Department of Materials Science and Engineering
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University of California, Los Angeles

MSE 104, MIDTERM (1 hour 50 minutes)
Spring 2022

NAME:________________________________

UCLA ID:______________________________

All work must be clearly shown with proper units in the final answer to receive full credit. Check that all parts are answered.

1 (18 pts)	
2 (13 pts)	
3 (20 pts)	
4 (15 pts)	
5 (10 pts)	
6 (14 pts)	
7 (10 pts)	
Total points	

Problem 1: Multiple Choice Questions (18 pts)

1- A fine-grained material is weaker that a coarse-grained material
A. True
B. False

2- As of result of strain hardening,
A. ductility increases and strength increases
B. ductility decreases and strength increases
C. ductility decreases and strength decreases

3- Plastic slip is most likely to occur
A. On planes with low planar density and along directions of high linear density
B. On planes with high planar density and along directions of low linear density
C. On planes with low planar density and along directions of low linear density
D. On planes with high planar density and along directions of high linear density

4- For ductile materials, due to plastic deformation at the crack tip,
A. The crack tip is typically blunted
B. The crack tip is typically sharp

5- In most metals, creep typically occurs at
A. Low temperatures, near the ductile to brittle transition
B. Room temperature
C. Elevated temperatures, approximately 0.4 times the melting temperature or more

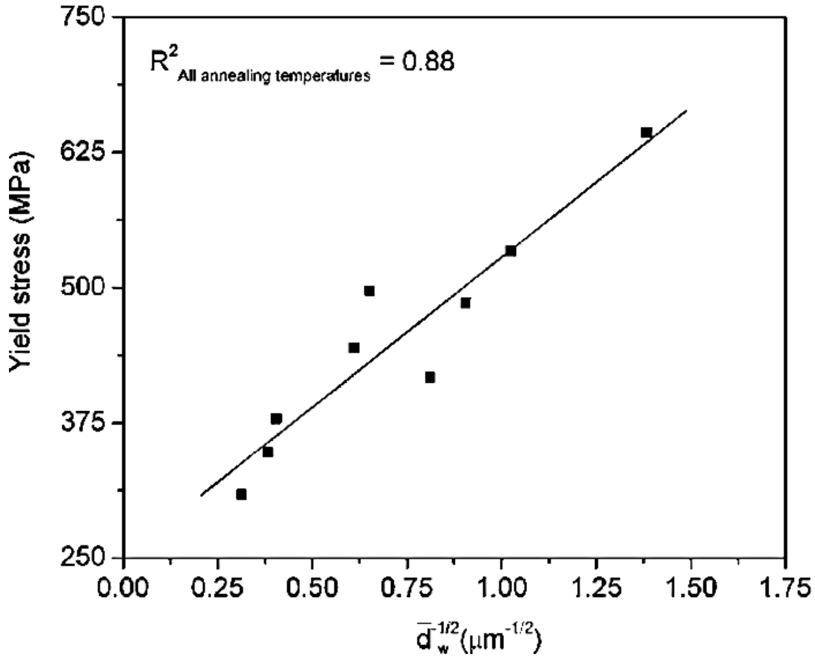
6- Cementite (Fe3C) is an example of
A. An interstitial solid solution in the BCC phase
B. An intermetallic compound

Problem 2: Short Answer (13 points)

