UNIVERSITY OF TORONTO

TUT 01	
TUT 02	
TUT 03	
TUT 04	
TUT 05	
TUT 06	
TUT 07	
TUT 08	
TUT 09	
TUT 10	
TUT 11	
TUT 12	

FACULTY OF APPLIED SCIENCE AND ENGINEERING

TERM TEST 2

17 MARCH 2015

First Year

APS 104S

INTRODUCTION TO MATERIALS AND CHEMISTRY

Exam Type B

Examiners: G. Azimi, C Chin, T. Mirkovic, J. Nogami

NAME: _____
　　　　Last　　　　　　First

STUDENT NO:_____

Q1	/20
Q2	/20
Q3	/20
Q4	/20
Q5	/20
Total	/100

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*.

- Exam papers filled out in pencil **will not be eligible for regrading**.

QUESTION 1: Ideal Gas Law (20 pts)

20 g of propane (C_3H_8) is in a 2 L container at 25°C.

a) what is the pressure in the container (in atm), assuming that propane behaves like an ideal gas ?
[2 pts]

b) assuming Van der Waals behavior, recalculate the pressure (a = 9.39 L^2 atm mol^{-1} and b=0.0905 L/mol) [4 pts]

c) calculate the exact number of moles of oxygen needed to burn all the propane according to:

$$C_3H_8 + 5O_2 = 3CO_2 + 4H_2O \ (g)$$ [2 pts]
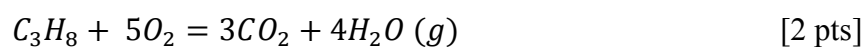
   d) If we add the exact number of moles of O_2 from part c) into the same 2L container, and assuming the reaction in part 1c) takes place completely, calculate the final pressure in the vessel assuming:

- ideal gas behavior
- the temperature rises to 150°C
- water remains as water vapor   [5 pts]

   e) recalculate the answer in part d) if you start with only half the amount of oxygen calculated in part c), and also calculate (in addition to the total pressure) the partial pressures and mole fractions of all the remaining gasses. [7 pts]

QUESTION 2: First Law of Thermodynamics (20 pts)

A quantity of 0.45 mol of neon is confined in a container at 3.5 atm and 298 K and then allowed to expand under three different conditions.

(a) In the first process, the gas expands adiabatically and reversibly to 1.00 atm. Calculate the <u>final temperature</u> and the <u>work done</u>. [**6 pts**]

(b) In the second process, the gas expands adiabatically against a constant pressure of 1.00 atm. Calculate the final temperature and the work done. [**6 pts**]

(a) In the third process, the gas expands isothermally and reversibly until its volume reaches the same value as the final volume in part (a). Determine the value of the final volume and the final pressure of this reversible isothermal expansion. [**4 pts**]

(d) On a P-V diagram, sketch the paths described in (a) and (c). In which process was more work performed? On the diagram, shade the area that represents the difference in the work done in process (a) and process (c) [**4 pts**]

Name: _____   Student No: _____

(a) The density of liquid water at 100℃ is 0.9584 g/cm^3, and that of steam at the same temperature is 0.000596 g/cm^3. If the enthalpy of evaporation of water at atmospheric pressure is 40.63 kJ/mol, what is ΔU? How much work is done by the system during the evaporation process? Hint: Consider calculating molar volumes first. [**5 pts**]

(b) Would you expect for the fusion process (ice to water) the difference between ΔU and ΔH to be larger or smaller than the one calculate in (a) for the vaporization process? Explain. [**3 pts**]

(c) How much heat is required to heat 2 moles of water (ice at -10℃) to gasous water vapour at 110℃? Sketch the process on a temperature vs heat graph. [**6 pts**]
Given: ΔH$_{fusion}$=6. 01 kJ/mol, ΔH$_{vapourization}$= 40.67 kJ/mol,

$\overline{C_P}^{ice} = 2.11 J/gK$ $\overline{C_P}^{water} = 4.18 J/gK$ $\overline{C_P}^{vapour} = 2.08 J/gK$

(d) A chunk of ice at 270 K, weighing 30 grams, is dropped into 300 g of liquid water at 300 K. Determine the final temperature of the system once equilibrium has been reached. Use any constants that you need from parth (c). [**6 pts**]

Question 4: Thermochemistry

A table (4.1) with thermodynamic data is provided. The heat of combustion for formaldehyde (CH_2O) is -233 kJ (mol^{-1} CH_2O) at the standard state (298.15 K, 1 bar, products and reactants are both in the gas phase).

