Tutorial Section Number:

UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

Q1	/20
Q2	/20
Q3	/17
Q4	/18
Q5	/20
Total	/95

TERM TEST 1

7 FEBRUARY 2013

First Year

APS 104S

INTRODUCTION TO MATERIALS AND CHEMISTRY

Exam Type B

Examiners: T. Bender, N. P. Kherani, T. Mirkovic

NAME: ____

Last First

STUDENT NO:____

INSTRUCTIONS:

- This is a Type B examination. Only non-programmable calculators are allowed.
- Answer all 5 questions.
- All work is to be done on the pages of this booklet.
- When answering the questions **include all the steps** of your work on these pages and then **fill the answer in** the respective **boxes**. For additional space, you may use the back of the preceding page.
- Do not unstaple this exam booklet.
- A Formula Sheet and the periodic table are attached to the end of this exam booklet; if you wish, you may tear-off these sheets *only*.

Name: ________________________________ *Student No:* __________________________

QUESTION 1: *Atomic and Molecular Bonding (20 pts)*

(a) Write the electron configuration for Mg^{2+}. [**2 pts**]

(b) Write the electronic configuration for Ti^0. **[2 pts]**

(c) Determine the precent ionic character (%IC) of the N-H bond in ammonia(NH_3).
Given: EN (X_N) (nitrogen) =3.04 EN (X_H) (hydrogen) = 2.20 [**3 pts**]

%IC =

(d) Name the type of bonding present in each of these materials between adjacent atoms (i.e. either covalent, polar covalent, ionic or metallic): **[5 pts]**

Ammonia: ______________________________

Si_3N_4: ______________________________

Fe: ______________________________

KBr: ______________________________

Water: ______________________________

(e) The function below is given for N_2 , where the constants are: A = 1.34×10^{-5} J pm^6 and B = 3.42×10^{10} J pm^{12}. [**8 pts**]

$$E = -\frac{A}{r^6} + \frac{B}{r^{12}}$$

Calculate the equilibrium separation $\boldsymbol{r_o}$ for the nitrogen molecule. *Note*: 1 pm = 10^{-12} m

r_o =

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QUESTION 2: *Molecular Theory of Gases (20 pts)*

Part I

(a) Define an open, closed and isolated system in terms of what can and cannot be removed from the system. **(6 pts)**

(b) A boundary of a system can be considered diathermic if it (circle the correct answer): **(1 pt)**

(i) allows the movement of heat.

(ii) does not allow the movement of heat.

(c) Pressure is created when (circle the correct answer): (**1 pt**)

(i) liquid molecules collide with the physical boundary of a container.

(ii) gas molecules collide with the physical boundary of a container.

(iii) gas molecules collide with one another within the boundaries of a container.

(iv) gas molecules interact with one another through secondary bonding interactions.

Part II

(a) 10 g of ethane (C_2H_6) gas is introduced into a 10 L (10 L = 10 dm^3) pressure vessel at 25 °C. **(4 pts)**

(i) assuming ideal gas behavior calculate the pressure in the vessel.

P =

(ii) assuming Van der Waals gas behavior calculate the pressure in the vessel (a = 5.507 atm dm^6 mol^{-1}; b = 6.51 x 10^{-2} dm^3 mol^{-1})

P =

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(b) Calculate the amount (mass and number of moles) of oxygen needed to burn all the ethane according to the following balanced chemical equation: $C_2H_6 + \frac{7}{2} O_2 \rightarrow 2\ CO_2 + 3\ H_2O$ **(2 pts)**

