Crystallography & Mineralogy

A book by Career Avenues

As per IIT-JAM Syllabus

GEOLOGY / EARTH SCIENCE

CAREER AVENUES

Crystallography And Mineralogy

Introduction

Mineralogy is the study of minerals. It is a subject of geology that deals with the crystal structure and chemical, physical and optical properties of minerals. It also includes the description of properties of minerals, that branch is called descriptive mineralogy.
Crystallography is a subset of mineralogy that need special attention. The minerals are made up of atoms and molecules in an orderly fashion. This ordered manner will reflect in the appearance and other properties of minerals. Crystallography mainly deals with the symmetry, classification and forms of crystals. The symmetry elements can be represented by stereographic projections.
The remaining portions of mineralogy are divided as crystal chemistry and physical and optical properties, structure and description of silicates and non-silicates. Silicate minerals are the important rock-forming minerals. While non-silicate forms economically important deposits.
X-ray diffraction (XRD) is used for the identification of mineral phases by determining the crystal structure.

Chapter 1
Crystallography– symmetry and crystal systems

JAM year	Weightage (Marks)
2020	
20177	
2016	
2015	
Average	

SAMPLE

Chapter 1
Crystallography– symmetry and crystal systems

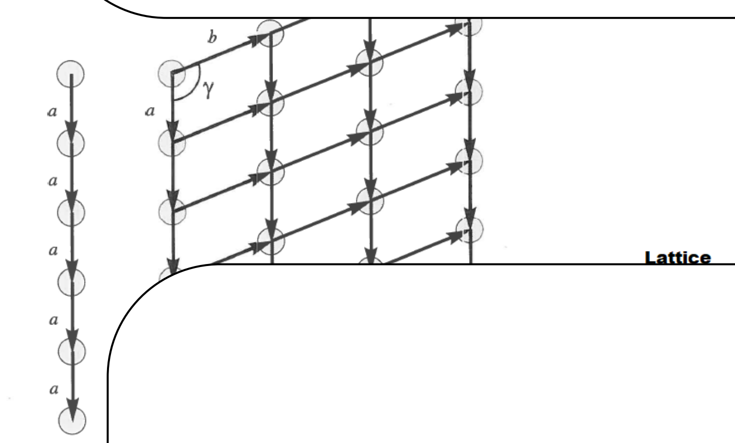
1.1. Crystallography - Introduction

- Crystallo … roperties of crysta…
- Min … y. This sym … ture of crys…
- Sym…
  - Tho…
  - Tho…
- A la … form a crys…

SAMPLE

1.2.

