



**NUI Galway**  
**OÉ Gaillimh**

***Autumn Examinations 2010 / 2011***

**Exam Code(s)**            0MB, 1BE, 1BG, 1BP, 1BO, 1BPM, 1BV  
**Exam(s)**                 1<sup>st</sup> Engineering, 1<sup>st</sup> Medicine, 1<sup>st</sup> Science

**Module Code(s)**        CH111  
**Module(s)**                Engineering and Medical Chemistry

**External Examiner(s)**   Professor Richard J. K. Taylor  
**Internal Examiner(s)**   Professor Paul V. Murphy  
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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. Answer all parts

- (i) Explain what is meant by entropy (S) and how it contributes to making a process spontaneous. Provide an example (chemical or non-chemical) of a process in which (a) entropy increases and (b) entropy decreases. **[6 marks]**

- (ii) Methane can be used to convert iron oxide into iron:



Using the data provided below, calculate:

- (a)  $\Delta G^\circ$  for the reaction. **[8 marks]**  
(b)  $\Delta G$  (400 °C) for the reaction, assuming  $\Delta H$  and  $\Delta S$  are independent of temperature. **[2 marks]**  
(c) The temperature for which  $\Delta G = 0 \text{ kJmol}^{-1}$ , again assuming  $\Delta H$  and  $\Delta S$  are independent of temperature. **[2 marks]**
- (iii) In the case of (ii)(c), explain the significance of the temperature calculated. **[2 marks]**

	$\Delta H^\circ_f$ (kJmol <sup>-1</sup> )	$S^\circ$ (Jmol <sup>-1</sup> K <sup>-1</sup> )
CH <sub>4</sub> (g)	-74.8	186.1
FeO(s)	-266.5	54.0
CO(g)	-110.5	197.6
Fe(s)	-	27.2
H <sub>2</sub> O(g)	-241.8	188.7

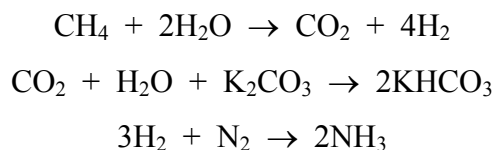
### 2. Answer all parts

- (i) Explain what is meant by an orbital and, using an example, what information is required to describe an orbital completely. **[5 marks]**
- (ii) Describe the principal sub-atomic particles from which atoms are constructed and explain how any one of them was discovered. **[5 marks]**
- (iii) Explain how, and why, the size of an atom varies (i) across a row and (ii) down a group in the Periodic Table. **[5 marks]**
- (iv) Using any example, explain how a heterogeneous catalyst works. **[5 marks]**

**Please turn over**

**3. Answer all parts**

- (i) The manufacture of ammonia (NH<sub>3</sub>) using methane (natural gas, CH<sub>4</sub>) as a source of hydrogen, involves the initial formation of a mixture of carbon dioxide and hydrogen from which the carbon dioxide is removed by reaction with potassium carbonate:



Calculate:

- (a) the mass of CO<sub>2</sub> produced when 1000 L of CH<sub>4</sub> reacts at STP **[4 marks]**  
(b) the mass of K<sub>2</sub>CO<sub>3</sub> required to remove this amount of CO<sub>2</sub> **[3 marks]**  
(c) the volume of NH<sub>3</sub> (at STP) that can be produced from 1000 L CH<sub>4</sub> **[3 marks]**

**[1 mole of a gas at STP occupies 22.4 L]**

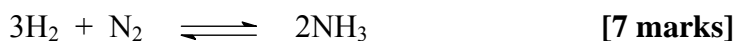
- (ii) One of the major irritants in atmospheric smog is formaldehyde (CH<sub>2</sub>O) which may be formed by the reaction of ozone (O<sub>3</sub>) with ethene (C<sub>2</sub>H<sub>4</sub>). This reaction is first order in both ozone and ethene and has a rate constant (k) of  $2 \times 10^3 \text{ L mol}^{-1} \text{ s}^{-1}$ .
- (a) Write down the rate equation for this reaction **[3 marks]**  
(b) Sketch a concentration vs. time plot for the reaction **[2 marks]**  
(c) If the concentrations of O<sub>3</sub> and C<sub>2</sub>H<sub>4</sub> in heavily polluted air are  $5 \times 10^{-8}$  and  $1 \times 10^{-8} \text{ mol L}^{-1}$ , respectively, calculate the rate of formation of CH<sub>2</sub>O under these conditions. **[3 marks]**  
(d) If the concentrations of O<sub>3</sub> and C<sub>2</sub>H<sub>4</sub> remain at these levels, how long will it take the concentration of CH<sub>2</sub>O to build up to  $2 \times 10^{-7} \text{ mol L}^{-1}$ , the concentration at which eye irritation becomes noticeable? **[2 marks]**