mass =
no of moles =

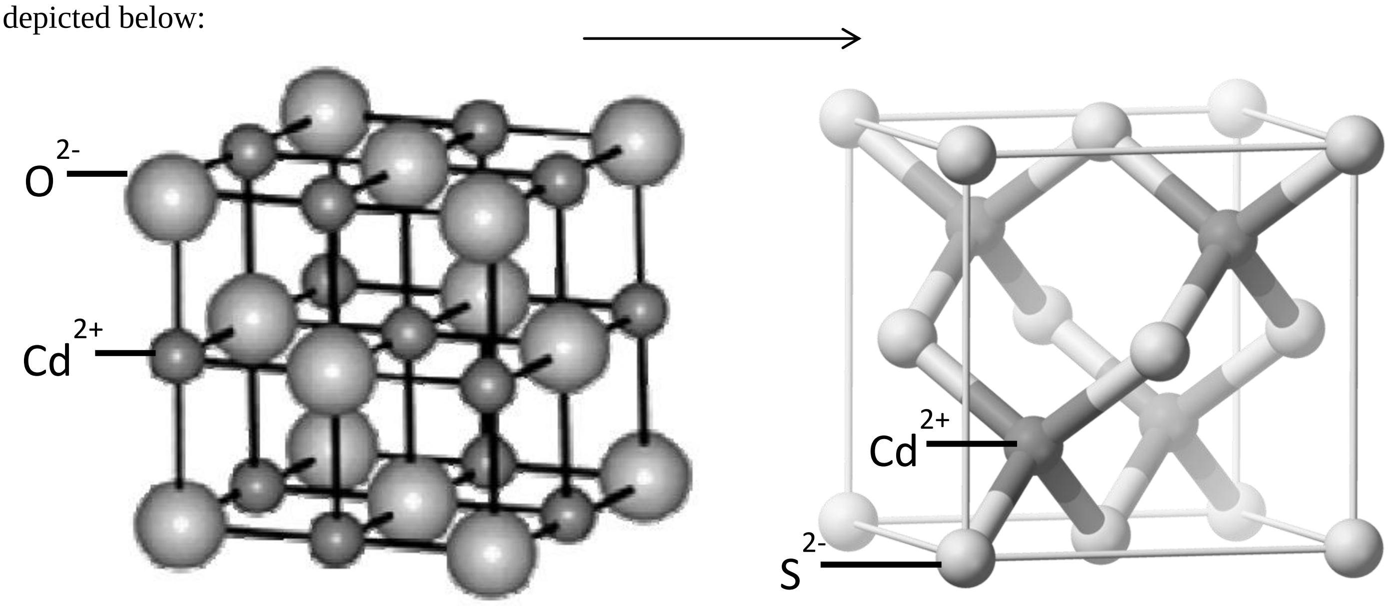
(c) You are told that the chemical reaction in part (II-b) takes place completely. Calculate the final pressure in the vessel assuming the following: ideal gas behavior, the temperature rises to 100 °C which is maintained, and that the water remains in the gaseous state. **(6 pts)**

P =

Name: ________________________________ *Student No:* __________________________

QUESTION 3: *Crystal Structures and Density (17 pts)*

When cadmium oxide (CdO) reacts to form cadmium selenide (CdS), a change in the unit cell occurs, as depicted below:



(a) What is the crystal structure of CdO? ____________________ **[1pt]**

What is the crystal structure of CdS? ____________________ **[1pt]**

(b) What positions do Cd^{2+} ions occupy within the framework of the anions?

In CdO: _________________ **[1pt]** In CdS: _________________ **[1pt]**

(c) What is the coordination number of Cd^{2+} in CdO and CdSe?

In CdO: _________________ **[1pt]** In CdS: _________________ **[1pt]**

(d) Would you expect Cd^{2+} to have a bigger radius in CdO or in CdS? **[1 pt]**

(e) What is the volume of the CdO unit cell in cm^3, given that**:** **[2 pts]**
$r(O^{2-})$ = 140 pm and $r(Cd^{2+})$ = 95 pm.

vol =

(f) What is the density of CdO. **[4 pts]**

ρ =

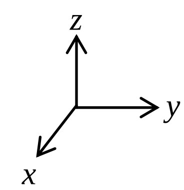
(g) Calculate the atomic packing factor of the CdO unit cell. **[4 pts]**

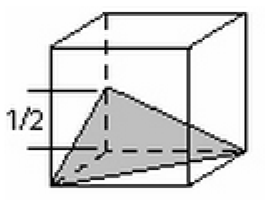
APF =

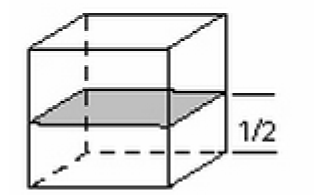
Name: ______________________________ *Student No:* ______________________________

