	Marks
UNIVERSITY OF TORONTO FACULTY OF APPLIED SCIENCE AND ENGINEERING Test 1 – October 9, 2018 First Year APS110/164 – ENGINEERING CHEMISTRY AND MATERIALS SCIENCE Exam Type: A Examiners – CQ Jia, SD Ramsay Permissible Calculators: Casio FX-991 or Sharp EL-520 Rulers permitted. Duration: 90 minutes • All questions are NOT of equal value • Answer all questions on this exam • All numerical responses must be expressed in the most appropriate units, including appropriate prefixes (ex. GPa rather than 10^9 Pa), and be written with appropriate significant figures	***Part A:*** *(/10)* ***Part B:*** **1.***(/10)* **2.***(/10)* **3.***(/10)* **4.***(/10)* **TOTAL:** *(/50)*

Part B. Please enter the correct answer for the following questions on the computer answer form. (Each question is worth 1 mark)

1. Which of the following materials would you expect to have the lowest Young's modulus?

    a) The conductor in an extension cord
    b) A car tire
    c) A car window
    d) A car door

2. Steel is plastically deformed by being pulled through a die to form a wire that is used to make nails. Another piece of steel is melted and poured into a mold to form a bracket. Comparing the Young's modulus of the nail to that of the bracket, which is true?

    a) The nail has a Young's modulus of rougly 200 GPa, while the bracket has a Young's modulus closer to 150 GPa.
    b) Both the nail and the bracket have a Young's modulus close to 200 GPa;
    c) The nail has a Young's modulus of roughly 150 GPa, while the bracket has a Young's modulus closer to 200 GPa.
    d) None of the above are reasonable outcomes.

3. What are the units of stress?

    a) N/m^2
    b) Pa
    c) Neither of these
    d) Both a) and b)

4. For the interstitial site having coordination number of 8, the cation sits at the center of a ________, where the corners are occupied by anions.

    a) Triangle
    b) Octahedron
    c) Cube
    d) Tetrahedron

5. Which of the following are generally true of elastic behaviour?

    a) Permanent
    b) Atoms move to new equilibrium positions
    c) Neither a) nor b)
    d) Both a) and b)

6. The linear dimension describing the size of the unit cell is known as:

    a) The unit cell
    b) The crystal
    c) The Miller indices
    d) The lattice parameter

7. The atomic diameter of an atom of a FCC crystal, in terms of the lattice parameter a is:

    a) a
    b) $\frac{a}{2\sqrt{2}}$
    c) $\frac{\sqrt{3}a}{2}$
    d) $\frac{a}{\sqrt{2}}$

8. Which of the following has long-range order?

    a) Glass window
    b) Polyethylene teraphthalate soda bottle
    c) Rubber sole of a shoe
    d) Aluminum can

9. The atomic packing factor of a crystal structure is the ratio of:

    a) Volume occupied by atoms to that by voids
    b) Total volume of unit cell to volume occupied by particles
    c) Area occupied by atoms to total area of plane
    d) None of the above

10. The Young's modulus is related to which of the following?

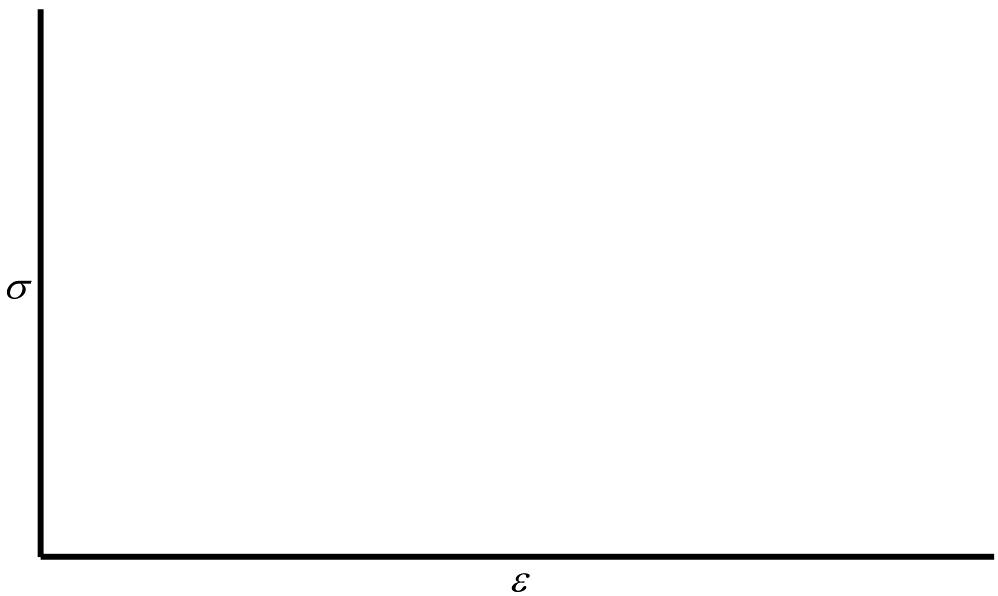
    a) The slope of the interatomic force separation curve taken at the equilibrium interatomic spacing
    b) The slope of the interatomic energy separation curve taken at the equilibrium interatomic spacing Region between the ultimate tensile strength and fracture
    c) The slope of the interatomic force separation curve taken at r=0
    d) Both a) and c)

