**CORK INSTITUTE OF TECHNOLOGY**
**INSTITIÚID TEICNEOLAÍOCHTA CHORCAÍ**

**Semester 2 Examinations 2014/15**

# Module Title: Biological Chemistry 2

**Module Code:** **CHEM 6009**

**School:** Science & Informatics

**Programme Title:** Bachelor of Science in Applied Biosciences
Bachelor of Science in Pharmaceutical Biotechnology
Bachelor of Science in Nutrition and Health Sciences
Bachelor of Science in Herbal Science

**Programme Code:** **SBIOS_7_Y1**
**SPHBI_8_Y1**
**SNHSC_8_Y1**
**SHERB_8_Y1**

**External Examiner(s):** Dr. C. Roche
**Internal Examiner(s):** Dr. William Doherty
Dr. Mary Lehane

**Instructions:** **Attempt THREE questions.**
**Section A is compulsory.**
**Attempt 8 out of 10 parts from Section A.**
**Attempt one question each from sections B and C.**
**Show all calculations and rough work on the answer book.**

**Duration:** 2 hours

**Sitting:** Semester 2 2014/15

**Requirements for this examination: Periodic Table of the Elements**

**Note to Candidates:** Please check the Programme Title and the Module Title to ensure that you have received the correct examination.
If in doubt please contact an Invigilator.

## SECTION A

**Q1**

i) Write the equilibrium expression (Kc) for each of the following reactions:

a. $H_2$ (g) + $Br_2$ (l) ↔ 2HBr (g)

b. $CO_2$ (g) + CaO (s) ↔ $CaCO_3$ (s)

c. $SO_2$ (g) + ½ $O_2$ (g) ↔ $SO_3$ (g)

d. 5CO (g) + $I_2O_5$ (s) ↔ $I_2$ (g) + 5$CO_2$ (g)

ii) For the following reaction,

2NOCl (g) ↔ 2NO (g) + $Cl_2$

the equilibrium concentrations were found to be: [NOCl] = 0.263M, [NO] = 0.037M, and [$Cl_2$] = 0.092M.

Using this data calculate the equilibrium constant Kc of this reaction.

iii) Write out the Henderson-Hasselbalch equation and explain what each term in the equation means.

iv) a. Distinguish between a ***strong and weak*** acid and base.

b. Explain how the value of the acid dissociation constant, Ka, can be used as an index to describe if a given acid is strong or weak.

v) Calculate the pKa values for the following species:

a. H3O+ (Ka = - 1.5)

b. NH3 (Ka = 36)

c. H2PO4 (ka = 7)

Explain why the pKa is often used to describe the strength of an acid rather than the Ka.

vi) Determine:

a. The pH of a 6.50 $10^{-3}$ M solution of KOH

b. The [H+] of an acid with a pH of 3.

The pH and pOH of a 0.05M solution of Carbonic Acid

vii) Draw the following alkanes:

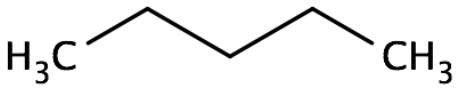
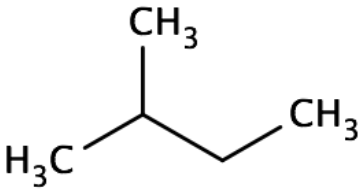
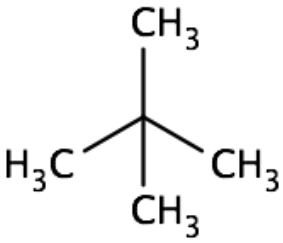
a. 2-bromo-2-methylbutane

b. 1-bromo-3-ethyl-5-methylcyclohexane

c. 2,3,4,5,6-Pentamethyloctane

viii) Draw any four isomers of octane.

ix) Account for the difference in the boiling points of the following isomers of pentane:

| Isomer | Boiling point [K] |
|---|---|
|  | **309** |
|  | **301** |
|  | **282** |

x) Explain the following terms

a. Carbocation

b. Electrophile

c. Nucleophile

d. Substitution Reaction

e. Addition Reaction

xi) Draw a 1° alcohol, a 2° alcohol and a 3° alcohol. Place them in order of increasing reactivity.

xii) a. Define saturation and unsaturation

b. Draw the moelcule benzene. How many unsaturations are there in benzene?

## SECTION B

**Q2**

a) Predict in the following reactions if products or reactants will predominate at equilibrium at a temperature of 25$^{o}$C. Justify your answer in each case:

i) $2N_2O\ (g) + O_2\ (g) \leftrightarrow 4NO\ (g)$ $\quad Kc = 3.03 \times 10^{-26}$

ii) $CH_4\ (g) + 2O_2\ (g) \leftrightarrow CO_2\ (g) + H_2O\ (g)$ $\quad Kc = 1.2 \times 10^{14}$

iii) $2IBr\ (g) \leftrightarrow I_2\ (g) + Br_2\ (g)$ $\quad Kc = 4.13 \times 10^{-2}$

iv) $2A\ (g) + 2B\ (g) \leftrightarrow 3C\ (g) + D\ (g)$ $\quad Kc = 22$

b) Consider the following endothermic chemical reaction, where $\Delta H = 94KJ$ :

$$N_2O_4\ (g) \leftrightarrow 2NO_2\ (g)$$

Predict the shift in the direction of the reaction as a consequence of the following stresses:

i) An increase in the concentration of $NO_2$

ii) A decrease in the volume of the reaction container.

iii) A decrease in the temperature.

iv) A decrease in the concentration of $N_2O_4$.

v) The addition of a palladium catalyst.

c) A 7.25 L flask is filled ***initially*** with 0.215 mol of HI at 698 K. What will be the concentration of $H_2$, $I_2$ and HI at equilibrium? The value of $K_{eq}$ is 0.0184.

$$H_{2(g)} + I_{2(g)} \leftrightarrow 2\ HI_{(g)}$$

d) Provide a brief explanation and draw an energy graph that shows why all chemical systems strive to attain equilibrium.