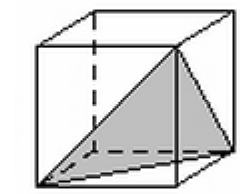
QUESTION 4: *Directions, Planes and Densities (18 pts)*

A. Find the Miller indices for the planes shown in the diagrams below. **(6 pts)**



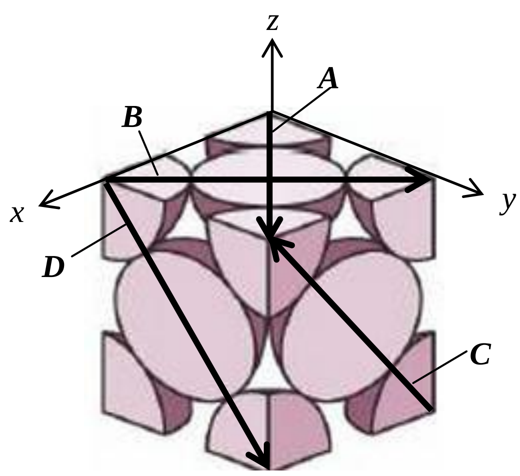






__________ __________ __________

B. Determine the indices of the crystallographic directions (***A***, ***B***, ***C***, and ***D***) illustrated below. **(6 pts)**



A: ( )

B: ( )

C: ( )

D: ( )

C. For the FCC crystal lattice shown in part B, determine the following:

(a) Linear atomic density for the crystallographic direction ***D***. **(2 pts)**

LD =

(b) Planar atomic density for the (001) plane. **(4 pts)**

PD =

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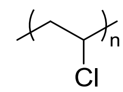
QUESTION 5: *Polymers (20 pts)*

(a) The following table lists molecular weight data for a sample of polyvinylchloride.



Molecular Weight Range (g/mol)	x_i	w_i
8,000–16,000	0.05	0.02
16,000–24,000	0.16	0.10
24,000–32,000	0.24	0.20
32,000–40,000	0.28	0.30
40,000–48,000	0.20	0.27
48,000–56,000	0.07	0.11

Calculate:

(i) the number-average molecular weight. **(5 pts)**

(ii) the weight-average molecular weight. **(5 pts)**

(iii) and the degree of polymerization. **(3 pts)**

(b) Sketch a picture illustrating the molecular arrangement of any two of the following polymeric molecular structures: *Linear*, *Branched*, *Cross-linked*, *Network* **(2 pts)**

(c) Draw the repeat units for the polymers named below. **(5 pts)**

polyethylene polytetrafluoroethylene polypropylene

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FORMULAE & CONSTANTS *(You may tear this sheet off.)*

Constants

R = 8.3145 J·K^{-1} mol^{-1} = 0.0820574587 L·atm· K^{-1} mol^{-1} = 0.083145 L·bar·K^{-1}·mol^{-1}
1 atm = 101.325 kPa = 1.01325 bar= 14.696 psi = 760 Torr = 760 mmHg
N_A = 6.022 x 10^{23} mol^{-1} k = 8.62 x 10^{-5} eV/K 1 eV = 1.60 x 10^{-19} J
T(K) = T(^{o}C) + 273.15 K;
STP: 273.15K, 1 bar ***SATP***: 298.15K, 1 bar