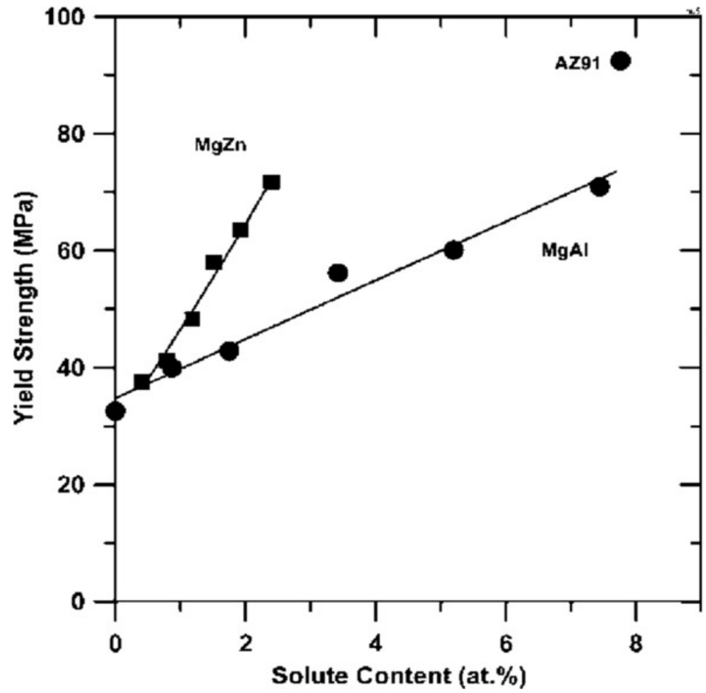
Part A: The following graphs represent a certain means to strengthen materials

In the space to the right of each graph, identify the strategy for strengthening and provide a 1-2 sentence description of the mechanism behind it.

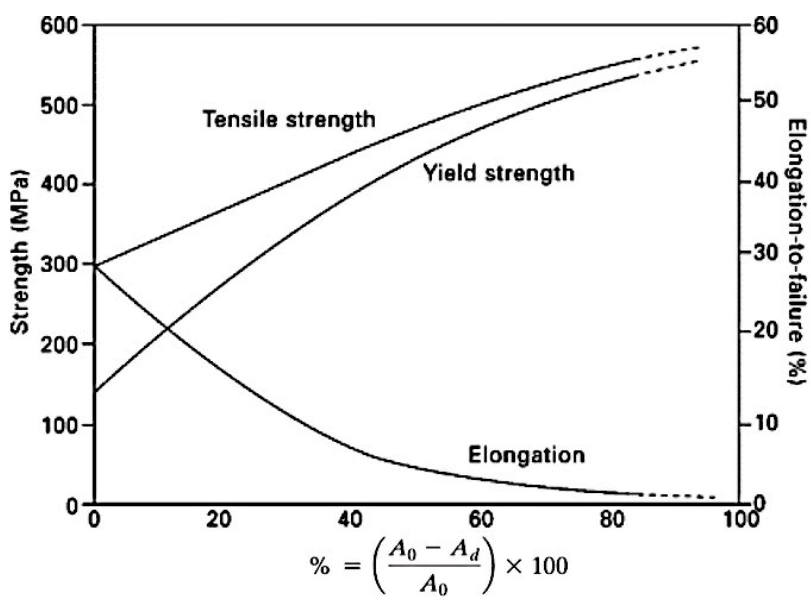
1.



