First Name: _____

Last Name: _____

Student Number: _____

UNIVERSITY OF TORONTO FACULTY OF APPLIED SCIENCE AND ENGINEERING	**Marks**
	Part A: _(/15)_
Test 2 – November 13, 2018	**_Part B:_** **1.**_(/10)_
First Year	
APS110/164 – ENGINEERING CHEMISTRY AND MATERIALS SCIENCE	**2.**_(/10)_
	3._(/10)_
Exam Type: A	**4.**_(/10)_
Examiners – CQ Jia, SD Ramsay	
Duration: 90 minutes	
• Permissible Calculators: Casio FX-991 or Sharp EL-520 • Rulers permitted • 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	**TOTAL:** _(/55)_

Please indicate your tutorial section:

☐ MY 315, Mon 11 am – 1 pm, TUT/PRA 3 & 4, Shwetank Yadav, Kevin Ton

☐ MY 420, Tue 9 am – 11 am, TUT/PRA 6, Bojan Miljkovic

☐ MY 380, Tue 9 – 11 am, TUT/PRA 13 & 14 Charlie Katrycz, Monika Kim

☐ MY 360, Tue 10-12 noon, TUT/PRA 9 & 10, Thomas Dingle, Shunyao Wang, Sourojeet Chakraborty

☐ SF 3202, Tue 10-12 noon, TUT/PRA 11 & 12, Alexander Vadillo, Jae Jin Lee

☐ BA 2185, Wed 9-11 am, TUT/PRA5, Eric Nicholson

☐ SF 3201, Wed 9-11 am, TUT/PRA 7 & 8, Yiran Zou, Antoine Dumont

☐ MY 315, Wed 11 am -1 pm, TUT/PRA 1 & 2, An Gu

☐ MY 380, Thu 5-7 pm, TUT/PRA 15 & 16, William Huxter, Sasan Rezaei, Pedro Henrique

Please indicate your lecture section: ☐Jia   ☐Ramsay   ☐Online (APS164)

Part A. 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 is not an explanation for the use of the 0.2% offset yield strength?

    a) Yielding begins at the onset of necking, but this is difficult to determine objectively

    b) Yielding begins close to the proportional limit, but this is difficult to determine objectively

    c) Yielding refers to permanent deformation, but the beginning of permanent deformation is difficult to determine objectively

    d) Yielding begins when dislocations begin to move, but this is difficult to determine in common practice

2. Which of the following is not a correct explanation of a microstructure-property relationship in metals?

    a) Plastic deformation increases the grain boundary to volume ratio within a polycrystalline metal thereby increasing the number of obstacles to dislocation movement.

    b) Heating a metal for an extended period of time would be likely to cause grain growth.

    c) Adding impurity atoms into a metal at low concentrations so that the impurities form a solid solution will introduce lattice strain that will inhibit dislocation movement.

    d) Adding impurity atoms into a metal at higher concentrations so that the impurities form second phase particles will introduce obstacles to dislocation movement

3. Which of the following is not an example of a two-dimensional imperfection??

    a) Grain boundary
    b) Substitutional impurity
    c) Free surface
    d) Both a) and b)

4. Which of the following is not an example of a point defect?

    a) Interstitial impurity
    b) Vacancy
    c) Second phase
    d) All of the above

5. A Boltzmann distribution of particles evenly distributed over all possible energy states would most closely describe a system at what temperature?

   a) Infinitely high temperature
   b) Absolute zero
   c) A temperature below absolute zero
   d) None of the above

6. Which of the following polymers would you expect to have the highest melting temperature?

   a) High molecular weight polyvinyl chloride
   b) Low density medium molecular weight polypropylene
   c) Low density low molecular weight polyethylene
   d) Unable to predict

7. A cross-linked and amorphous polymer is likely to be:

   a) A thermoplastic
   b) A thermoset

8. Which of the following polymers is most likely to be high strength and brittle?

   a) A network polymer
   b) A low crystallinity and low molecular weight polymer
   c) An elastomer
   d) A highly branched polymer

9. An increase in temperature from 10°C to 45°C would be likely to cause which of the following changes to the mechanical behaviour of a polymer?

   a) Decrease in strength
   b) Decrease in elastic constant
   c) Increase in strain to fracture
   d) All of the above