Formulae from Callister

$$V=\frac{4\pi\ r^3}{3} \quad \rho=\frac{m}{V} \quad \rho=\frac{nA}{V_C N_A} \quad \rho=\frac{n'(\Sigma A_C+\Sigma A_A)}{V_C N_A} \quad \%IC=\{1-\exp[-0.25(X_A-X_B)^2]\}\times 100$$

$$E=\int F\,dr \quad \frac{d}{dx}(x^n)=nx^{n-1}$$

$$APF=\frac{TotalSphereVolume}{TotalUnitCellVolume} \quad LD=\frac{NumberOfAtomsCentredOnDirectionVector}{LengthOfDirectionVector}$$

$$PD=\frac{NumberOfAtomsCentredOnAPlane}{AreaOfPlane} \quad DP=\frac{\overline{M_n}}{m} \quad \overline{M_n}=\sum x_i M_i \quad \overline{M_w}=\sum w_i M_i$$

$$N_V=N\exp(-\frac{Q_v}{kT}) \quad N_S=N\exp(-\frac{Q_S}{2kT}) \quad N_{fr}=N\exp(-\frac{Q_{fr}}{2kT})$$

$$E=\frac{\sigma}{\varepsilon} \quad \sigma=\frac{F}{A} \quad \epsilon=\frac{\Delta l}{l} \quad \tau=\frac{F}{A} \quad \tau=G\gamma \quad U_r=\frac{1}{2}\sigma_Y\varepsilon_Y \quad \%CW=\left(\frac{A_0-A_d}{A_0}\right)\times 100 \quad G=E/(2(1+\nu))$$

$$\sigma_y=\sigma_0+k_y d^{-1/2} \quad \nu=-\frac{\epsilon_x}{\epsilon_z}=-\frac{\epsilon_y}{\epsilon_z} \quad \tau_R=\sigma\cos\phi\cos\lambda \quad \sigma_y=\frac{\tau_{crss}}{(\cos\phi\cos\lambda)_{max}} \quad V=IR \quad \rho=\frac{RA}{l}$$

$$\sigma=\frac{1}{\rho} \quad J=\sigma E \quad E=\frac{V}{l} \quad v_d=\mu_e E \quad \sigma=n|e|\mu_e \quad \theta=\cos^{-1}\left(\frac{u_1 u_2+v_1 v_2+w_1 w_2}{\sqrt{(u_1^2+v_1^2+w_1^2)(u_2^2+v_2^2+w_2^2)}}\right)$$

Formulae from Engel & Reid

Idea gas equation of state: $PV=nRT$

Van der Waals equation of state: $P=\frac{nRT}{(V-nb)}-\frac{an^2}{V^2}$

Name: ______________________________ *Student No:* ______________________________

You may tear this sheet off.