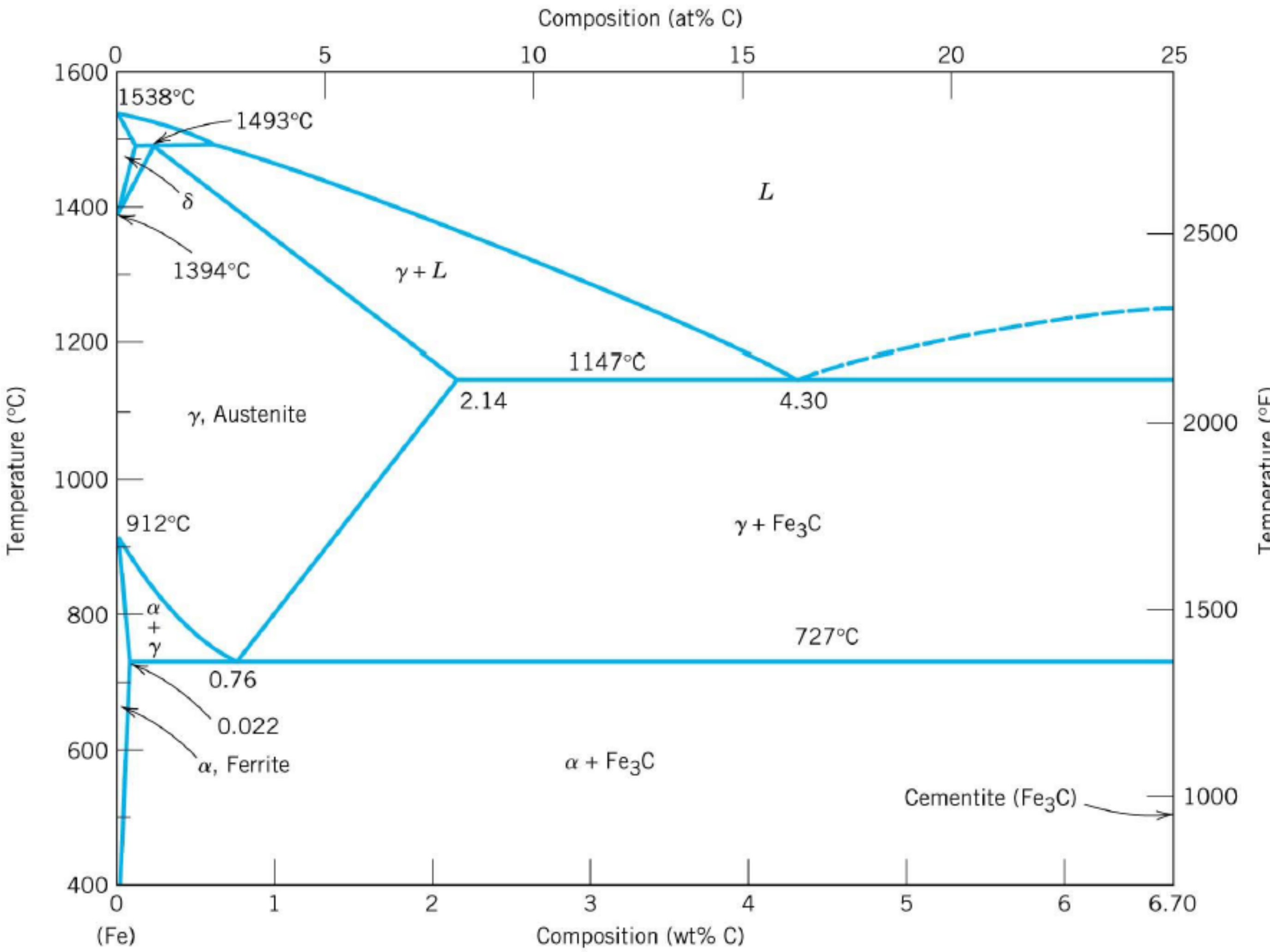
2.


AZ91
MgZn
MgAl
Yield Strength (MPa)
100
80
60
40
20
0
0
2
4
6
8
Solute Content (at.%)

3.


Tensile strength
Yield strength
Elongation
Strength (MPa)
Elongation-to-failure (%)
600
500
400
300
200
100
0
60
50
40
30
20
10
0
0
20
40
60
80
100
$\% = \left(\frac{A_0 - A_d}{A_0}\right) \times 100$

Part B: Fe-C phase diagram. For the iron-carbon phase diagram shown below. Determine approximate compositions and temperatures of all eutectic and eutectoid points. (4 pts)



