TEVETA

Technical Education, Vocational and Entrepreneurship Training Authority

DIPLOMA IN SCIENCE LABORATORY TECHNOLOGY

LEVEL 6 YEAR III EXAMINATIONS

FINAL INTEGRATED SUMMATIVE EXAMINATIONS

SITTING: NOVEMBER / DECEMBER 2025

SUBJECT: INSTRUMENTATION II

TIME: THREE (3) HOURS **TOTAL MARKS: 100**

PASS MARK: 50

INSTRUCTIONS TO CANDIDATE

1. Write your Examination number and National Registration Card (NRC) number on the answer booklet provided.
2. Write the ANSWER SCRIPT SERIAL NUMBER on the examination register and on the entry slip.
3. This paper has seven (7) Questions. Question one (1) is compulsory. Answer four (4) Questions from the remaining six (6) Questions.
4. Diagrams may be used where necessary to clarify your answer.
5. Cell phone and programmable calculators are not allowed in the examination room.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

QUESTION ONE (COMPULSORY)

(a) Define chemical shift in NMR spectroscopy. **[2 marks]**

(b) Explain the:

(i) use of tetramethyl silane (TMS) as a reference. **[2 marks]**

(ii) **four (4)** types of information obtained from an NMR spectrum. **[4 marks]**

(iii) role of a superconducting *magnet* in NMR. **[2 marks]**

(c) State the nucleus that is most studied in NMR. **[2 marks]**

(d) Calculate the:

(i) Larmor frequency for ^1H at 9.4 T (γ = 42.58 MHz/T). **[2 marks]**

(ii) signal-to-noise ratio (S/N) if the peak height is 120 units. **[2 marks]**

(c) Distinguish between spin-spin coupling and chemical shift. **[2 marks]**

(d) Predict the splitting pattern for a proton adjacent to two equivalent protons. **[2 marks]**

[Total: 20 marks]

QUESTION TWO

(a) (i) Define mass-to-charge ratio (m/z). **[2 marks]**

(ii) State the function of the ionizer in a mass spectrometer. **[2 marks]**

(b) (i) Explain **four (4)** types of mass analysers. **[2 marks]**

(ii) State the analysers that offers the highest resolution. **[2 marks]**

(c) **(**i) Explain the electron impact ionization (EI) works. **[2 marks]**

(ii) Calculate the m/z for a singly charged ion with mass 100 Da. **[2 marks]**

(d) (i) Distinguish between *hard* and *soft* ionization techniques. **[2 marks]**

(ii) State an application of MALDI (Matrix-Assisted Laser Desorption/Ionization). **[2 marks]**

(e) Calculate the resolving power (R) if two peaks at 1000.0 and 1000.5 m/z are baseline-separated. **[2 marks]**

(f) Determine the required R to resolve CO^+ (27.9949 Da) and N_2^+ (28.0061 Da).

[2 marks]

[TOTAL: 20 MARKS]

QUESTION THREE

(a) (i) Define Bragg's Law and write its equation. **[2 marks]**

(ii) State the purpose of the X-ray tube in XRD. **[2 marks]**

(b) (i) Explain **four (4)** applications of XRD. **[4 marks]**

(ii) Identify which crystal system has all axes equal (a = b = c). **[2 marks]**

(c) (i) Explain why monochromatic X-rays are used in XRD. **[2 marks]**

(ii) Calculate the diffraction angle (2θ) for a (100) plane (d = 2.5 Å, λ = 1.54 Å). **[1 mark]**

(d) Distinguish between powder and single-crystal XRD. **[4 marks]**

(e) Calculate the d-spacing for a peak at 2θ = 30° (λ = 1.54 Å). **[3 mark]**

[TOTAL: 20 MARKS]

QUESTION FOUR

Study diagram below and answer the questions

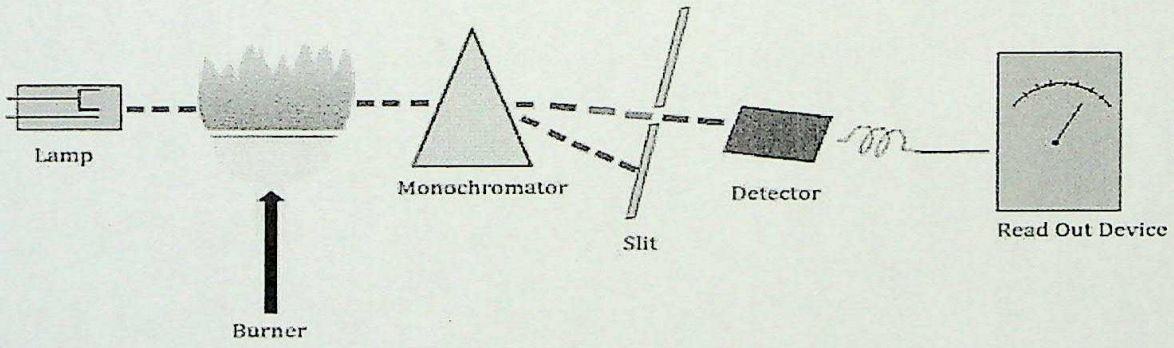


FIG Q4

(a) Identify the instrument above **[3 marks]**

(b) With the help of sketch or diagram explain ways the lamp produces the needed frequency **[10 marks]**

(c) Identify the two transducers in this instrument **[4 marks]**

(d) Explain function of the burner **[3 marks]**

[TOTAL: 20 MARKS]

QUESTION FIVE

(a) State **four (4)** sources of ultraviolet (UV) radiation used in UV instruments. **[4 marks]**

(b) With the aid of diagrams, explain the following types of UV instruments.

(i) Single beam instruments **[6 marks]**

(ii) Double beam instruments **[6 marks]**

(c) Differentiate between absorption by organic compounds and absorption by inorganic compounds in relation to the application of ultraviolet visible molecular absorption spectrometry **[4 marks]**

[TOTAL: 20 MARKS]

QUESTION SIX

(a) (i) Define atomic absorption spectroscopy (AAS) with its primary application. **[2 marks]**

(ii) State the reason for using a hollow cathode as the light source. **[2 marks]**

(b) (i) State **four (4)** elements commonly analysed by AAS. **[4 marks]**

(ii) Indicate the type of AAS (flame or graphite furnace) that offers lower detection limits. **[2 marks]**

(c) (i) Explain the role of the nebulizer in flame AAS. **[2 marks]**

(ii) Calculate the frequency of a photon absorbed by a sodium atom (λ = 589 nm). **[2 marks]**

(d) (i) Distinguish between atomic absorption and atomic fluorescence spectrometry. **[4 marks]**

(ii) Explain an advantage of atomic fluorescence over absorption. **[2 marks]**

[TOTAL: 20 MARKS]

QUESTION SEVEN

(a) Sketch a neat well labelled diagram of a gas chromatograph technique. **[4 marks]**

(b) Describe the function of the following parts in gas chromatographic instrument:

(i) Column **[3 marks]**

(ii) Pump **[3 marks]**

(iii) Detector **[3 marks]**

(iv) Drain **[3 marks]**

(c) With the help of a diagram describe the operation of a thermal conductivity detector. **[4 marks]**

[TOTAL: 20 MARKS]