Ceramics	Metals
• Crystalline structure	• Crystalline structure
• Ionic, covalent bonds	• Metallic bonds (Sea of $\bar{e}$)
• Impurities are foriegn atoms in ceramics	• Point defects, substitutional interstitial
• Ceramics are brittle	

• Tests used are:

1) Flexural strength → material's ability to resist bending
2) Fracture toughness
3) Hardness

Types of ceramics:

→ Clay products
→ refractory products
→ Glasses & Glass ceramics
→ Cement
→ Abrasives
→ Advanced Ceramics (Si_3N)
→ Allotropes of C

Taxonomy of Ceramics:

- Glass
  - Optical composite
- refractory
  - Bricks for high T furnances
- Cement
  - Composites
  - structural
- Abrasives
  - Sandpaper
  - cutting
  - polishing
- Advanced ceramics
  - Engine
  - rotor
- clay
  - brick
  - white

reinforce
containers

- household
  - ↳ Glass
  - ↳ Glass ceramics

- valves

Engineering Ceramics:

- Oxides
- Nitrides
- Carbides
- optical fibres

Metals	Ceramics
• Crystal structure	• Crystal structure
• large no. of free $\bar{e}_s$	• Captive $\bar{e}_s$
• Metallic bond	• Covalent / ionic bond
• Good ductility	• Poor ductility
• Opaque	• Transparent

• Good electrical conductivity	• Poor electrical conductivity
• High tensile strength	• low tensile strength
• Uniform atoms	• Non-uniform atoms
• Low shear strength	• High shear strength
• Plasticity	• None

Bonding:

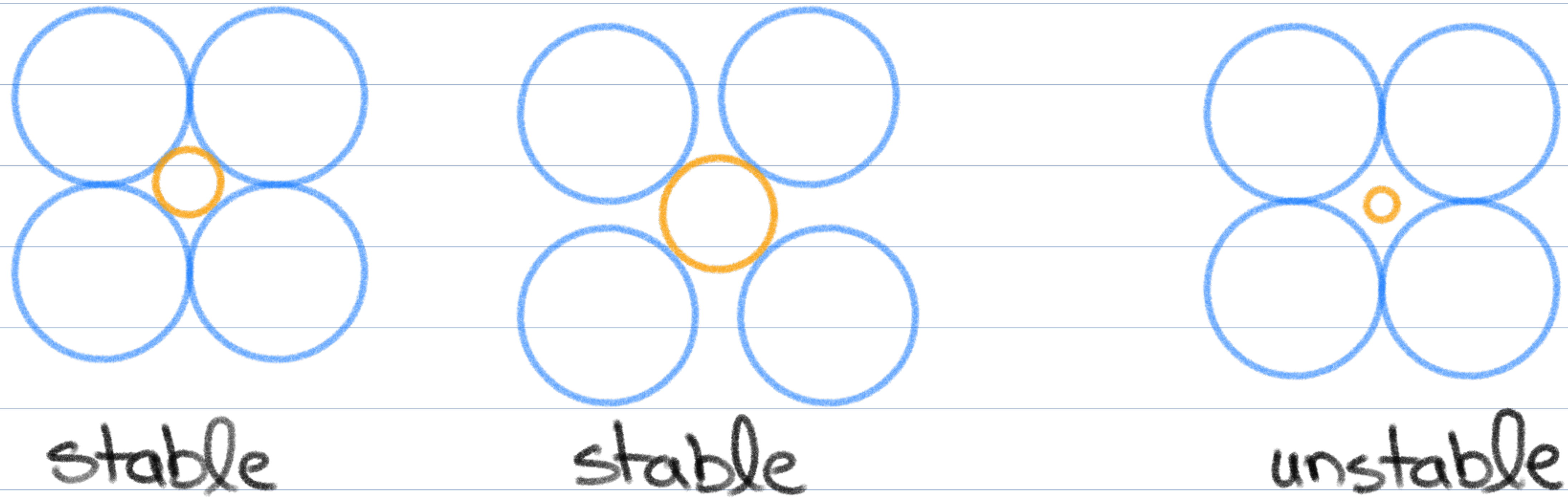
- Ionic to covalent
- Mostly ionic
- Ionic % increases with difference in electronegativity
- Charge neutral (Net is 0)

$A_m X_p$

Eg:

$CaF_2 \Rightarrow Ca^{+2} + \begin{matrix} F^- \\ F^- \end{matrix} = 0$

- Stable structure:
  - ↳ Relative sizes of cation (r_c) & anion (r_A)
  - ↳ Anion in contact with cation



