

2922/304
ENVIRONMENTAL ANALYTICAL
TECHNIQUES
Oct./Nov. 2021
Time: 3 hours



THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN ENVIRONMENTAL SCIENCE AND TECHNOLOGY

MODULE III

ENVIRONMENTAL ANALYTICAL TECHNIQUES

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:

Answer booklet;

Non-programmable scientific calculator.

This paper consists of TWO sections; A and B.

Answer ALL the questions in section A and any THREE questions from section B in the answer booklet provided.

Each question in section A carries 4 marks while each question in section B carries 20 marks.

Maximum marks for each part of a question are shown.

Candidates should answer the questions in English.

This paper consists of 5 printed pages.

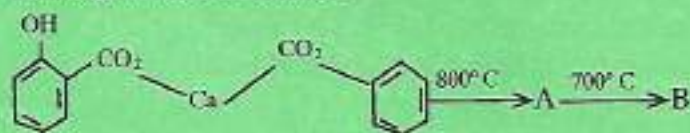
Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

SECTION A (40 marks)

Answer ALL questions in this section.

1. Distinguish between each of the following as used in redox titrations:
 - (a) titrant and analyte; (2 marks)
 - (b) oxidizing agent and reducing agent. (2 marks)
2. (a) Define ligand as used in complexometry. (2 marks)
(b) Draw the structure of the complex $[Cu(NH_3)_4]^{2+}$ showing its dative bonds. (2 marks)
3. Determine the coordination number of the central atom in each of the following complexes:
 - (a) $[Ag(CN)_2]^-$; (2 marks)
 - (b) $[Fe(CN)_6]^{3-}$. (2 marks)
4. List four characteristics of an ideal precipitate in gravimetry. (4 marks)
5. (a) Complete the chemical reaction equation $H_2S_{(aq)} + 4 Cl^-_{(aq)} + 2 H^+_{(aq)} \rightarrow$ (2 marks)
(b) Write the solubility product expression for the reaction in (a). (2 marks)
6. Distinguish between colloidal precipitates and crystalline precipitates in relation to effect of gravity. (4 marks)
7. In the analysis of 0.4011 g of an impure chloride containing sample, 0.6805 g of $AgCl$ was precipitated. Determine the percentage by mass of chloride in the sample
 $AgCl = 143.32 g/mol, Cl = 35.45 g/mol$. (4 marks)
8. Classify the following colloids as either hydrophilic or hydrophobic:
 - (a) $AgCl$; (1 mark)
 - (b) $Fe(OH)_3$; (1 mark)
 - (c) $MgNH_4PO_4 \cdot 6 H_2O$; (1 mark)
 - (d) $Al(OH)_3$. (1 mark)

9. (a) Define the term thermogravimetry as used in gravimetric analysis. (2 marks)
- (b) Write the chemical formulae of the products labelled A and B in the following thermogravimetric scheme. (2 marks)



10. A hot piece of copper weighing 360 g was dropped into 425 mL of water raising its temperature from 24.0 °C to 42.7 °C. Assuming that there is no heat exchange with the surrounding, calculate the initial temperature of the piece of copper (4 marks)

$$(C_p(\text{cu}) = 0.449 \text{ J/g}\cdot^\circ\text{C}; \quad C_p(\text{H}_2\text{O}) = 4.184 \text{ J/g}\cdot^\circ\text{C}.)$$

SECTION B (60 marks)

Answer any THREE questions from this section.

11. (a) Outline the process of preparing a 0.1 M solution of AgNO_3 (169.872 g/mol) in a 100 mL volumetric flask. (5 marks)
- (b) (i) Draw the structure of the complex formed in the reaction between ethylene diamine and copper (II) ions. (4 marks)
- (ii) Describe the type of reaction in b (i). (2 marks)
- (iii) Explain the type of bonding in the complex formed in b (i). (2 marks)
- (c) Describe chelate in complexation reactions. (3 marks)
- (d) (i) Define the term masking agent as used in complexometry. (2 marks)
- (ii) Explain how masking agents can be abused in the athletics industry. (2 marks)

12. (a) Name three types of redox titrations. (3 marks)
- (b) State the importance of Nernst equation in redox titrations. (2 marks)
- (c) (i) Outline the process of preparing a 0.02 M solution of potassium permanganate in a 1 dm^3 volumetric flask ($KMnO_4 = 158.03\text{ g/mol}$). (7 marks)
- (ii) Explain why the solution prepared in c (i) should be stored in dark bottles. (2 marks)
- (d) The purity of a sample containing sodium oxalate ($Na_2C_2O_4$) was determined by titrating with standard $KMnO_4$ solution. Determine the percent w/w $Na_2C_2O_4$ in the sample given that a 0.5016 g sample requires 26.50 mL of 0.05 M $KMnO_4$ to reach end point. $Na_2C_2O_4 = 134$; mole ratio $KMnO_4:Na_2C_2O_4 = 2:5$. (6 marks)

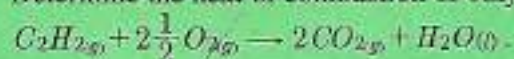
13. (a) (i) State two reasons for washing a precipitate in gravimetric analysis. (4 marks)
- (ii) Explain why de-ionised water is not a preferred wash solution in gravimetry. (2 marks)

- (b) A 50 g fruit sample preserved using SO_2 was dissolved in de-ionised water and 3% H_2O_2 solution added to convert the SO_2 to SO_4^{2-} ions. Excess $BaCl_2$ solution was then added to the solution and the SO_4^{2-} precipitate formed was filtered, dried and weighed giving the following results

Mass of dry filter paper	0.864 g
Mass of dry filter paper + $BaSO_{4(s)}$	1.338 g

- (i) Write an ionic equation for the reaction. (2 marks)
- (ii) Determine the percent w/w of SO_2 in the fruit sample. (8 marks)
- (iii) State two reasons for grinding the fruit sample before extraction. (2 marks)
- (iv) State the reason for drying the precipitate after filtration process. (2 marks)
14. (a) Outline the procedure for determining the amount of lead present in a soil sample containing lead (II) ions. (10 marks)
- (b) Describe the relationship between solubility of crystals and their filterability in gravimetric analysis. (4 marks)
- (c) Sketch a thermogravimetric curve describing the complete decomposition of $CaC_{14}H_{10}O_6 \cdot 2H_2O$ into CaO with $CaC_7O_5H_4$, $CaCO_3$; and $CaC_{14}H_{10}O_6$ as intermediates. (6 marks)

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- (a) State Hess's law. (2 marks)
- (b) Distinguish between heat of formation and heat of combustion. (4 marks)
- (c) Draw energy level diagrams for the following thermochemical reactions:
- (i) $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$ $\Delta H = -890.4 \text{ kJ}$; (5 marks)
- (ii) $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$ $\Delta H = +177.8 \text{ kJ}$. (5 marks)
- (d) Determine the heat of combustion of ethyne described by the following equations: (4 marks)



$$\Delta H_f(C_2H_{2(g)}) = +227 \text{ kJ/mol}; \quad \Delta H_f(CO_{2(g)}) = -393.5 \text{ kJ/mol};$$

$$\Delta H_f(H_2O_{(l)}) = -285.8 \text{ kJ/mol}$$

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