

Ollscoil na hÉireann, Gaillimh  
THE NATIONAL UNIVERSITY OF IRELAND, GALWAY

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AUTUMN EXAMINATIONS, 2002

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FIRST UNIVERSITY EXAMINATION  
in  
BIOMEDICAL SCIENCE, BIOTECHNOLOGY,  
ENVIRONMENTAL SCIENCE

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CHEMISTRY

Professor I. Fleming, FRS  
Professor R.N. Butler  
Dr. A.V. Savage  
Dr. F. Aldabbagh

Time allowed: *Three hours*

Use a separate answer book for *Section C*

Answer *five* questions of which no more than two may be from any one section.

All questions carry *equal* marks.

Atomic masses (amu): H = 1.008, C = 12.001, N = 14.007, O = 15.99

**Section A**

**1**

- (a) The alkaloid nicotine, a component of tobacco, contains 74.1% C, 8.6% H, and 17.3% N. Determine the empirical formula of nicotine. **[8 marks]**
- (b) If the molecular weight of nicotine is  $162 \text{ g mol}^{-1}$ , determine the molecular formula. **[4 marks]**
- (c) Draw a structure for nicotine. (Hint: it contains a pyridine ring and a heterocyclic five-membered ring). **[5 marks]**
- (d) Is nicotine considered to be an acid or a base? Explain your answer. **[3 marks]**

**2**

- (a) Briefly discuss Boyle's Law and Charles's Law and give practical examples of each. **[6 marks]**
- (b) If  $200 \text{ cm}^3$  of  $\text{N}_2$  at  $25^\circ\text{C}$  and a pressure of 35 kPa are mixed with  $350 \text{ cm}^3$  of  $\text{O}_2$  at  $25^\circ\text{C}$  and a pressure of 45 kPa so that the resulting volume is  $330 \text{ cm}^3$ , what would be the final pressure of the mixture at  $25^\circ\text{C}$ ? **[10marks]**
- (c) Under what experimental conditions do gases deviate from ideal behaviour? **[4marks]**

3

- (a) Draw a heating curve for gases, liquids and solids, and compare their properties. [6marks]
- (b) Write a note on X-ray diffraction of solids and the Bragg equation. [8marks]
- (c) Discuss the crystal structure of NaCl. [6marks]

4

- (a) Discuss the following terms (i) enthalpy change, (ii) entropy change, (iii) Hess' Law. [9 marks]
- (b) Calculate  $\Delta H$  for the reaction:  
$$\text{NO}_{(g)} + \text{O}_{(g)} \rightarrow \text{NO}_{2(g)}$$
 given the following information:  

|       |  |                              |            |
|-------|--|------------------------------|------------|
| (i)   | $\text{NO}_{(g)} + \text{O}_{3(g)} \rightarrow \text{NO}_{2(g)} + \text{O}_{2(g)}$ | $\Delta H = -198.9\text{kJ}$ |            |
| (ii)  | $\text{O}_{3(g)} \rightarrow 3/2 \text{O}_{2(g)}$                                  | $\Delta H = -142.3\text{kJ}$ |            |
| (iii) | $\text{O}_{2(g)} \rightarrow 2 \text{O}_{(g)}$                                     | $\Delta H = +495.0\text{kJ}$ | [11 marks] |

Section B

5. Answer each of the following and discuss your answer in each case:
- (a) Arrange each set of atoms in order of increasing atomic size: C, O, Be [3 marks]
  - (b) Arrange each set of atoms in order of increasing ionisation energy: N, B, Ne [3 marks]
  - (c) Arrange each set of atoms in order of increasing metallic character: Ca, Rb, S [2 marks]
  - (d) Indicate whether each of the following atoms or ions are diamagnetic, paramagnetic, or ferromagnetic in their ground state:  
Si, Be, Fe,  $\text{V}^{3+}$ ,  $\text{Co}^{3+}$ ,  $\text{Ag}^{+}$  [12 marks]

6

- (a) Complete each of the following nuclear equations:
  - (i)  $^{226}\text{Ra} \longrightarrow ^{222}\text{Rn} +$  [2 marks]
  - (ii)  $^{90}\text{Mo} \longrightarrow ^{90}\text{Nb} +$  [2 marks]
  - (iii)  $^{38}\text{K} \longrightarrow ^{38}\text{Ar} +$  [2 marks]
  - (iv)  $^{234}\text{Th} \longrightarrow ^{234}\text{Pa} +$  [2 marks]
  - (v)  $^{235}\text{U} + ^1_0\text{n} \longrightarrow$  [4marks]
- (d) Given that the half-life of  $^{239}\text{Pu}$  is 24,000 years, how many years will it take for the level of radioactivity from plutonium in a sample of it to decrease to 1% of its original value? [8 marks]

7

- (a) Discuss the neutralization of phosphoric acid by a strong base. [6 marks]
- (b) Calculate the pH of a solution made by mixing 20 cm<sup>3</sup> 0.5M H<sub>2</sub>SO<sub>4</sub> with 30 cm<sup>3</sup> 0.3M NaOH. [6 marks]
- (c) A solution is prepared that is 0.025M CH<sub>3</sub>COOH and 0.02M CH<sub>3</sub>COONa. Show that this is a buffer solution and calculate the pH. [8 marks]
- $K_a$  for acetic acid is  $1.8 \times 10^{-5}$

8

Write an essay on the importance of hydrogen bonding in biological systems [20 marks]

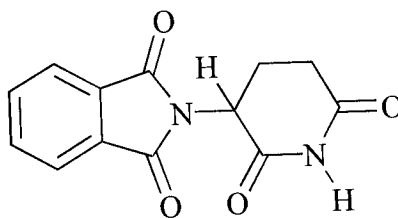
### Section C

9

- (a) Draw structural formulae showing all of the atoms of each of the following: dichloromethane, acetone, ethanoic acid and nitrobenzene. [12 marks]
- (b) Using resonance structures, discuss the following statement; *phenols are much stronger acids than aliphatic alcohols*. [8 marks]

10

- (a) Draw the three constitutional isomeric alkanes of formula C<sub>5</sub>H<sub>12</sub>. [6 marks]
- (b) Draw the two geometric (*cis* and *trans*) isomers of 1,2-dichloroethene. [4 marks]
- (c) Briefly explain why (*R*)-thalidomide and (*S*)-thalidomide have different biochemical effects in the human body. [4 marks]



thalidomide

Draw the *R* and *S* forms of thalidomide.

[6 marks]

11

Compare and contrast the chemical structures of DNA and RNA.

[20 marks]