



# MERU UNIVERSITY OF SCIENCE AND TECHNOLOGY

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**University Examinations 2023/2024**  
FIRST YEAR SECOND SEMESTER EXAMINATION FOR THE DEGREE MASTER OF  
SCIENCE IN CHEMISTRY

**SCH 7126: X-RAY CRYSTALLOGRAPHY**

**DATE: APRIL 2024**

**TIME: 2 HOURS**

**INSTRUCTIONS:** Answer question *one* and any other *two* questions

**QUESTION ONE (30 MARKS)**

- a) The wavelengths of first-order X-rays are  $2.20 \text{ \AA}$  at  $27^{\circ}8'$ . Find the distance between the adjacent Miller planes. (2 marks)
- b) i) Discuss the key principles and working of X-ray instrument (5 marks)  
ii) State three advantages and disadvantages of this technique in analysis (2 marks)  
iii) State four application areas of x-ray crystallography (2 marks)
- (i) Explain the difference between bremsstrahlung radiation, white radiation and the continuous spectrum.
- (ii) Are these radiations made in an X-ray tube?
- (iii) How or Why? (3 marks)
- c) What are the advantages of synchrotron radiation over a lab x-ray source? (at least 4) (2 marks)
- d)  $[100]$  indicates the direction  $100 (u,v,w)$ . What do  $(100)$ ,  $\{100\}$  and  $\langle 100 \rangle$  refer to? (2 marks)
- e) What are the 3 reference frames (coordinate systems) of importance to the study of orientation of crystals in an x-ray diffraction measurement? (2 marks)

## QUESTION TWO (20 MARKS)

- a) Discuss the instrumentations of x-ray crystallography (10 marks)
- b) State the limitations of x-ray crystallography (3 marks)
- c) Give the crystal structure and number of atoms in a unit cell for  $\alpha$ -iron,  $\gamma$ -iron, silicon, diamond. (2 marks)
- d) Distinguish between constructive and destructive interference of waves (2 marks)
- e) Give the two examples of static and dynamic elastic scattering and describe the correlation function associated with each. (3 marks)

## QUESTION THREE (20 MARKS)

- a) Differentiate between Reflection versus Diffraction (2 marks)
- b) Discuss the key steps involved in order to determine the atomic structure of a crystal using x-ray crystallography (10 marks)
- c) i) State Bragg's Law and State two applications of Bragg's law (3 marks)  
ii) Using the example of a halogen lamp and a pen laser, explain what a collimated beam of electromagnetic radiation is. Why is collimation important to Bragg's Law? (3 marks)
- d) Explain the observation "Colloids can't really form crystals from a kinetic perspective even if they had perfect structure". (2 marks)

## QUESTION FOUR (20 MARKS)

- a) Compare Laue versus Bragg (2 marks)
- b) Atoms of a given type are indistinguishable while objects on the colloidal/nanoscales have a distribution in size and shape. How can this effect the difference between scattering in the XRD range of angle and scattering at small-angles. (Give an example of an object on the colloidal or nanoscale). (5 marks)
- c) X-rays are electromagnetic radiation of higher energy compared to visible light. If you could see X-rays in the same way you can see light would they appear brighter than light? Explain. (3 marks)
- d) i) What is the dependence of X-ray absorption coefficient on wavelength? (2 marks)

- ii) In order to calculate the thickness of lead needed to shield an X-ray generator using a copper target and running at 20 mA and 50 kV what wavelength would you use to determine the absorption coefficient. (4marks)
- e) Using the example of a halogen lamp and a pen laser, explain what a collimated beam of electromagnetic radiation is. Why is collimation important to Bragg's Law? (4 marks)