- Plan…
- Rep…
- The…

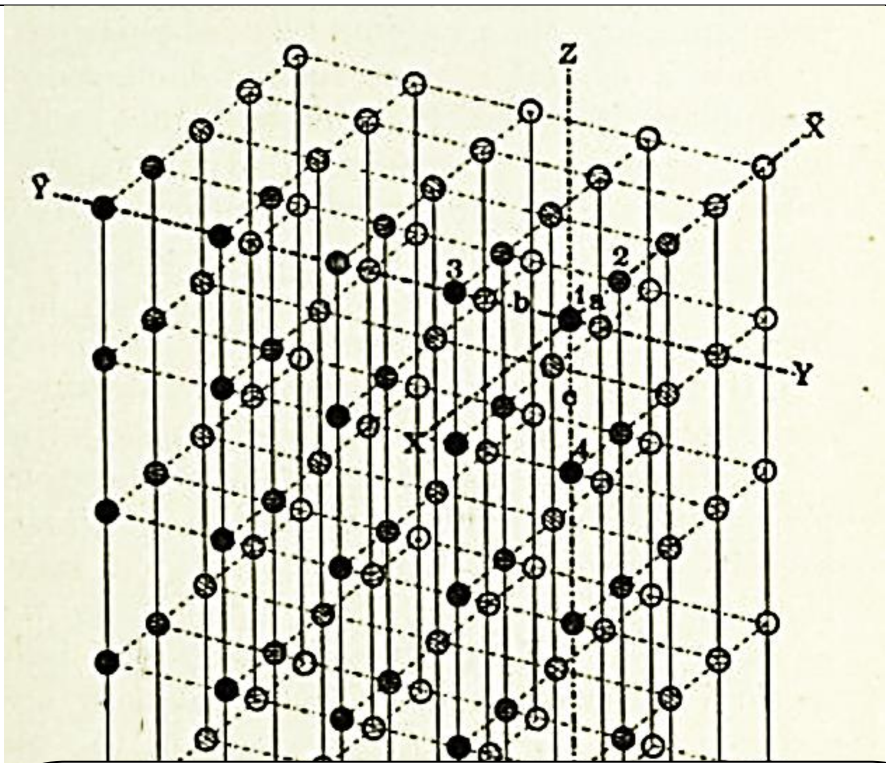


SAMPLE

- The fiv … wo dimensi … ue plane la … ed unit mes…
- Diamon…

1.3. Spa…

- A regula … at the inter…
- If the tw … to allow for … ice.



SAMPLE

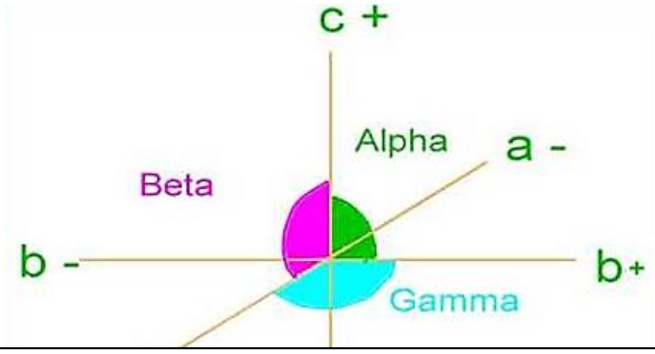
1.4. Un

- The uni ... stal structur
- The vol
- The edge ... rsect at a point ca

- The crystal axes have positive and negative ends

axes / Positive/negative	a	B	c
Positive	To the front	To the right	Upward
Negative	To the back	To the left	downward

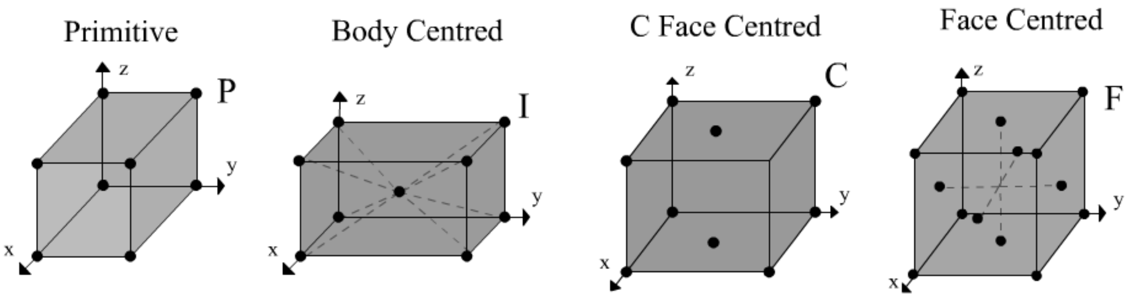
- The angle between b and c $\rightarrow \alpha$
  The angle between a and c $\rightarrow \beta$
  The angle between a and b $\rightarrow \gamma$



SAMPLE

1.5. ...

- Brav ... sed to desc...
- The ... space lattic...
- Not ... every lattic ... lattice point...
- Non-...
  - Body...
  - Face...
  - Face...
- Primi...
  Body-ce...
  Face centred (C) unit cells contain lattice nodes on the corners and two opposite sides
  Face centred (F) unit cells contain lattice nodes at the corners and the centre of each face.



- Crystal systems
  - The primary method of classification of crystals.
  - 14 Bravais lattices are grouped into six groups based on the shape of the unit cell. These are called crystal systems.