10. The glass transition temperature is best described as which of the following?

   a) The minimum temperature required for the secondary bonds within the crystalline regions of a polymer to be overcome
   b) The minimum temperature required for the secondary bonds within the amorphous regions of a polymer to be overcome
   c) The minimum temperature required for the primary bonds within the crystalline regions of a polymer to be overcome
   d) The minimum temperature required for the primary bonds within the amorphous regions of a polymer to be overcome

11. The model of a polymer as a collection of strings is a useful model to explain all but which of the following properties?

    a) The strength of a polymer
    b) The melting point of a polymer
    c) The color of an amorphous polymer
    d) The resistance to being dissolved in a solvent

12. Which of the following are correct explanations of the optical behaviour of a polymer?

    a) Sapphire is single crystal Al_2O_3 and is ionic and therefore has a high band gap and no internal scattering events and is therefore transparent
    b) Polymethylmethacrylate has a large group on the mer unit that prevents crystallization, therby avoiding any internal scattering events within the polymer and allowing it to be transparent
    c) Both a) and b)
    d) Neither a) nor b)

13. Which of the following would be most likely to cause cross-linking of a polymer?

    a) Radio frequency radiation
    b) Microwave radiation
    c) X-ray radiation
    d) Gamma radiation

14. Which of the following is the correct electronic configuration for a neutral atom of Sc^{3+}?

    a) [Ar]
    b) [Kr] $4d^1$
    c) [Kr] $3d^1$
    d) [Kr] $3d^14s^1$

15. What type of bonding is present in carbon in the diamond cubic crystal structure?

    a) Ionic
    b) Covalent
    c) Metallic
    d) Mixed ionic and covalent

Part B.
1. (10) On the axes below, sketch generalized stress-strain curves for a typical ductile metal as well as a plastic polymer.
   a. On the curve for the metal identify the following points or regions:
      i. Yield strength
      ii. Ultimate tensile strength
      iii. Fracture strength
      iv. Linear elastic region
      v. Uniform elastic deformation
      vi. Uniform plastic deformation
      vii. Non-uniform plastic deformation
      viii. Onset of necking
   b. On the curve for the polymer identify the following points or regions
      i. Yield strength
      ii. Tensile strength

σ

ε
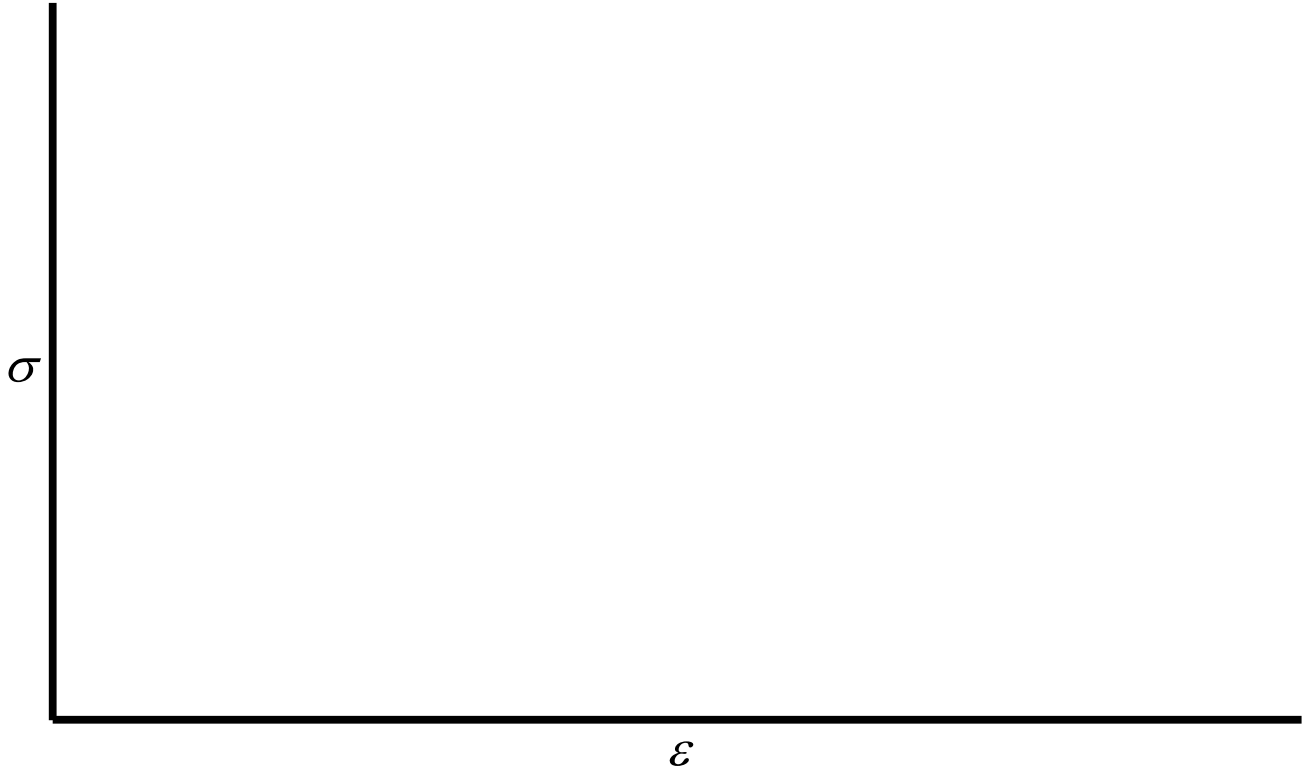
2. (10) This question pertains to the band theory of solids.
   a. (3) In the space below, sketch a graph of the allowable energy levels for the 4s electron in potassium K, as a function of the number of atoms in a solid. Begin with one atom of the left and move to a mole of atoms on the right.