Part B.

1. Show that the ratio of cation radius to anion radius for a coordination number of 8 is 0.732. (10)

2. This question pertains to the tensile test.
    a. Draw a typical metallic tensile specimen. On your sketch, identify the following features: grip region, reduced section, gauge length. (4)

    b. On the axes below, sketch the generalized stress strain curves for a metal, ceramic, and a polymer. (3)

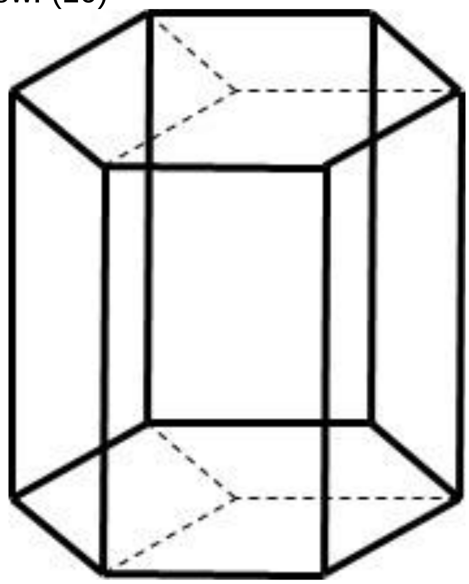


    c. Explain why, in the characterization of materials, engineering stress and engineering strain are used rather than force and elongation. (1)

    d. Provide two differences between elastic and plastic deformation. (2)

3. Strontium selenide ($SrSe$) forms the rock salt crystal structure and has a density of $4.54\ \frac{g}{cm^3}$. The radius of the selenium anion in this structure is 184 pm. Calculate the radius of the strontium cation in this structure, in pm. Note: 1 pm = 10^{-12} m. (10)

4. The volume of an HCP unit cell is $\frac{3\sqrt{3}}{2}a^2c$. Show that the atomic packing factor of the HCP crystal structure is 0.74. Begin by sketching the atom positions, as small dots, in the unit cell below. (10)



You may remove these pages from your test.

Constants

1 atm = 101.325 kPa = 1.01325 bar = 14.696 psi $N_A = 6.022 \times 10^{23}\ mol^{-1}$ $e = 1.602 \times 10^{-19}$ C

1 eV = 1.602×10^{-19} J $\varepsilon_0 = 8.854 \times 10^{-12}\ \frac{F}{m}$ $R = 8.314\ \frac{J}{mol\cdot K} = 0.082067 \frac{L\cdot atm}{mol\cdot K}$

$T_{(K)} = T_{(°C)} + 273.15$ $k = 8.62 \times 10^{-5}\ \frac{eV}{atom\cdot K}$ $k = 1.38 \times 10^{-23}\ \frac{J}{atom\cdot K}$ F = 96486 C·mol^{-1}

Microstructure

LD = $^{\#}/_{Length}$ $LPF = \frac{\text{length of atoms}}{\text{length of vector}}$ PD = $^{\#}/_{Area}$ $PPF = \frac{\text{area of atoms}}{\text{area of plane}}$ $V = \frac{4}{3}\pi r^3$

$A = \pi r^2$ $A_\Delta = \frac{1}{2}bh$ $\rho = \frac{n \cdot A}{V_C \cdot N_A}$ $\rho = \frac{m}{V}$ $\rho = \frac{n_A A_A + n_C A_C}{V_C N_A}$ $APF = \frac{V_S}{V_C}$

$N = \frac{N_A \rho}{A}$ $N_v = N \exp\left(-\frac{Q_v}{kT}\right)$ $a = 2\sqrt{2}R$ $a = \frac{4}{\sqrt{3}}R$

Mechanical Behaviour

$\sigma = \frac{F}{A}$ $\varepsilon = \frac{\Delta l}{l_o}$ $\sigma = E\varepsilon$ $\sigma_{3-point\ bend} = \frac{3FL}{2w\cdot h^2}$ $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Electrical Behaviour