- Six crystal systems are
  - Isometric system
  - Tetragonal system
  - Hexagonal sys
  - Orthorh
  - Mono
  - Tricli
  - 14 Ty
- Out c ional space enote the di nding angle

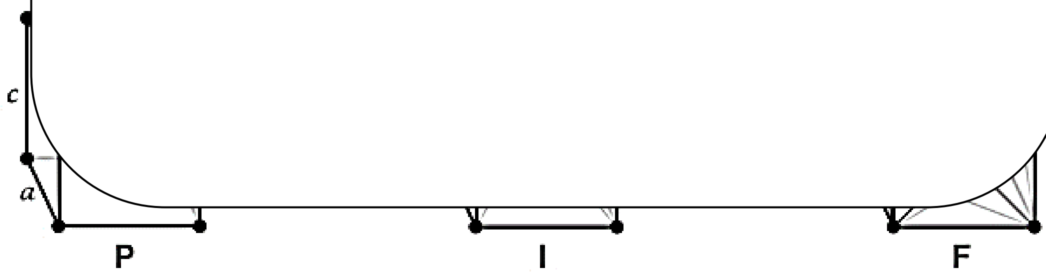
Isome

- In Br

  a = b

  α = β
- The 3

SAMPLE



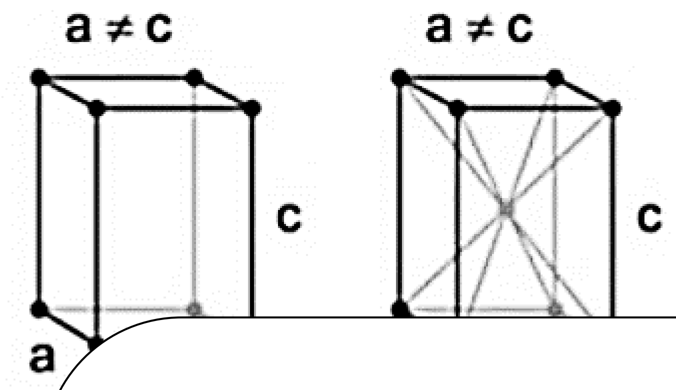
- These three possible cubic Bravais lattices are,
  - Primitive (or Simple) Cubic Cell (P)
  - Body-Centred Cubic Cell (I)
  - Face-Centred Cubic Cell (F)
- Examples: Polonium has a simple cubic structure, Iron has a body-centred cubic structure, and copper has a face-centred cubic structure.

Tetragonal Systems

- In tetragonal Bravais lattices, the following relations are observed:

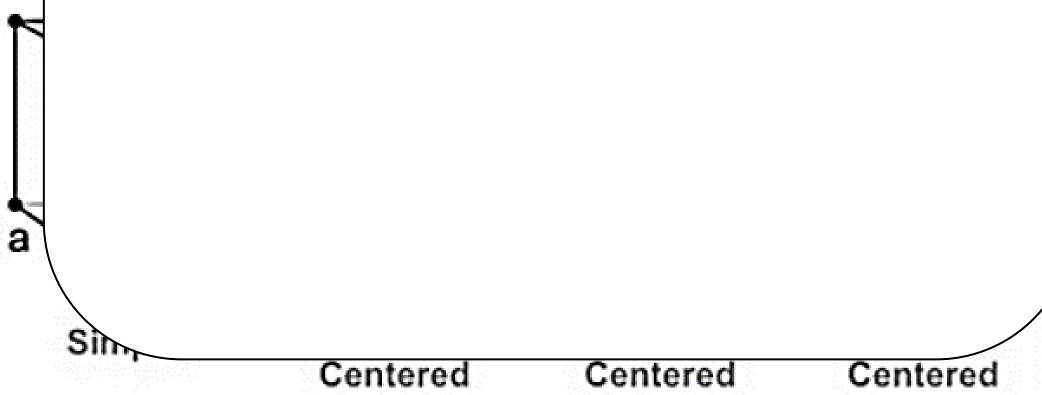
  $a = b \neq c$

  $\alpha = \beta = \gamma = 90^o$
- The two types of tetragonal systems are simple tetragonal cells and body-centred tetragonal cells,