a) Determine the heat of formation for formaldehyde (CH_2O) at standard state. [5 pts]

b) The heat of reaction for the reverse Water-Gas-Shift reaction (298.15 K, 1 bar) is:

CO_2 (g) +H_2(g) → H_2O (l) +CO (g) $\Delta H^0_{RXN} = -288$ kJ (mol^{-1})
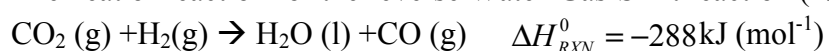
Determine the heat of reaction for the following reaction at standard state:
CH_2O (g) → CO (g) +H_2(g)
Show your work. [5 pts]
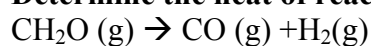
c) Determine the heat of combustion **(in kJ (mol^{-1} CH_2O))** for formaldehyde at 500 K. [4 pts]

d) Using Bond Enthalpy Table (Bond Dissociation Energies for the various bonds listed below), estimate the heat of reaction for the following reaction at the standard state. [4 pts]
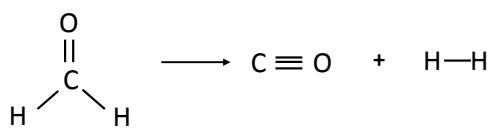
e) The heat capacity for CO_2 (liquid) is HIGHER   LOWER   than CO_2(gas) (circle one) [2 pts]

Table 4.1 Thermodynamic Data

	Heat of formation at standard state, $\Delta H_f^0 (kJmol^{-1})$ 298.15 K, 1 bar	Heat Capacity at constant pressure, $C_P (Jmol^{-1}K^{-1})$ *independent of temperature
CO_2 (g)	-108	37
H_2O (g)	-241	33
H_2O (l)	-286	75
O_2 (g)	0	29
CH_2O	Not given for this problem	34
H_2 (g)	0	

Table 9.2 Average Bond Energies (kJ/mol)

Bond	Energy	Bond	Energy	Bond	Energy	Bond	Energy
Single Bonds							
H—H	432	N—H	391	Si—H	323	S—H	347
H—F	565	N—N	160	Si—Si	226	S—S	266
H—Cl	427	N—P	209	Si—O	368	S—F	327
H—Br	363	N—O	201	Si—S	226	S—Cl	271
H—I	295	N—F	272	Si—F	565	S—Br	218
		N—Cl	200	Si—Cl	381	S—I	~170
C—H	413	N—Br	243	Si—Br	310		
C—C	347	N—I	159	Si—I	234	F—F	159
C—Si	301					F—Cl	193
C—N	305	O—H	467	P—H	320	F—Br	212
C—O	358	O—P	351	P—Si	213	F—I	263
C—P	264	O—O	204	P—P	200	Cl—Cl	243
C—S	259	O—S	265	P—F	490	Cl—Br	215
C—F	453	O—F	190	P—Cl	331	Cl—I	208
C—Cl	339	O—Cl	203	P—Br	272	Br—Br	193
C—Br	276	O—Br	234	P—I	184	Br—I	175
C—I	216	O—I	234			I—I	151
Multiple Bonds							
C=C	614	N=N	418	C≡C	839	N≡N	945
C=N	615	N=O	607	C≡N	891		
C=O	745	O_2	498	C≡O	1070		
	(799 in CO_2)						

Question 5: Entropy

i) In a process taking place inside a system, 1.5 mole of a monoatomic ideal gas is expanded adiabatically from 500°C and 5 bar to a final pressure of 2 bar. Calculate ΔS_{system}, $\Delta S_{surroundings}$, and $\Delta S_{universe}$ for the following conditions:

   a) if the process is reversible; [3 pts]

   b) if the process is irreversible and expansion is made against vacuum. [4 pts]

   c) if the process is irreversible and the work produced is 6000 J; [4 pts]

ii) Are the following statements true or false? [4 pts]
   Check one
   T   **F**

   ☐   ☐   The entropy of a system cannot increase in any adiabatic process.

   ☐   ☐ ΔS (universe) for melting ice to water at 0 °C is ZERO.

   ☐   ☐   It is possible to have the efficiency of the Carnot cycle equal to "1".