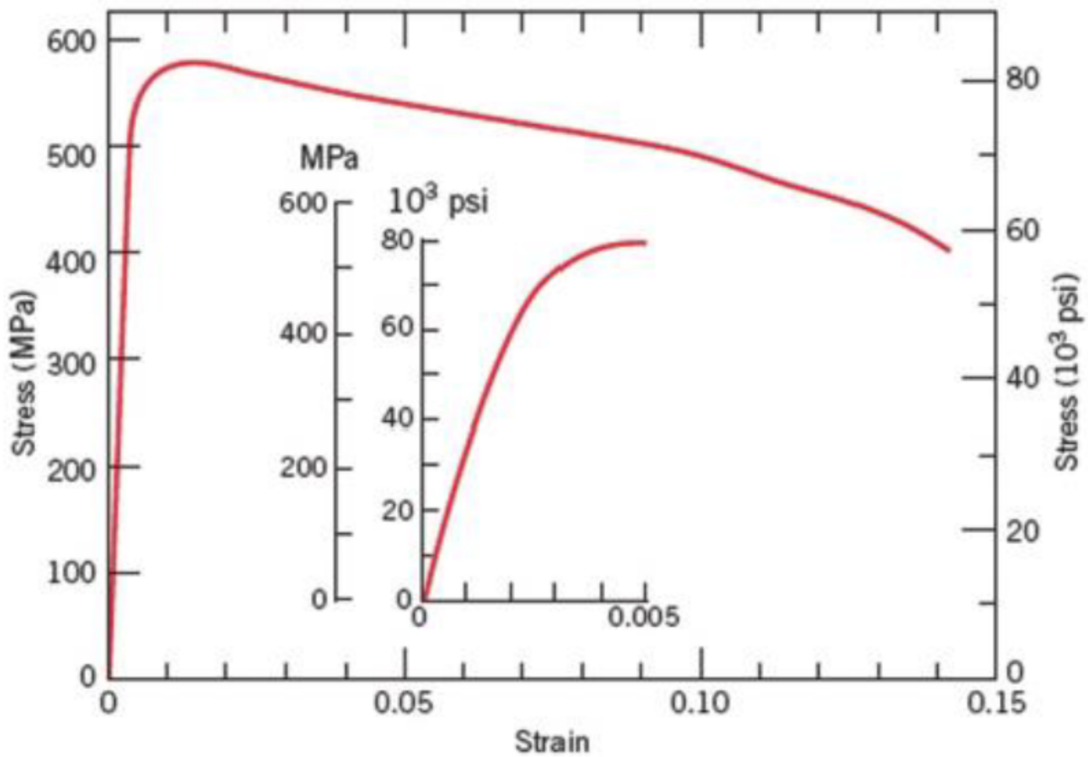
Problem 3: (20 pts) Crystal structure of CdS: Assuming that Cd and S ionic radii in the CdS ceramic compound are r(Cd^{2+}) = 0.109 nm and r(S^{2-}) = 0.170 nm, determine:
(a) (5pts) Sketch the unit cell structure of CdS. You must justify your answer using the table below.

Cation-Anion Radius Ratio	Coordination Number	Coordination Geometry	Coordination Geometry
0.225 – 0.414	4	Tetrahedral	Zinc blende
0.414 - 0.732	6	Octahedral	Rock salt
0.731 – 1.000	8	Cubic	Cesium chloride

(b) (5pts) Compute the lattice parameter (length of the edge of the unit cell).
(c) (5pts) Calculate the theoretical density of CdS (g/cm3). Atomic mass of Cd is 112.4 g/mol, S is 32.1 g/mol.
(d) (5pts) CdO is soluble in CdS. What kinds of point defects are introduced when CdO is dissolved in a bulk CdS crystal?

NOTE: If you do not know the answer to part (a), proceed by assuming any of the three structures.

Problem 4 (15 pts)
Stress-Strain behavior:
The figure to the right shows the tensile stress– strain curve for a plain-carbon steel.
Conceptually estimate:
(a) Elastic Modulus (GPa) (5Pts)
(b) Modulus of Resilience (Joule/cm3) (5Pts)
(c) Toughness (Joule/cm3) of this material (5Pts)
(*A rough calculation is fine, but please use the number in figures and necessary equations to do the calculation instead of just giving conceptual explanation*.)