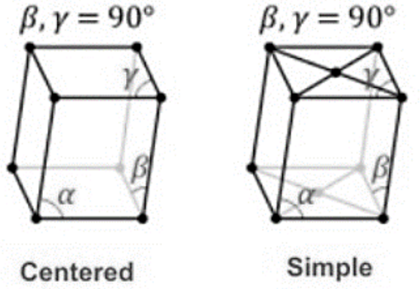
SAMPLE

- Stru
  Ortl
- The
  a ≠
  α =
- The



<u>Monoclinic Systems</u>

- Bravais lattices having monoclinic systems obey the following relations:
  a ≠ b ≠ c
  β = **γ** = 90^o and **α** ≠ 90^o
- The two possible types of monoclinic systems are primitive and base centred monoclinic cells,



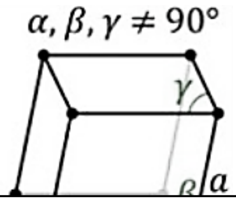
Triclinic System

- There exists only one type of triclinic Bravais lattice, which is a primitive cell. It obeys the following rel
  a ≠ b ≠
  α ≠ **β**
- An ill

SAMPLE

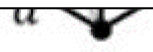
Hexagon

- Only t by:
  a = b =
  α = **β** = **γ**
- An illustration of the primitive rhombohedral cell is



SAMPLE

- Hexag
- The or ving relatio
- a = b ≠
- **α** = **β**
- An illu



- Thus, it can be noted that all 14 possible Bravais lattices differ in their cell length and angle relationships. It is important to keep in mind that the Bravais lattice is not always the same as the crystal lattice.

1.6. Point symmetry

- Point s...
- Moti... ...tructure of a...
- Poi...
- Ref...
- Rot...
- Inv...
- Rot...
  - Rot... ...n axis.
  - Not...
  - A_1 ...
  - Rot...
  - Sym...

SAMPLE

R...		
1-fold	360° rotation	none
2-fold	180° rotation	
3-fold	120° rotation	▲
4-...		

SAMPLE

- Refle...
  - A refl... ...t the patter...
  - Refle...
  - Mono... ...n has none.

- Inversion
  - If a crystal has inversion or centre of symmetry, any line drawn through the origin will find identical features equidistant from the origin on opposite sides of the crystal.
  - Inversion symmetry is indicated by the letter ‘i’.

Compound symmetry operations

- Rotoinversion
   - Rotoinversio
   - There ar ... d as $\bar{A}_1, \bar{A}_2, \bar{A}$
   - 1-fold r ... by inversio
     So, $\bar{A}_1 =$
   - 2-fold r ... on through
     So, $\bar{A}_2 =$
   - 3-fold ro ... gh the cent ... hat also pos
     $\bar{A}_3 = A_3$
   - 4-fold r ... the centre. $\bar{A}_4$ ... ns.
   - 6-fold rotoinversion axis ($\bar{A}_6$) involves 60° rotation followed by inversion through the centre.
     $\bar{A}_6$ is same as a 3-fold rotation axis at right angle to a mirror.
     $\bar{A}_6 = A_3 + m$

1.7. Sy

- Symm
- Centre
- Mirror
- Axis o ... fold axes of

1.8. Po

- There
- Each p
- Each po ... ystal forms)
- Name of point group (crystal class) and then Herman-Magaum symbol

Crystal system	Crystal class/ point	Name of the class
Tric		
Mo		
Ort		
Tet		
	4/m	Tetragonal-dipyramidal
	422	Tetragonal-trapezohedral
	4mm	Ditetragonal-pyramidal
	$\bar{4}2m$	Tetragonal-scalenohedron
	6mm	Dihexagonal-pyramidal
	$\bar{6}m2$	Ditrigonal-dipyramidal
	6/m2/m2/m	Dihexagonal-dipyramidal
Isometric	23	Tetaroidal