**4. Answer all parts**

- (i) A mixture of the three gases N<sub>2</sub>, H<sub>2</sub> and NH<sub>3</sub> is at equilibrium at 300 °C and has the following composition:

$$[\text{N}_2] = 0.25 \text{ mol L}^{-1}; [\text{H}_2] = 0.15 \text{ mol L}^{-1}; [\text{NH}_3] = 0.09 \text{ mol L}^{-1}$$

Calculate the equilibrium constant, K, at 300°C for the reaction:



- (ii) If the forward reaction is exothermic explain what reaction conditions (T, P and concentration) you would use to maximise the formation of NH<sub>3</sub>. **[8 marks]**
- (iii) The reaction is catalysed by iron oxide (FeO). What effect would the addition of FeO have on a mixture of the three gases which is at equilibrium? Explain your answer. **[5 marks]**

**Please turn over**

## Section B

5. Discuss the chemistry involved in the production of steel, including the conversion of iron ore into pig iron and the subsequent conversion of pig iron into steel. Balanced chemical reaction equations should be provided where appropriate. **[20 marks]**

6. **Answer all parts**

(i) Potassium metal can be manufactured by the electrolysis at 950 °C of molten potassium chloride. Draw a simple diagram showing how the electrolysis might be carried out. **[5 marks]**

(ii) Label the cathode and the anode on this diagram. Write down the reaction equation for each electrode and for the overall process. **[5 marks]**

(iii) Calculate the mass of potassium that would be produced by a current of 10 A flowing for 25 min (**1 F = 96,500 C**). **[5 marks]**

(iv) Explain why potassium is not produced when the electrolysis involves a solution of potassium chloride in water, rather than molten potassium chloride. What actually happens in water? **[5 marks]**

7. **Answer all parts**

(i) Describe, in detail, the three types of **intermolecular** (*between* molecules) bonding. An example should be provided for each type of intermolecular bond. **[12 marks]**

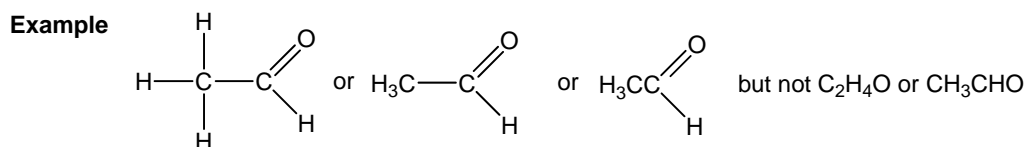
(ii) Explaining your answer, indicate what type of intermolecular bond exists in each of the following:

HF (liquid), H<sub>2</sub>O (solid), CO<sub>2</sub> (gas), CO<sub>2</sub> (liquid) **[8 marks]**

**Please turn over**

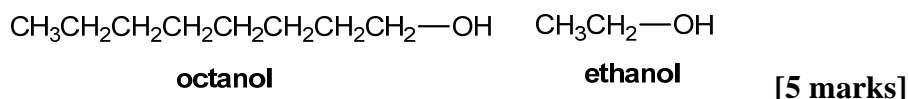
## Section C

**Structural formulae, and not molecular formulae, must be used in answering the questions in this section:**



**8. Answer all parts**

- (i) Using **two** examples, explain what is meant by a substitution reaction. **[5 marks]**
- (ii) Explain what is meant by an electrophile and, using an example, how the carbon atom in the carbonyl group of a ketone behaves as an electrophile. **[5 marks]**
- (iii) Explain why octanol has a higher boiling point but a lower water solubility than ethanol.

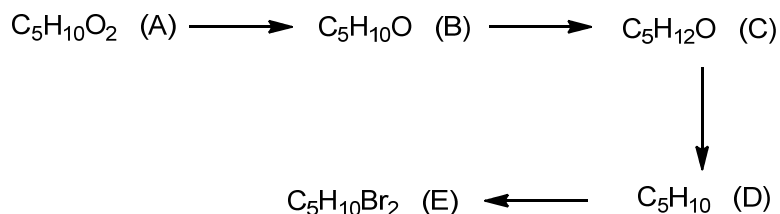


- (iv) Explain what is meant by optical isomerism and why only certain molecules can be optically active. Why is this concept of importance for the pharmaceutical industry. **[5 marks]**

**9. Discuss the chemistry of the alkenes under the following headings:**

- (a) structure and isomerism **[10 marks]**
- (b) chemical reactions: at least three reactions should be discussed **[6 marks]**
- (c) mechanism for any addition reaction involving an alkene. **[4 marks]**

**10. The following scheme outlines a series of reactions involving compounds (A) to (E)**



**(A) Contains a straight chain of carbon atoms and turns blue litmus red.**

- (a) Provide structures for (A) - (E); the functional group should be named and clearly labelled in each case **[10 marks]**
- (b) Describe two other reactions of (D) **[4 marks]**
- (c) Suggest reagents that could be used to carry out the various reactions in the above scheme **[6 marks]**