PERIODIC TABLE OF THE ELEMENTS

http://www.ktf-split.hr/periodni/en/

GROUP NUMBERS IUPAC RECOMMENDATION (1985) — 13; GROUP NUMBERS CHEMICAL ABSTRACT SERVICE (1986) — IIIA

ATOMIC NUMBER — 5; RELATIVE ATOMIC MASS (1) — 10.811; SYMBOL — B; ELEMENT NAME — BORON

PERIOD	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.0079 **H** HYDROGEN																	2 4.0026 **He** HELIUM
2	3 6.941 **Li** LITHIUM	4 9.0122 **Be** BERYLLIUM											5 10.811 **B** BORON	6 12.011 **C** CARBON	7 14.007 **N** NITROGEN	8 15.999 **O** OXYGEN	9 18.998 **F** FLUORINE	10 20.180 **Ne** NEON
3	11 22.990 **Na** SODIUM	12 24.305 **Mg** MAGNESIUM											13 26.982 **Al** ALUMINIUM	14 28.086 **Si** SILICON	15 30.974 **P** PHOSPHORUS	16 32.065 **S** SULPHUR	17 35.453 **Cl** CHLORINE	18 39.948 **Ar** ARGON
4	19 39.098 **K** POTASSIUM	20 40.078 **Ca** CALCIUM	21 44.956 **Sc** SCANDIUM	22 47.867 **Ti** TITANIUM	23 50.942 **V** VANADIUM	24 51.996 **Cr** CHROMIUM	25 54.938 **Mn** MANGANESE	26 55.845 **Fe** IRON	27 58.933 **Co** COBALT	28 58.693 **Ni** NICKEL	29 63.546 **Cu** COPPER	30 65.39 **Zn** ZINC	31 69.723 **Ga** GALLIUM	32 72.64 **Ge** GERMANIUM	33 74.922 **As** ARSENIC	34 78.96 **Se** SELENIUM	35 79.904 **Br** BROMINE	36 83.80 **Kr** KRYPTON
5	37 85.468 **Rb** RUBIDIUM	38 87.62 **Sr** STRONTIUM	39 88.906 **Y** YTTRIUM	40 91.224 **Zr** ZIRCONIUM	41 92.906 **Nb** NIOBIUM	42 95.94 **Mo** MOLYBDENUM	43 (98) **Tc** TECHNETIUM	44 101.07 **Ru** RUTHENIUM	45 102.91 **Rh** RHODIUM	46 106.42 **Pd** PALLADIUM	47 107.87 **Ag** SILVER	48 112.41 **Cd** CADMIUM	49 114.82 **In** INDIUM	50 118.71 **Sn** TIN	51 121.76 **Sb** ANTIMONY	52 127.60 **Te** TELLURIUM	53 126.90 **I** IODINE	54 131.29 **Xe** XENON
6	55 132.91 **Cs** CAESIUM	56 137.33 **Ba** BARIUM	57-71 **La-Lu** Lanthanide	72 178.49 **Hf** HAFNIUM	73 180.95 **Ta** TANTALUM	74 183.84 **W** TUNGSTEN	75 186.21 **Re** RHENIUM	76 190.23 **Os** OSMIUM	77 192.22 **Ir** IRIDIUM	78 195.08 **Pt** PLATINUM	79 196.97 **Au** GOLD	80 200.59 **Hg** MERCURY	81 204.38 **Tl** THALLIUM	82 207.2 **Pb** LEAD	83 208.98 **Bi** BISMUTH	84 (209) **Po** POLONIUM	85 (210) **At** ASTATINE	86 (222) **Rn** RADON
7	87 (223) **Fr** FRANCIUM	88 (226) **Ra** RADIUM	89-103 **Ac-Lr** Actinide	104 (261) **Rf** RUTHERFORDIUM	105 (262) **Db** DUBNIUM	106 (266) **Sg** SEABORGIUM	107 (264) **Bh** BOHRIUM	108 (277) **Hs** HASSIUM	109 (268) **Mt** MEITNERIUM	110 (281) **Uun** UNUNNILIUM	111 (272) **Uuu** UNUNUNIUM	112 (285) **Ub** UNUNBIUM		114 (289) **Uuq** UNUNQUADIUM				

LANTHANIDE

Period															
6	57 138.91 **La** LANTHANUM	58 140.12 **Ce** CERIUM	59 140.91 **Pr** PRASEODYMIUM	60 144.24 **Nd** NEODYMIUM	61 (145) **Pm** PROMETHIUM	62 150.36 **Sm** SAMARIUM	63 151.96 **Eu** EUROPIUM	64 157.25 **Gd** GADOLINIUM	65 158.93 **Tb** TERBIUM	66 162.50 **Dy** DYSPROSIUM	67 164.93 **Ho** HOLMIUM	68 167.26 **Er** ERBIUM	69 168.93 **Tm** THULIUM	70 173.04 **Yb** YTTERBIUM	71 174.97 **Lu** LUTETIUM

ACTINIDE

Period															
7	89 (227) **Ac** ACTINIUM	90 232.04 **Th** THORIUM	91 231.04 **Pa** PROTACTINIUM	92 238.03 **U** URANIUM	93 (237) **Np** NEPTUNIUM	94 (244) **Pu** PLUTONIUM	95 (243) **Am** AMERICIUM	96 (247) **Cm** CURIUM	97 (247) **Bk** BERKELIUM	98 (251) **Cf** CALIFORNIUM	99 (252) **Es** EINSTEINIUM	100 (257) **Fm** FERMIUM	101 (258) **Md** MENDELEVIUM	102 (259) **No** NOBELIUM	103 (262) **Lr** LAWRENCIUM

(1) Pure Appl. Chem., 73, No. 4, 667-683 (2001)
Relative atomic mass is shown with five significant figures. For elements have no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.
However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

Editor: Aditya Vardhan (adivar@nettlinx.com)