Problem 5 (10 pts)

A wing component on an aircraft is fabricated from an aluminum alloy that has a plane strain fracture toughness of $40\ MPa\sqrt{m}$ $(36.4\ ksi\sqrt{in.})$. It has been determined that fracture results at a stress of 365 MPa (53,000 psi) when the maximum internal crack length is 2.5 mm (0.10 in.). For this same component and alloy, compute the stress level at which fracture will occur for a critical internal crack length of 4.0 mm (0.16 in.).

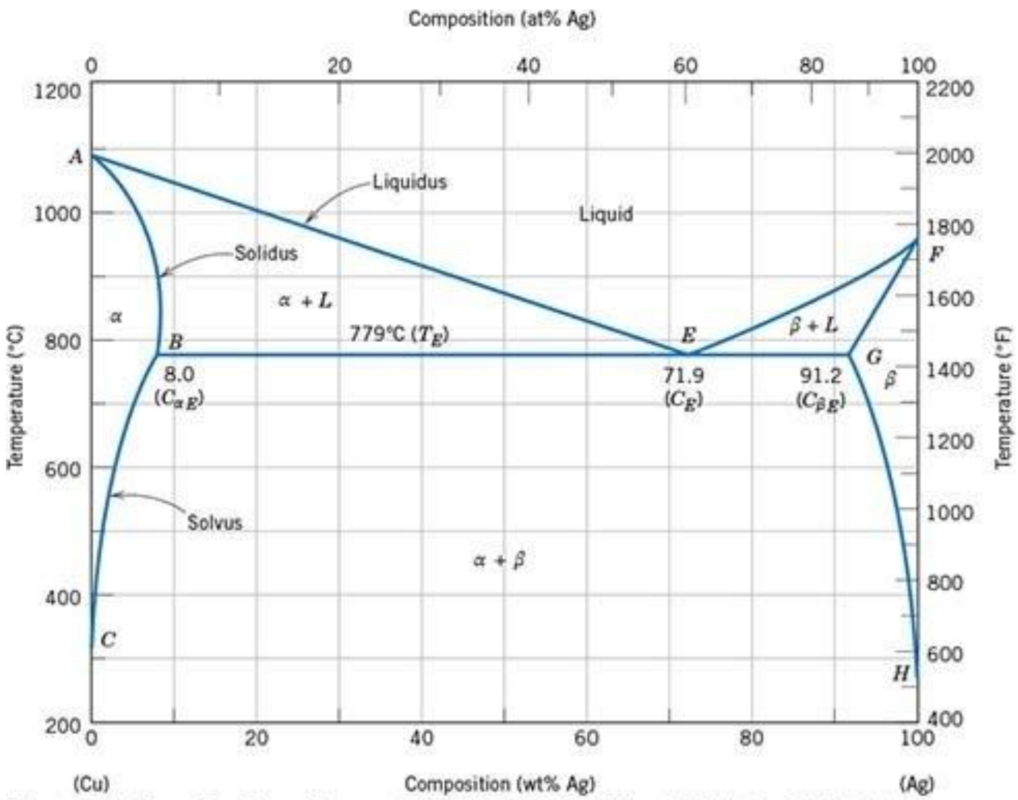
Problem 6 (14pts)

For a copper-silver alloy of composition 35 wt% Ag-65 wt% Cu and at 775°C (1425°F) do the following:

(a) (5 points) Determine the mass fractions of α and β phases.

(b) (5 points) Determine the mass fractions of primary α and eutectic microconstituents.

(c) (4 points) Determine the mass fraction of eutectic α.



Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 1, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.

