Semester 1 Examinations 2013-2014

Paper 1

Exam Code(s) 1BO, 0MB, 1BPM, 1BMS, 1BY, 1EH, 1BPP
Exam(s) Foundation Medicine, 1st Science

Module Code(s) CH120, CH130
Module(s) Chemistry: molecular science
Chemistry: world of the molecule

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

Duration 2 hr
Number of pages 4 (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. **Answer all parts**
   Zinc blende (ZnS) is a common zinc ore from which the metal can be produced in a two-step process:
   \[
   \begin{align*}
   \text{ZnS} + \frac{3}{2}\text{O}_2 & \rightarrow \text{ZnO} + \text{SO}_2 \\
   \text{ZnO} + \text{C} & \rightarrow \text{Zn} + \text{CO}
   \end{align*}
   \]
   The sulfur dioxide (SO₂) produced can be removed from the stack gases by reaction with calcium oxide:
   \[
   \text{CaO} + \frac{1}{2}\text{O}_2 + \text{SO}_2 \rightarrow \text{CaSO}_4
   \]
   (a) What mass of zinc oxide is produced from 1 tonne of ore? [5 marks]
   (b) What volume of SO₂ (STP) would be produced in processing 1 tonne of ore? [5 marks]
   (c) What mass of zinc can be produced from the same mass of ore? [5 marks]
   (d) What volume of CO (STP) would be produced in processing 1 tonne of ore? [5 marks]
   (c) What mass of CaO would be required to remove this volume of SO₂? [5 marks]
   
   [1 tonne = 1000 kg; 1 mole of a gas occupies 22.4 L at STP]

2. **Answer all parts**
   (a) Using **two examples**, explain how a catalyst affects a chemical reaction. [7 marks]
   (b) An active pharmaceutical ingredient (API), X, is thermally unstable and breaks down at temperatures above 370 K:
   \[
   X \rightarrow \text{decomposition products}
   \]
   As part of a study of the shelf-life of the API, the following data were collected for this reaction at 400K:
   
<table>
<thead>
<tr>
<th>Time (min)</th>
<th>0</th>
<th>15</th>
<th>30</th>
<th>45</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>[X] (molL⁻¹)</td>
<td>2.00</td>
<td>1.40</td>
<td>1.00</td>
<td>0.70</td>
<td>0.50</td>
</tr>
</tbody>
</table>

   (i) Use these data to determine the order of the reaction (**graph paper is available**) and write down the rate equation for the reaction. [9 marks]
   (ii) Determine the rate constant, k, for the reaction. [5 marks]
   (iii) Calculate the reaction rate when the concentration of X is 0.65 molL⁻¹. [4 marks]
3. **Answer all parts**

(a) Outline the basic features of the theory of atomic structure developed by Bohr and explain how it accounts for the absorption and emission of light by an atom. [7 marks]

(b) Explain the difference between an orbit and an orbital, and how a 2p_x and a 3p_y orbital are related to each other. [6 marks]

(c) Using nitrogen as an example, outline the rules involved in filling the energy levels (orbitals) of an atom with electrons. [6 marks]

(d) When Mendeleev listed the elements known at the time in order of increasing atomic mass, he obtained the following sequence of elements as part of his list:

```
......Cu  Zn  As  Se  Br.....
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Explain how he knew there were two elements, unknown at the time, missing from the list between Zn and As, and how he was able to make use of this information. [6 marks]

4. **Answer all parts**

(a) What does MRI stand for? Explain how nuclear magnetic resonance, the technique on which MRI is base, provides information about the nuclei of the atoms in a molecule? [5 marks]

(b) Explain how an MRI scan of a patient is obtained [6 marks]

(c) Discuss the differences between MRI and X-ray imaging [6 marks]

(d) Discuss the use of MRI in obtaining information about internal problems in a patient's body [8 marks]

**Section B**

5. **Answer all parts**

(a) Explain how gaseous diffusion can be used to produce enriched uranium for use as a nuclear fuel. [8 marks]

(b) List three of the assumptions that underpin the Kinetic Theory of Gases and use the equation derived from them (PV = \( \frac{1}{3}nmc^2 \)) to deduce Charles’s Law. [7 marks]

(c) A 0.20 m\(^3\) sample of gas at 300 K and 2.00 \( \times 10^5 \) Nm\(^{-2}\) contains 0.50 moles of O\(_2\) and 0.70 moles of Ne

(i) Calculate the partial pressure of each gas. [6 marks]

(ii) Are there any other gases present in the mixture? If so, calculate their combined partial pressure. [4 marks]

\[ R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1} \]
6. Answer all parts
   (a) Using a specific example in each case, explain in detail how the three types of **intramolecular** bonding come about. [9 marks]
   (b) Explain, using examples, how the type of intramolecular bonding that exists in a particular molecule can be predicted. [8 marks]
   (c) Determine the type of intramolecular bonding that exists in each of the following molecules:
       CsI, SiCl4, H2O, MgO [8 marks]

   [A table of electronegativity values can be found in the mathematical tables which are available]

7. Answer all parts
   (a) Use the Electron Pair Repulsion Theory to predict the shape of the following: (i) PCl5 and (ii) PCl4+ [7 marks]
   (b) A characteristic property of any metal is its ability to conduct electricity and heat. Explain how the type of bonding that exists in a metal can be used to account for its electrical properties. [6 marks]
   (c) Explain what is meant by superconductivity, outlining an experiment which demonstrates superconductivity and mentioning **two** applications of the phenomenon. [6 marks]
   (d) The order of the boiling points of the hydrogen halides is as follows:
       HF > HI > HBr > HCl
       Explain why the boiling point of HI is greater than the boiling point of either HBr and HCl but less than that of HF [6 marks]

8. Answer all parts
   (a) Outline the fundamental thermodynamic factors which must be taken into account in deciding whether a chemical reaction will be spontaneous or not. [7 marks]
   (b) The burning of methanol (CH₃OH) produces carbon dioxide and water:
       \[
       \text{CH}_3\text{OH(l)} + \frac{3}{2}\text{O}_2(g) \rightarrow \text{CO}_2(g) + 2\text{H}_2\text{O(l)}
       \]
       Use the following data to determine the standard free energy change (\(\Delta G^\circ\)) for the reaction:

       |                  | \(\Delta H^\circ_f \text{ (kJ mol}^{-1}\) | \(S^\circ \text{ (J}^{-1} \text{ mol}^{-1} K^{-1}\) |
       |-----------------|------------------------------------------|
       | CH₃OH(l)        | -238.7                                   | 126.8                                   |
       | H₂O(l)          | -285.8                                   | 69.9                                    |
       | CO₂(g)          | -393.5                                   | 213.6                                   |
       | O₂(g)           | -                                        | 205.0                                   |
       [14 marks]
   (c) Assuming \(\Delta H\) and \(\Delta S\) are independent of temperature, calculate the temperature at which the reaction ceases to be spontaneous. [4 marks]