   ☐   ☐   In a process, «graphite» is transformed to «diamond». ΔS for this process is negative.

iii)

    a) Calculate the change in the entropy when 20 g of solid mercury (Hg(s)) at -50°C and 1 bar transforms to gaseous mercury at its boiling point. Below are the required thermodynamic data (specific heat capacities, $C_{p,m}$, are independent of temperature): [3 pts]

$\Delta H_{fusion} = 2.33$ kJ/mol

$\Delta H_{vaporization} = 59.11$ kJ/mol

$C_{p,m\ Hg(s)} = 28.2$ J/mol.K

$C_{p,m\ Hg(liq)} = 27.9$ J/mol.K

Melting temperature = -39°C

Boiling temperature = 357°C

    b) Using the thermodynamic data provided in part (a), sketch a qualitative graph of the molar entropy of mercury (Hg) as a function of temperature in the range of 0 to 700 K at constant pressure. [2 pts]

Name: _____   Student No: _____

FORMULAE & CONSTANTS *(You may tear these sheets off.)*

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   F = 9.6485309 × 10^4 C mole^{-1} e = 1.60217733 × 10^{-19} C
STP: 273.15K, 1 atm   ***SATP***: 298.15K, 1 bar   1L atm = 101.325 J

Idea gas equation of state: $PV = nRT$
Van der Waals equation of state:

$$P = \frac{nRT}{(V-nb)} - \frac{an^2}{V^2}$$

First law, closed systems
$\Delta U = q + w$ $dU = dq + dw$
$dw = -P_{ext}dV$
$dU = nC_{v,m}dT$

$H \equiv U + PV$
$dH = nC_{p,m}dT$
For ideal gases, $C_{p,m} = C_{v,m} + R$
Solids, Liquids, $C_{p,m} = C_{v,m}$
$G \equiv H - TS$

$$dS \equiv \frac{dQ_{reversible}}{T}$$

For a process at constant temperature
$\Delta G = \Delta H - T\Delta S$

For an isothermal reversible process (ideal gas):

$$W_{rev} = -\int_{V_1}^{V_2} \frac{nRT}{V}dV = -nRT\ln\frac{V_2}{V_1} = -nRT\ln\frac{P_1}{P_2}$$

Adiabatic reversible process (ideal gas):

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$
$T_1V_1^{(\gamma-1)} = T_2 V_2^{(\gamma-1)}$ $T_1 P_1^{[(1-\gamma)/\gamma]} = T_2 P_2^{[(1-\gamma)/\gamma]}$ $\left(\dfrac{\overline{C_P}}{\overline{C_V}}\right) = \gamma$

υ_i: stoichiometric coefficient
Assuming no phase change, constant C_p
$\Delta H°_{rxn} = \Sigma\upsilon_i * \Delta H°_{f,i} + \Delta C_p*(T-25°C)$
$\Delta C_p = \Sigma\upsilon_i * C_{p,i}$

Efficiency = $|w|/q_{in}$

ε(ideal) = $1 - T_C/T_H$

For solids or liquids:

Phase transition $\Delta S_{trans} = \dfrac{\Delta H_{trans}}{T_{trans}}$

$\Delta S°(T_2) = \Delta S°(T_1) + \int_{T_1}^{T_2}\Delta C_p \dfrac{dT}{T}$

Standard entropy of the reaction $\Delta S°_{rxn} = \Sigma\upsilon_i * S_m°_i$

$\Delta S = nR\ln\dfrac{V_f}{V_i}$ (isothermal)

$\Delta S = nC_V\ln\dfrac{T_f}{T_i}$ (change in T at const V)

$\Delta S = nC_p\ln\dfrac{T_f}{T_i}$ (change in T at const P)

$$\Delta S = n\overline{C_p}\ln\left(\frac{T_2}{T_1}\right) - nR\ln\left(\frac{P_2}{P_1}\right)$$

$$\Delta S = n\overline{C_v}\ln\left(\frac{T_2}{T_1}\right) + nR\ln\left(\frac{V_2}{V_1}\right)$$

$$\frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{-R/\overline{C_v}}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{R/\overline{C_p}}$$

Name: _____   Student No: _____

PERIODIC TABLE OF THE ELEMENTS

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

GROUP NUMBERS
IUPAC RECOMMENDATION (1985)

GROUP NUMBERS
CHEMICAL ABSTRACT SERVICE (1986)

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

GROUP	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	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) Uub UNUNBIUM		114 (289) Uuq UNUNQUADIUM				

LANTHANIDE

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

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)