



MACHAKOS UNIVERSITY

University Examinations 2022/2023 Academic year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR SECOND SEMESTER EXAMINATIONS FOR
BACHELOR OF SCIENCE (ANALYTICAL CHEMISTRY)

SAN 205: AQUATIC CHEMISTRY

DATE: 20/4/2023

TIME: 8:30 – 10:30 AM

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks)

QUESTION ONE COMPULSORY (30 MARKS)

- (a) Water (H_2O) is a dihydride of oxygen which is in group 16 of the periodic table. The other dihydrides down the group are H_2S , H_2Se and H_2Te .
- (i) Explain why water is the most common solvent used among the dihydrides in this group. (2 marks)
- (ii) Explain the anomalous behavior exhibited by water among the other dihydrides in the group. (2 marks)
- (b) Unpolluted rainwater has a pH of 5.5 to 6.5 but the pH of polluted water is highly acidic. Explain in details the cause of acidity in polluted water. (3 marks)
- (c) Water which does not produce lather with soap but forms a white precipitate is called hard water.
- (i) Explain chemically, the two types of water hardness and their causes. (3 marks)
- (ii) Explain how both types of water hardness are removed from water. (3 marks)
- (ii) Explain how hardness of water is determined by the EDTA method. (3 marks)
- (iv) Explain the problems encountered when using hard water for many different applications? (2 marks)

- (d) Based on the definitions of an acid and a base by Bronsted and Lowry;
- Explain with the help of equations, what is an acid and a base, respectively. (2 marks)
 - Based on the definition in (d) above, water is both a base and an acid and hence, it is amphoteric in nature. Explain both the acidic and basic behavior of water with chemical equations. (2 marks)
- (e) Based on the observation in d (ii) above and given equilibrium constants for acid and base are denoted by K_a and K_b , respectively;
- Derive equations for K_a and K_b , respectively. (3 marks)
 - Show that $K_w = K_a.K_b$, where K_w is the autoionization constant of water, K_a is acid ionization constant and K_b is the base ionization constant. (3 marks)
- (f) HCl is a strong acid, with $K_a = 10^7$. Determine the pH of 10M HCl. Show all the steps in your calculations. (2 marks)

QUESTION TWO (20 MARKS)

- (a) The expression of normal concentration is based on the definitions that are related to the types of reactions in which the solution constituents are involved.
- Name the three types of reactions on which the equivalent weight of a reactant is based. (3 marks)
 - Find the normality of the solution of 155 mg of $(Ca)_3(PO_4)_2/L$, given that $Ca_3(PO_4)_2$ participates in the dissolution reaction $(PO_4)_2 \longrightarrow 3 Ca^{2+} + 2 PO_4^{2-}$
Given (Ca = 40, P = 31, O = 16). (4 marks)
- (b) Both temporary and permanent hardness of water is expressed in terms of $CaCO_3$. Calculate the temporary and permanent hardness in terms of $CaCO_3$ for a water sample containing the following;
- $Ca(HCO_3)_2 = 16.2 \text{ mg/L}$ (4 marks)
 - $NaCl = 58.5 \text{ mg/L}$ (4 marks)
- (c) Describe in details the difference between water softening by use of zeolites and deionization of water using the ion exchange resins (5 marks)

QUESTION THREE (20 MARKS)

The largest source of water are seas and oceans constituting 97% of the total water surface. However, this water source is highly saline. In order to remove the salt content and make the water potable, we can carry out either reverse osmosis or electrodialysis. Describe both methods under the following.

- (a) The principles behind each method in the removal of the salt content. (5 marks)
- (b)
 - (i) With the help of a suitable diagram describe fully how reverse osmosis accomplishes the removal of salt. (6 marks)
 - (ii) With the help of a suitable diagram, describe in details how electrodialysis is able to generate potable water from sea water. (9 marks)

QUESTION FOUR (20 MARKS)

- (a) The various forms of water are rain, streams, rivers, lakes, seas and oceans. The composition of water would vary in these different forms.
 - (i) Explain why the pH of rain water is not neutral (pH =7) but is slightly acidic (5.5 to 6.5). (4 marks)
 - (ii) How is the composition of rain water affected when it falls on the soil surface? (4 marks)
 - (iii) Compare the composition of land surface water and ground water in terms of mineral contents. (3 marks)
- (b) Water as a unique solvent forms solutions with ionic compounds whose concentrations can be expressed in different units such as mg/L or parts per million (ppm). Based on the foregoing statement, a solution of ammonium nitrate (NH_4NO_3) was analyzed for ammonium ion (NH_4^+) and for nitrate ion (NO_3^-) and found that 100 ml of solution contained 36 mg NH_4^+ and 124 mg NO_3^- , (N = 14.000, O= 16.000, H = 1.000).
 - (i) Determine the conc. of NH_4^+ in mg/L (3 marks)
 - (ii) Determine the conc. of NO_3^- in mg/L (3 marks)
 - (iii) Determine the conc of nitrogen (N) in ppm. (3 marks)

QUESTION FIVE (20 MARKS)

- (a) Systems are required to maintain environments of constant pH.
- (i) State the operational (how does it do ?) and technical (what does it do?) definitions of a buffer. (3 marks)
 - (ii) Write equations that show what happens when a small amount of a strong acid (H^+) or a strong base (OH^-) are added to a buffer? (3 marks)
 - (iii) Explain why the pH does not change very much when a small amount of strong acid or base is added to a buffer? (3 marks)
 - (iv) Explain what is the buffering capacity of a buffer. (3 marks)
- (b) Derive the Handerson- Hasselbalch (H-H) equation for providing a recipe for making a buffer of a given pH. (8 marks)