Problem 7 (10 pts)

(a)Zirconia (ZrO_2) is often stabilized with calcium (CaO). If Ca^{+2} substitutes for Zr^{+4} ions, will the vacant sites be anion or cation? Show or explain your reasoning (5 pts)

(b)What is the difference between creep and fatigue? (one to two sentence short answer is sufficient).(5 pts)

Data Sheet

$N_A = 6.023 \times 10^{23}$ molecules/mol

$k = 1.38 \times 10^{-23}$ J/atom-K $= 8.62 \times 10^{-5}$ eV/atom-K

$R = 8.31$ J/mol-K

$$a = 2R\sqrt{2} \qquad a = \frac{4R}{\sqrt{3}} \qquad APF = \frac{V_S}{V_C} \qquad \rho = \frac{nA}{V_C N_A}$$

$$n\lambda = 2d_{hkl}\sin\theta \qquad N_v = N\exp\left(-\frac{Q_v}{kT}\right) \qquad N = \frac{N_A \rho}{A}$$

$$C_A = \frac{m_A}{m_A + m_B} \times 100 \qquad C_A' = \frac{m_A/A_A}{m_A/A_A + m_B/A_B} \times 100 \qquad \sigma = \frac{F}{A_o}$$

$$\varepsilon = \frac{l - l_o}{l_o} = \frac{\Delta l}{l_o} \qquad \tau = \frac{F}{A_o} \qquad \sigma = E\varepsilon \qquad \tau = G\gamma \qquad \sigma_w = \frac{\sigma_y}{N}$$

$$\nu = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\varepsilon_y}{\varepsilon_z} \qquad E = 2G(1+\nu) \qquad U_r = \frac{1}{2}\sigma_y \varepsilon_y = \frac{\sigma_y^2}{2E}$$

$$\%AR = \left(\frac{A_o - A_f}{A_o}\right) \times 100 \qquad \%EL = \left(\frac{l_f - l_o}{l_o}\right) \times 100 \qquad TS(psi) = 500 \times HB$$

$$TS(MPa) = 3.45 \times HB \qquad \tau_R = \sigma\cos\phi\cos\lambda \qquad \sigma_y = \sigma_o + k_y d^{-1/2}$$

$$\sigma_y = \frac{\tau_{crss}}{(\cos\phi\cos\lambda)_{\max}} \qquad \%CW = \left(\frac{A_o - A_d}{A_o}\right) \times 100 \qquad \sigma_m = 2\sigma_o\left(\frac{a}{\rho_t}\right)^{1/2}$$

$$\sigma_c = \left(\frac{2E\gamma_s}{\pi a}\right)^{1/2} \qquad G = 2(\gamma_s + \gamma_p) \qquad K_c = Y\sigma\sqrt{\pi a} \qquad K_{Ic} = Y\sigma\sqrt{\pi a}$$

$$\sigma_m = \frac{\sigma_{\max} + \sigma_{\min}}{2} \qquad R = \frac{\sigma_{\min}}{\sigma_{\max}} \qquad \sigma_r = \sigma_{\max} - \sigma_{\min} \qquad \sigma_a = \frac{\sigma_r}{2} = \frac{\sigma_{\max} - \sigma_{\min}}{2}$$