$\sigma = n|e|\mu_e + h|e|\mu_h$ $\sigma = n|e|\mu_e$ $\sigma = h|e|\mu_h$

Thermodynamics

PV = nRT $\Delta U = q + w$ $\Delta U = q - P_{ext}\Delta V$ $H \equiv U + PV$ $G \equiv H - TS$ $\Delta S = \frac{q_{rev}}{T}$

For process at constant T: $\Delta G = \Delta H - T\Delta S$ $q = mc\Delta T = nC_p\Delta T$ $\Delta G = \Delta H - T\Delta S$

$W_{phase} = \frac{length\ of\ opposite\ side\ of\ lever}{total\ length\ of\ lever}$ For $aA + bB \rightarrow cC + dD$, $Q = \frac{a_C^c \cdot a_D^d}{a_A^a \cdot a_B^b}$

υ_i: stoichiometric coefficient Assuming no phase change, constant C_p:

$$\Delta H^\circ_{reaction} = (\Sigma \upsilon_i \Delta H^\circ_{f,i})_{products} - (\Sigma \upsilon_i \Delta H^\circ_{f,i})_{reactants}$$

$$\Delta S^\circ_{reaction} = (\Sigma \upsilon_i \Delta S^\circ_{m,i})_{products} - (\Sigma \upsilon_i \Delta H^\circ_{m,i})_{reactants}$$

$$\Delta G^\circ_{reaction} = \Delta H^\circ_{reaction} - T\Delta S^\circ_{reaction} \qquad \Delta G_{reaction} = \Delta G^\circ + RT lnQ$$

$$\Delta G^\circ = -RT lnK$$

Electrochemistry

$E = E^\circ - \frac{RT}{nF} lnQ$ $E = E^\circ - \frac{0.0592}{n} lnQ$, at 25°C $I = \frac{nC}{t}$ $w = nFE^\circ$

Key

29
Cu
63.54

29 — Atomic number
Cu — Symbol
63.54 — Atomic weight

Metal

Nonmetal

Intermediate

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															

Rare earth series	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
Actinide series	89 Ac (227)	90 Th 232.04	91 Pa (231)	92 U 238.03	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (249)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (254)	103 Lw (257)

STANDARD FORMATION ENTHALPY, STANDARD ENTROPY AND STANDARD FORMATION GIBBS ENERGY AT 298.15 K

Species	$\Delta_f H^\circ$ [kJ/mol]	S° [J/mol·K]	$\Delta_f G^\circ$ [kJ/mol]
C (s, graphite)	0	5.74	0
CH_4 (g)	-74.81	186.2	-50.75
C_2H_2 (g)	226.7	200.93	
C_3H_8 (g)	-103.8	269.9	-23.49
CaC_2 (s)	-59.8	70.3	
CaF_2 (s)	-1225	68.87	-1162
CaF_2 (l)	-1186	92.6	
$Ca(OH)_2$ (s)	-987.0	83.0	
CO_2 (g)	-393.5	213.6	-394.4
Cu_2O (s)	-168.6	93.1	
Cu_2O (l)	-154.79		
Cu (s)		33.2	
Fe (s)	0	27.3	0
Fe_2O_3 (s)	-824.2	87.4	
H_2O (g)	-241.8	188.7	-228.6
H_2O (l)	-285.8	69	
O_2 (g)	0	205.0	0

MISCELLANEOUS ENTHALPIES

Substance	**Reaction**	ΔH [kJ/mol]
F-F	Bond dissociation	157
F	Electron affinity F (g) $\rightarrow$ F^- (g)	-328
Ca	Second Ionization energy Ca (g) $\rightarrow$ Ca^{2+} (g)	1734

SPECIFIC HEATS AND HEAT CAPACITIES

Substance	**Specific Heat c** [J/g·K]	**Molar Heat Capacity C_p** [J/mol·K]
CO_2 (g)	0.843	37.1
H_2O (g)	2.03	36.4
H_2O (l)	4.184	75.3
H_2O (s)	2.09	37.7

TEMPERATURES AND ENTHALPIES OF PHASE CHANGES

Substance	**Melting Point** [°C]	$\Delta_{fus}H^\circ$ [kJ/mol]	**Boiling Point** [°C]	$\Delta_{vap}H^\circ$ [kJ/mol]
Al	658	10.6	2467	284
Ca	851	9.33	1487	162
CH_4	-182	0.92	-164	8.18
H_2O	0	6.01	100	40.7
Fe	1530	14.9	2735	354