**Q3**

a) In the following reactions identify the acid, the base and their respective conjugate pairs:

i) $HNO_2(aq) + HS^-(aq) \leftrightarrow NO_2^-(aq) + H_2S(aq)$

ii) $HClO + SO_4^{-2} \leftrightarrow HSO_4^- + ClO^-$

iii) $NH_4 + + H_2O \leftrightarrow NH_3 + H_3O^+$

iv) $C_2O_4^{2-} + HC_2H_3O_2 \leftrightarrow HC_2O_4^- + C_2H_3O_2^-$

v) $HCO_3^- + HCl \leftrightarrow H_2CO_3 + Cl^-$

b) i) Derive the Henderson- Hasselbalch Equation.

ii) Consider the following dissociation reaction:

$CH_3COOH \leftrightarrow H + + CH_3COO^-$ $\quad$ $Ka = 1.74 \times 10^{-5}$

The concentration of the acetic acid, $CH_3COOH$, is 0.255M and the concentration of the $CH_3COO^-$ anion is 0.015M use the Henderson-Hasselbalch equation to determine the pH of the solution.

c) $H_2S$ is a weak acid and it dissociates in the following fashion:

$H_2S \leftrightarrow H^+ + HS^-$ $\quad$ $Ka = 1 \times 10^{-7}$

Given that the initial concentration of $H_2S$ is 0.136M, calculate the concentration of all reaction components at equilibrium and hence determine the pH.

d) Draw the pH profile that you may expect if you:

i) titrate a strong acid with a weak base

ii) titrate a strong acid with a strong base

iii) titrate a weak acid with a weak base.

## SECTION C

**Q4 (a)** Equilin is a horse tranquiliser that consists of carbon, hydrogen and oxygen only. If 6.71 g of equilin is combusted in excess oxygen, 19.80 g of $CO_2$ and 4.50 g of $H_2O$ are produced.

(i) What are the % weights of carbon, hydrogen and oxygen in equilin?

[8 marks]

(ii) What is the empirical formula? [4 marks]

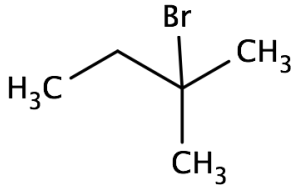
(iii) If the moelcular weight is 268.36 g $mol^{-1}$ what is the molecular formula?

[4 marks]

(iv) Write a balanced equation for the combustion of equilin. [4 marks]

(b) (i) State Zaitsev's Rule [3 marks]

(ii) For 2-bromo-2-methylbutane (in the figure below) draw the Zaitsev product.




2-bromo-2-methylbutane

[7 marks]

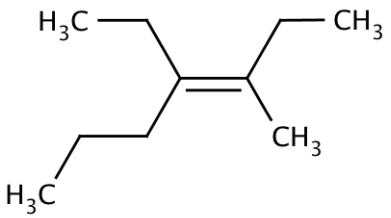
**Q5 (a)** Draw the following molecules:

(i) (2Z)-5-bromo-6-methylhept-2-ene

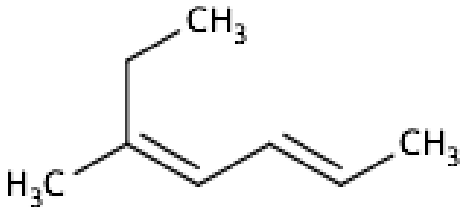
(ii) (3E,6Z)-4-ethyl-7-methylnona-1,3,6-triene

[4 marks]

(b) Name the following molecules:




(i)



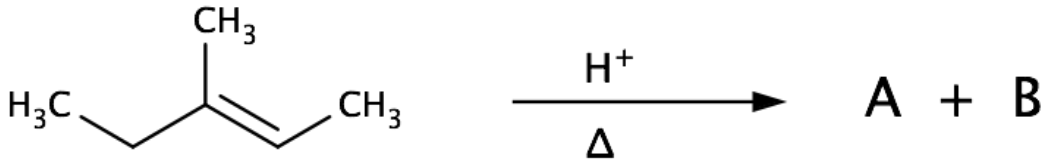

(ii)

[4 marks]

**continued overleaf…**

(c) (i) State Markovnikov's rule. [4 marks]

(ii) For the following reaction, identify products A and B and identify the Markovnikov product.




[8 marks]

(iii) To produce the "anti-Markovnikov" product exclusively, a different reagent is used. Name and sketch this reagent. Sketch the mechanism of the reaction explaining why the "anti-Markovnikov" is produced. [10 marks]