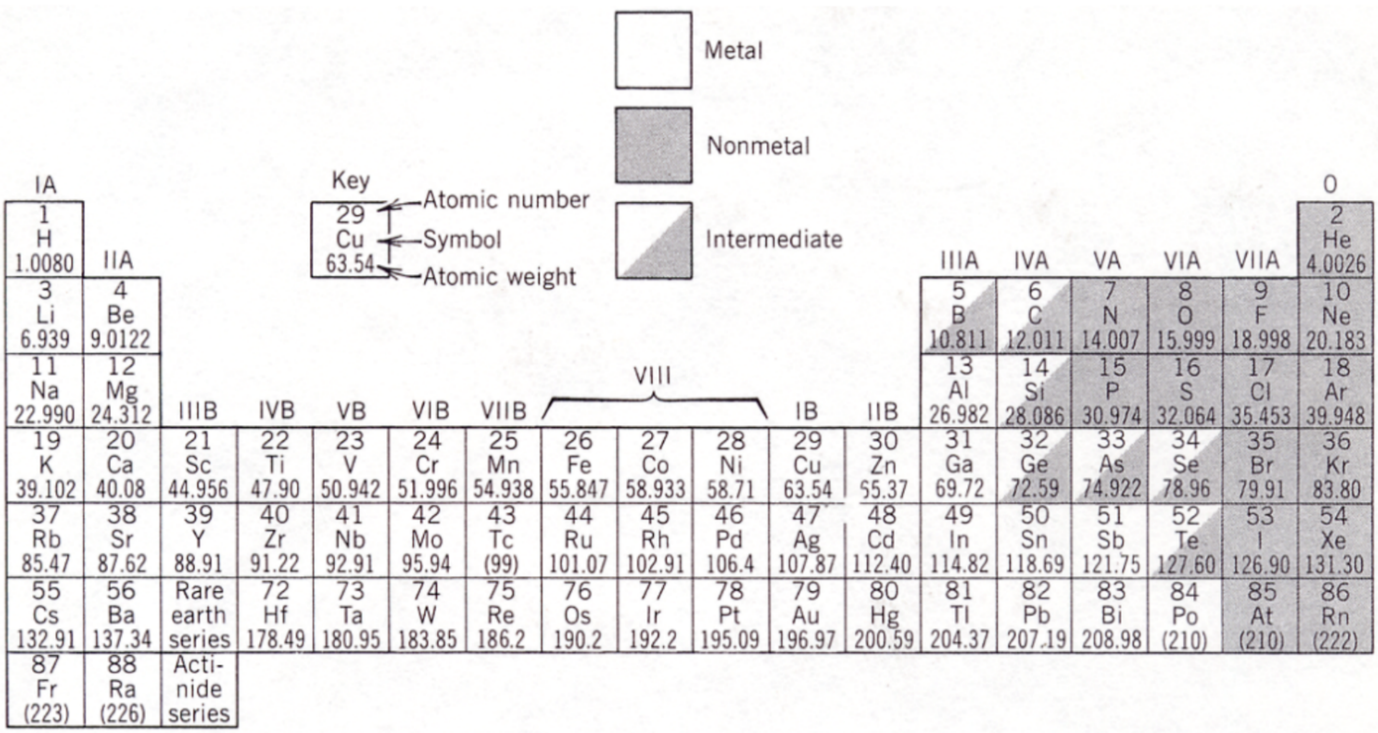
$$\dot{\varepsilon}_s = K\sigma^n \exp\left(-\frac{Q_c}{RT}\right) \qquad W_\alpha = \frac{C_\beta - C_0}{C_\beta - C_\alpha} \qquad W_\beta = \frac{C_0 - C_\alpha}{C_\beta - C_\alpha}$$

$$J = \frac{1}{A}\frac{dM}{dt} \qquad J = -D\frac{dC}{dx} \qquad \frac{dC}{dx} \approx \frac{\Delta C}{\Delta t} = \frac{C_a - C_b}{x_a - x_b} \qquad \frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\left(D\frac{\partial C}{\partial x}\right)$$

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} \qquad D = D_o\exp\left(-\frac{Q_d}{RT}\right) \qquad \frac{C_x - C_o}{C_s - C_o} = 1 - erf\left(\frac{x}{2\sqrt{Dt}}\right)$$

$$\sigma_{mr} = \frac{3F_f L}{2bd^2} \qquad \sigma_{mr} = \frac{F_f L}{\pi R^3} \qquad \eta = \frac{F/A}{d\upsilon/dy} = \frac{\tau}{d\upsilon/dy}$$

Factor by Which Multiplied	*Prefix*
10^9	giga
10^6	mega
10^3	kilo
10^{-2}	centi[a]
10^{-3}	milli
10^{-6}	micro
10^{-9}	nano
10^{-12}	pico



IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
1 H 1.0080																	2 He 4.0026
3 Li 6.939	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.183
11 Na 22.990	12 Mg 24.312											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.064	17 Cl 35.453	18 Ar 39.948
19 K 39.102	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.91	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (99)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.91	56 Ba 137.34	Rare earth series	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.98	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	Acti-nide series															