   b. (5) Sketch and label the band diagram for potassium and based on the band diagram explain whether you expect it to be electrically conductive or insulating.

   c. (2) Again, based on the band structure in part b. explain what you would expect the optical properties of potassium to be.

3. (10) Germanium Ge, is used as a semiconducting material. It may be doped with gallium Ga. Assume a sample of Ge is doped with Ga at a concentration of 10^{16} cm^{-3}, gallium atoms are assumed to be ionized (i.e., one charge carrier exists for each gallium atom). The electron and hole mobilities are 3900 cm^2/Vs and 1900 cm^2/Vs, respectively.

   a. (3) Explain whether this is an intrinsic or extrinsic semiconductor and if appropriate, whether p or n-type.

   b. (3) Estimate the electrical conductivity of this material.

   c. (4) Using a band diagram, please sketch the generalized band structure of this semiconductor and label all important features.

4. (10) This question pertains to crystalline imperfections. Please provide a sketch of each of the following types of crystalline imperfection. For each imperfection explain how the imperfection may increase, decrease or have no effect on the strength of a metal.

    a. (2) Interstitial impurity

    b. (2) Substitutional impurity (solute atom larger than solvent)

    c. (2) Dislocation

    d. (2) Grain boundary

    e. (2) A hypothetical material with a rock salt second phase within a simple square lattice of atoms

Constants

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

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

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

Microstructure

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

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

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

Mechanical Behaviour

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

Electrical Behaviour

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

Thermodynamics

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

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

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

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

$$\Delta H°_{reaction} = (\Sigma v_i \Delta H°_{f,i})_{products} - (\Sigma v_i \Delta H°_{f,i})_{reactants}$$

$$\Delta S°_{reaction} = (\Sigma v_i \Delta S°_{m,i})_{products} - (\Sigma v_i \Delta H°_{m,i})_{reactants}$$

$$\Delta G°_{reaction} = \Delta H°_{reaction} - T\Delta S°_{reaction} \quad\quad \Delta G_{reaction} = \Delta G° + RT\ln Q$$

$$\Delta G° = -RT\ln K$$

Electrochemistry

$$E = E° - \frac{RT}{nF}\ln Q \quad\quad E = E° - \frac{0.0592}{n}\ln Q, \text{ at } 25°C \quad\quad I = \frac{nC}{t} \quad w = nFE°$$

Key

29
Cu
63.54

29 — Atomic number
Cu — Symbol
63.54 — Atomic weight

Metal (white) · Nonmetal (shaded) · Intermediate (diagonal)

IA	IIA	IIIB	IVB	VB	VIB	VIIB	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)	Actinide 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	$\Delta_f H°$ [kJ/mol]	$S°$ [J/mol·K]	$\Delta_f G°$ [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]	$\Delta_{fus} H°$ [kJ/mol]	Boiling Point [°C]	$\Delta_{vap} H°$ [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