)</td>
<td>-</td>
<td>205.0</td>
</tr>
</tbody>
</table>

[10 marks]

4. (a) A substance X is composed of small covalently bound molecules. Describe what happens at a molecular level as a sample of X is heated and changes from a solid to a liquid and then to a gas. [10 marks]

(b) 35 L of oxygen at 85 °C and 92,000 Nm⁻² are added to a 40 L stainless steel cylinder containing carbon dioxide at 40 °C and 70,000 Nm⁻². Calculate the final pressure in the cylinder if after the addition the final temperature is 55 °C. [10 marks]
Section B

5. The oxides of nitrogen, sulfur and carbon play an important role in air pollution. Outline the role played by the oxides of any two of these elements in air pollution; in the case of carbon, only carbon monoxide should be considered. Chemical reactions must be provided where appropriate.  

[2 x 10 marks]

6. (a) Draw a diagram of a standard hydrogen half-cell and describe the use to which it is put.  

[6 marks]

(b) Describe the basic features of the corrosion process as it occurs in iron and outline any two methods by which its effects can be minimised.  

[7 marks]

(c) A proposed technical process involves a solution of Pb\(^{2+}\) ions coming into contact with steel (iron) fittings. Write down the chemical reaction that could occur and the cell description corresponding to the reaction. Calculate the EMF of the cell given Fe\(^{2+}/\text{Fe}\) = -0.409 V and Pb\(^{2+}/\text{Pb}\) = -0.126 V. Should the process be modified and if so, what sort of changes would you make?  

[7 marks]

7. (a) Explain why the boiling point of H\(_2\)Te (-2.2°C) is greater than that of H\(_2\)S (-60.7°C) but less than that of H\(_2\)O.  

[5 marks]

(b) In terms of the structure of a crystal, explain what is meant by the term “unit cell”. Draw diagrams showing the three cubic unit cells.  

[5 marks]

(c) Describe the types of intramolecular and intermolecular bond that exist in liquid water  

[5 marks]

(d) Give an account of the bonding that exists in sodium metal and how it is responsible for its electrical and mechanical properties.  

[5 marks]

Section C

8. Discuss the chemistry of alcohols under the following headings:  

(a) Structure and physical properties.  

[6 marks]

(b) Methods of making alcohols.  

[7 marks]

(c) Typical reactions of alcohols.  

[7 marks]

Structures and chemical reactions must be provided where appropriate.
9. (a) Draw structures for all the structural isomers of pentane and provide an IUPAC name for any one of them. [5 marks]

(b) Explain what is meant by “cracking” and “reforming” in the context of the petrochemical industry. [5 marks]

(c) Draw the structure of any ketone and, using an appropriate reaction as an example, explain why it would be attacked by a nucleophile. [5 marks]

(d) Explain (i) what happens when chlorine (Cl₂) reacts with methane and (ii) why the reaction is considered to be a photochemical, free radical substitution reaction. [5 marks]

10 Answer all parts

Answer the following questions in relation to the reaction scheme shown below:

\[
\begin{align*}
\text{C}_4\text{H}_8\text{O}_2 \quad \text{(A)} & \quad \rightarrow \quad \text{C}_4\text{H}_8\text{O} \quad \text{(B)} & \quad \rightarrow \quad \text{C}_4\text{H}_{10}\text{O} & \quad \text{(C)} \\
& \quad \downarrow & \quad \text{(E)} & \quad \text{Br}_2 & \quad \text{C}_4\text{H}_8 \quad \text{(D)}
\end{align*}
\]

N.B. (A) contains a straight chain of carbon atoms, with a functional group at one end. It turns blue litmus red.

(a) Provide structures for compounds (A) – (E). The functional group should be clearly labelled and named in each case [10 marks]

(b) Where none is indicated, suggest reagents which could be used to carry out each reaction. [5 marks]

(c) Outline two other reactions for (D) and provide reaction equations for them. [5 marks]