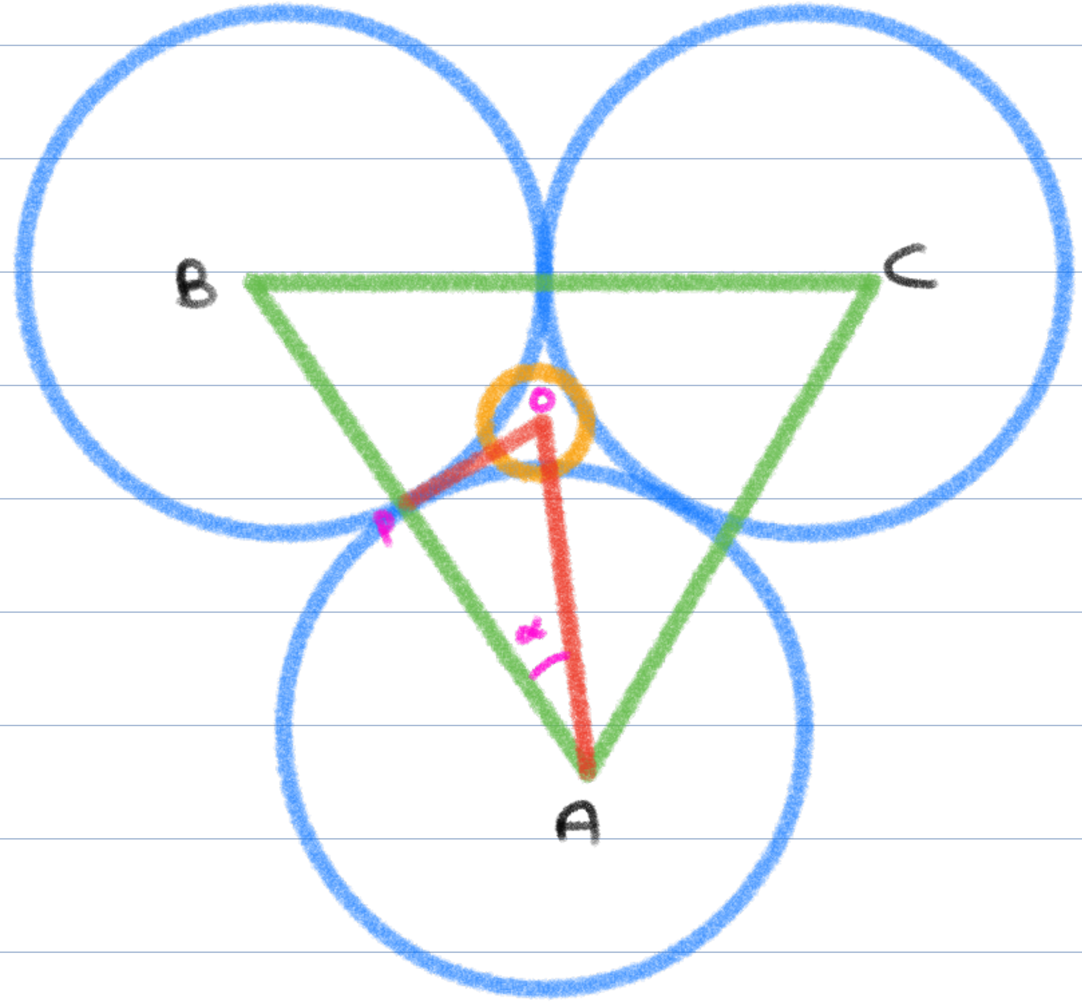
Proof:

$$\frac{r_c}{r_A} = 0.155$$

Consider ΔAOP;

$$\overrightarrow{AP} = r_A$$

$$\overrightarrow{AO} = r_A + r_C$$



$$\frac{AP}{AO} = \cos\alpha$$

$$\alpha = 30^\circ$$

$$\frac{AP}{AO} = \cos 30^\circ$$

$$\frac{r_A}{r_A + r_C} = \frac{\sqrt{3}}{2}$$

$$\frac{r_C}{r_A} = \frac{1 - \sqrt{3}/2}{\sqrt{3}/2}$$

$$= 0{\cdot}155$$

⇒ Equal CSA

AX Type structure:

• CsCe	• ZnS	• NaCl
C.NO = 8	C.NO = 4	C.NO = 6
Cs^+ Ce^-	Zn^{+2} S^{-2}	Na^+ Cl^-
		$r_A = 0.102$
		$r_C = 0.181$

A_mX_p type structure: → unequal C&A

CaF_2

C.No = 8

Ca^{+2} occupies half as many spaces ac F^- to maintain neutrality.

Ca^{+2}:

Centre = 2 = +4

$\frac{r_c}{r_A} = 0.8$

$\bar{F}$:

corner = 8/8 = 1

Faces = 2/2 = 1

Edges = 8/4 = 2

$A_m B_n X_p$ Type crystal structure:

$BaTiO_3$

Ti^{+4} Ba^{+2} $\bar{O}^{2}$ = 0

$YBa_2Cu_3O_7$ ⟶ super conductor

Size of ion:

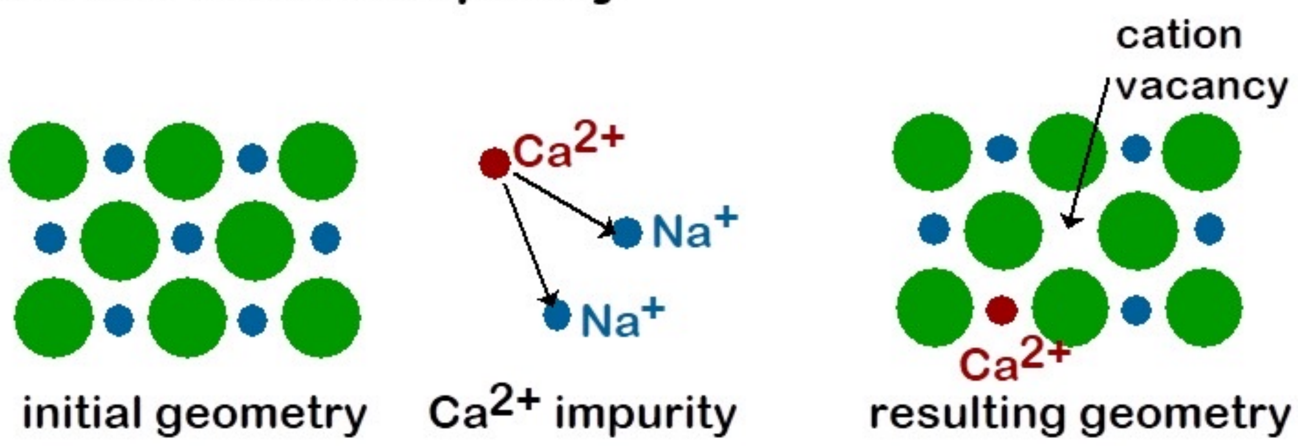
- More coordination number, more Ionic radius
- C.No 8 > C.No 6 > C.No 4
- $Fe^{+2} = 0.077$ $Fe^{+3} = 0.069$

  $Fe = 0.124$

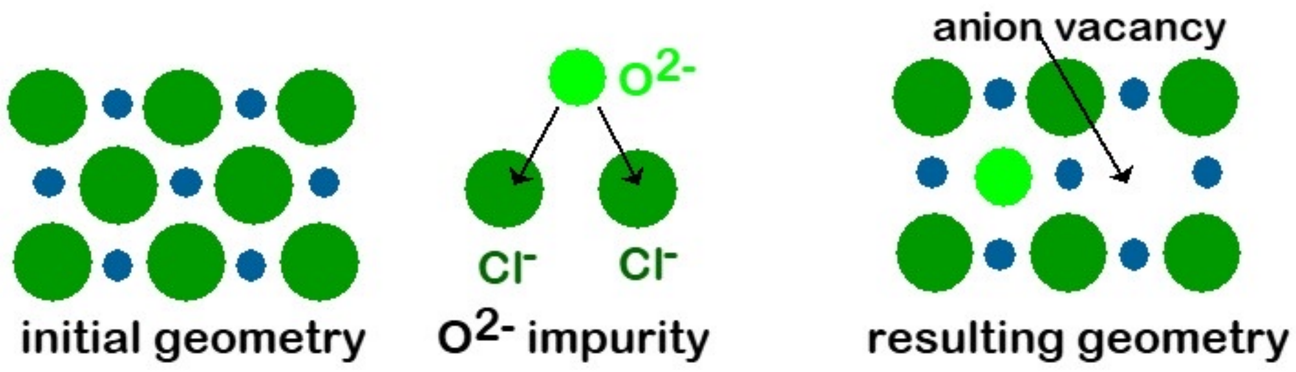
IMPURITIES

Example: NaCl Na^+ ● Cl^- ●

- **Substitutional cation impurity**



- **Substitutional anion impurity**



Glass manufacturing:

1) Fabrication within specified viscosity range

2) Thermal stresses may stay in material (particularly) glasses due to different cooling rates leading to frequent thermal shocks

3) Such stresses can be removed by annealing heat treatment

4) Further hardening by thermal tempering

Amorphous Ceramics:

Glass Ceramics:

1. Main ingredient is Silica (SiO_2)
2. If cooled very slowly will form crystalline structure.
3. If cooled more quickly will form amorphous structure consisting of disordered and linked chains of Silicon and Oxygen atoms.
4. Polycrystalline structure accounts for its transparency as it is the crystal boundaries that scatter the light, causing scattering. (nano crystals are transparent)
5. Glass can be tempered to increase its toughness and resistance to cracking.

Eg: Soda lime glass

used as:Oven ware, table ware, oven windows etc

Trade Names: Pyroceram; Corningware; Cercor; Vision

1. High Mech. Strength , hardness, and light weight
2. Low coefficient of expansion (thermal shock proof)
3. Withstand high Temperature
4. Good dielectrics
5. Biologically compatible
6. Transparent, opaque
7. Easily fabricated into pore-free products
8. Low fracture toughness compared to metals
9. Resist corrosion

Eg: Fine grain polycrystalline produced by heat treatment of amorphous glass.

Flexural Testing:

- Flexural testing preferred over tensile test:
  - ↳ Test sample of required geometry difficult to produce
  - ↳ Gripping brittle materials is problematic
  - ↳ Alignment required as at strain $\leq 0.1\%$ fracture occurs.

Therefore, 3-point bending test used for brittle materials to find flexural strength or stiffness