

## Atomic bonding

Ionic: Anions gain electrons, cations lose electrons

Covalent: electrons shared between two atoms

Metallic: electrons shared between many atoms

Van der Waals: temporary or permanent dipole

Interacts with other objects

## Crystal structures

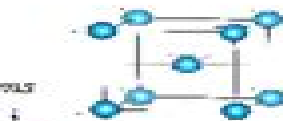
### BODY CENTERED CUBIC

$$4R = \sqrt{a^2 + a^2 + a^2}$$

$$4R = a\sqrt{3}$$

1 center atom, 8 corner atoms

2 atoms per unit cell



### FACE CENTERED CUBIC

$$4R = \sqrt{a^2 + a^2}$$

$$4R = a\sqrt{2}$$

6 face atoms, 8 corner atoms

4 atoms per unit cell



Volume of a cubic =  $a^3$

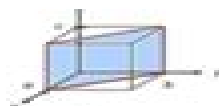
$$A = 10^{-10} \text{ m}$$

$$\text{Avogadro No} = 6.022 \times 10^{23} \left( \frac{\text{atoms}}{\text{mol}} \right)$$

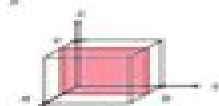
$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{\# \text{ of atoms} \times \text{atomic mass}}{\text{volume of unit cell} \times \text{Avogadro}}$$

## Miller Indices

crystal	h	k	l
1. Intercepts	1	1	1
2. Reciprocals	1/1	1/1	1/1
3. Reduction	1	1	1
4. Miller indices	(111)		



crystal	h	k	l
1. Intercepts	1/2	1	1
2. Reciprocals	2/1	1/1	1/1
3. Reduction	2	1	1
4. Miller indices	(211)		



$$\text{Planar Density} = \frac{\text{atoms per face}}{\text{area of face}}$$

$$\text{Packing Factor} = \frac{\text{volume of atom} \times \text{number of atoms}}{\text{volume of the unit cell}}$$

## Point Defects

$$n_v = n \cdot e^{-\frac{Q_v}{RT}}$$

$$n_v = \# \frac{\text{vacancies}}{\text{cm}^3}, n = \# \frac{\text{atoms}}{\text{cm}^3}$$

$Q_v$  = energy for 1 mol of vacancies,  $T$  = Temp

$$R = \text{Gas constant} = 1.987 \frac{\text{cal}}{\text{mol} \cdot \text{K}} = 8.314 \frac{\text{joules}}{\text{mol} \cdot \text{K}}$$

## Diffusion

$$D = D_0 \cdot e^{-\frac{Q}{RT}}$$

$D_0$  = constant based on material

$Q_v$  = energy for 1 mol of vacancies,  $T$  = Temp

$$R = \text{Gas constant} = 1.987 \frac{\text{cal}}{\text{mol} \cdot \text{K}} = 8.314 \frac{\text{joules}}{\text{mol} \cdot \text{K}}$$

$$J = -D \cdot \frac{dc}{dx}, x = \text{thickness}, J = \text{Flux} \text{ - Fick's 1st law}$$

$c$  = Compositions in atomic percent

## Mechanical Properties

$$\text{Engineering stress (S)} = \frac{F}{A_0}$$

$$\text{Engineering Strain (e)} = \frac{\Delta l}{l}$$

$$\text{Young Modulus (E)} = \frac{S}{e}$$

$F$  = Force,  $A_0$  = Area

$\Delta l$  = Change in length,  $l$  = Original length

$$K_c \text{ or } K_{Ic} = f \sigma \sqrt{a}$$

$\sigma$  = Exposed stress,  $a$  = flaw size

$f$  = geometry factor for the specimen and flaw

$K_{Ic}$  = fracture toughness

$K_{Ic}$  = plain strain fracture toughness

$$\pm \sigma = 5.09 \cdot \frac{FL}{d^3}$$

$F$  = Applied Load,  $L$  = Length of shaft

$d$  = diameter of shaft

$$1 - K(V) = \exp \left[ - \left( \frac{\sigma}{\sigma_0} \right)^m \right]$$

$m$  = Weibull Modulus,  $\sigma_0$  = Flexural Strength

$F$  = Failure,  $\sigma_0$  = Initial Flexural Strength

$$\text{Poissons Ratio (v)} = \frac{-\epsilon_{lateral}}{\epsilon_{longitudinal}}$$

$$\text{Modulus of resilience (E}_r) = \frac{1}{2} (\text{yield strength}) (\text{strain@yielding})$$

$$\text{Ductility \%Elongation} = \frac{l_f - l_0}{l_0} \cdot 100\%$$

$$\text{Ductility \%Reduction in area} = \frac{A_0 - A_f}{A_0} \cdot 100\%$$

$$\text{True Stress} = \frac{F}{A_f}$$

$$\text{True Strain} = \ln \left( \frac{l}{l_0} \right)$$

$$\sigma_t = K \epsilon_t^n$$

$n$  = strain coefficient,  $K$  = Constant

$\epsilon_t$  = True strain,  $\sigma_t$  = True Stress

$$\sigma_m = 2\sigma_a \left( \frac{a}{r_c} \right)^{\frac{1}{2}}$$

$\sigma_m$  = Stress @ Crack tip,  $\sigma_a$  = Applied stress

$a$  = Crack Length,  $r_c$  = radius of curvature

$$\sigma_c = \left( \frac{2E\gamma_s}{\alpha\pi} \right)^{\frac{1}{2}}$$

$\sigma_c$  = Critical Stress,  $E$  = elastic modulus

$\gamma_s$  = specific surface energy

$\alpha$  = one half length of internal crack

## Solidification and Nucleation

# Material Science Final Exam Key

**Michael Rajnik**



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