SAMPLE

SAMPLE

	$2/m\overline{3}$	Diploidal
	432	Gyroidal

- Symme

Syster								
cubic								
tetragona								
	$4mm$		1				4	
	$\overline{4}2m$				2 (3)	1	2	
	$4/m$		1				1	i
	$\overline{4}$				(1)	1		
	4		1					
hexagonal (hexagonal)	$6/m2/m2/m$	1			6		7	i
	622	1			6			
	$6mm$	1					6	
	$\overline{6}2m$			(1)	2	1	3 (4)	
hexago (trigona								
orthorh								
monoc								
triclinic								

- Hermann–
  - Hermann–Mauguin notation is used to represent the symmetry elements in point groups.
  - m - mirror planes
    1, 2, 3, 4, 6 - rotational axes (1-fold, 2-fold, 3-fold….etc.)

1, 2, 3, 4, 6 - rotoinversion axes (1-fold, 2-fold, etc.)
i – Inversion

- Determination of Hermann-Mauguin notation: example
  - Hermann-Mauguin notation of an orthorhombic crystal

SAMPLE

  - Ther … metry.
  - Step …
  - Step …
  - Step III … slash (/)' in between them.

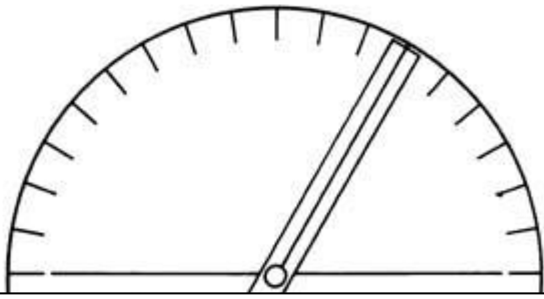
$$2/m2/m2/m$$

- Steno's …
  - This … gles of the … d sizes and …

SAMPLE

The …

- Measurement of crystal angles
  - Crystal angles can be measured with an instrument called a goniometer.
  - Simple contact goniometer



SAMPLE

1.9. Sp

- The sp ... onal symme
- Combi ... tion of glid ... 230 space g
- A glid ... tion follow
- A silico
- Glide plane, ... the point group symmetry.
- A screw is produced by a combination of translation a specific distance and direction followed by a rotation. The axis about which rotation occurs is called the screw axis.

1.10. Crystal faces

SAMPLE

- A pla
- Cryst ... th the resul ... igned ratio
- Law
- Law ... attice node

1.11. A

- Axia ... y are norm ... ratio is de

  Axia
  Or
  Axial R
- For example,

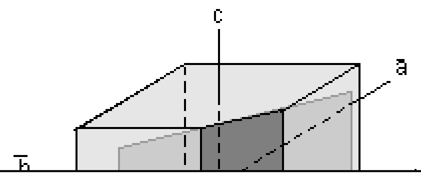
For ...
a ...

SAMPLE

1.12. ...

- We...
  - We... ...pect to the ...
  - Exa...
    A c...

    As an e... ...out not the c axis.



SAMPLE

Assum... ...eters for thi...

- Miller...
  - Miller... ...phic planes...
  - The or... ...lane (or any...
  - • (h,k,...
    • Nega...
    • [hkl] ...
    • <hkl> r...
    • (hkl) represents a plane
    • {hkl} represents a family of planes
  - Determination of Miller index of a plane
    - Step I: Determine the intercepts (a,b,c) of the plane along the crystallographic axes, in terms of unit cell dimensions.
    - Step II: Take the reciprocals of the intercepts.
    - Step III: Clear fractions and reduce to lowest terms by multiplying each intercept by the denominator of the smallest fraction.

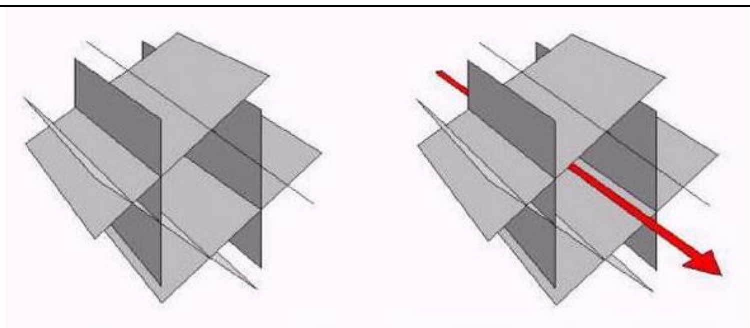
- Step IV: If a plane has negative intercept, the negative number is denoted by a bar (¯) above the num
- Step V … three indic

SAMPLE

- Mille
    - For t … three in th … axis. Cons … Miller indic … $h+k$

1.13. Z

- A zo … led a zone



- The zo … [uvw].

SAMPLE

Practice questions

1. The total number of Bravais lattices.
a. 6
b. 1
c.
d.

2.

SAMPLE

a.
b.
c.
d.

3. Whic
a. (100)
b. {10
c.
d.

4.
a.
b.
c.
d.

SAMPLE

5.
a.
b.
c.
d.

6.
a. 2
b. $\bar{2}$
c. 3
d. $\bar{3}$

7. Cho… to the
I. …
r…
I…
I… le to a
r…

a. I…
b. I…
c. I…
d. I…

SAMPLE

8. F…

a…

a. 0…
b. 0…
c. 0…
d. 0.4…

9. Match the following classes in Group I to symbols in Group II

Group I	Group II
P. …	…
Q…	…
R…	…
S…	…
…	…

a. P-…
b. P-…
c. P-…
d. P-…

SAMPLE

10. Hermann- Mauguin symbol of the following crystal

SAMPLE

a. 4/
b. 4/m2/
c. 4/m4/m4/m
d. 4/m2m2/m

11. A crystal face has the following intercepts for the crystallographic axes: ∞a1, 1a2, 1c The Mi

SAMPLE

Mult
12.
a.
b.
c.
d.

13.
a. 2
b. 3
c. 4
d. 6

14. … simpler s
a. 2-
b. 3-fo
c. 4-fold rotoinversion axis
d. 6-fold rotoinversion axis

15. Which of the following symbol(s) does NOT represents a point group(s) in the hexagonal system?

a. $\bar{3}2/m$
b. $2/m\bar{3}$

c.
d.

16.
a.
b.
c.

SAMPLE

d.

17.
a.
b.
c.
d.

18. Wh
a. Tetragonal-dipyramidal
b. Gyroidal
c. Dihexag
d. Di

19. F
a. 2
b. 6
c. 3
d. F

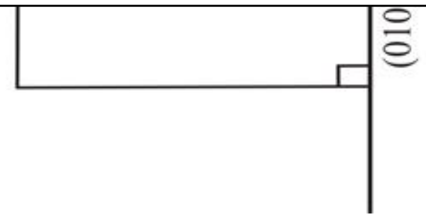
SAMPLE

Answers

1. b
2.
3.
4.
5.
6.
7.
8.
9.
10
11
12
13
14
15
16
17.
18. b,
19. a, c, d

SAMPLE

JAM	
2020	If (326) is the Miller Index of a crystal face, then the value of **x** in the SAMPLE
2020	Mark 1 Ans 3 Explanation: $(\bar{4}1h0) \rightarrow (hkil)$ We know, h+k+i=0 SAMPLE
2017	SAMPLE 1).
2017	43. The Weiss symbol of a crystal face is 4a: 2b : c . The value of h in the corresponding Miller Index (hkl) is ___________. Mark: 1

	A ... s
2016	... h SAMPLE  Mark: 1 Ans: 130 SAMPLE
2015	... 1, ... le
2015	Mark 1 Ans 9

	roup) of es.

SAMPLE