Name: Student #:

VERSION A
CH110/120 – Fundamentals of Chemistry/Introductory Chemistry
Midterm #1

Friday, November 13th, 2015
5:30-6:45 pm
Instructor: Dr. Louise Dawe

Instructions:

Multiple choice:

1. On your IFAT card, write your student number where it says Subject

2. On this paper test, mark your first (and second, and third) answers. Your IFAT card will not be returned, but this paper test will, and you might want a record of your answers for later study.

3. On your IFAT card, scratch your selection. A star will identify the correct answer
    - Star can be anywhere in the box, not just the middle!
    - Little scratches count as an attempt
    - Be careful to keep your place if you skip questions!
    - Scratch with care to avoid tearing the form
    - Plastic (ID cards) seems to be gentler than metal (coins)

4. Each multiple choice is worth 1 point. If you get a question wrong (no star where you scratch), go back and re-read the questions and try again
    - If it is right on the second try it is worth 1/2 point.
    - If it is right on the third try it is still worth 1/4 point.

5. After you are finished, go back and make note of any questions that you would like discussed.

6. Only your IFAT card will count for marks, so it is your responsibility to ensure that you return it to the exam room proctors. Missing IFAT cards will get zero marks.

7. You only get one IFAT card. If you "mess it up", there will be no replacement provided.

8. Keep your IFAT card turned face-down when you are not using it.

Long Answer Problems: Answer in the space provided.

Allowed aids: Non-programmable calculator. No additional aids permitted.

Good luck!

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MC 1		LA 1	/1	n_{KOH}, n_{CA}
MC 2			/1	L.R., 'n'
MC 3			/1	formula, units, sf.
MC 4			/1	values in formula
MC 5		LA 2a	/1	E
MC 6			/1	λ
MC 7			/0.5	sf., units
MC 8		LA 2b	/1	$E_{ionization}$
MC 9			/0.5	Justification
MC 10				
		Bonus	/1	
Total	/10	Total	/8	
Overall Total	/18			

Some useful constants and equations (also see the last page of this exam)

Rydberg's constant (R_H) = 1.097 x 107 m^{-1} = 2.179 x 10^{-18} J (pay attention to units!)

Velocity of light in a vacuum (c) = 2.998 x 10^8 m/s

Planck's constant (h) = 6.626 x 10^{-34} J s

E(photon) = hν

$$\Delta E = -Z^2 2.179 \times 10^{-18} J \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) = h\nu$$

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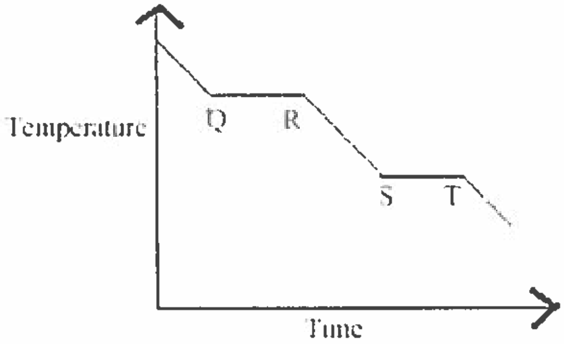
I. Multiple Choice Questions (10 questions, 1 mark each)

1. Which of the following is NOT a state function?

A) density
B) enthalpy
C) volume
D) temperature
[✓ E) heat]

For question 2 and 3 refer to the following graph which shows gaseous H_2O above its boiling point being cooled to a solid below its freezing point.



2. Which occurs from points S to T?

A) kinetic energy decreases, potential energy does not change
[✓ B) potential energy decreases, kinetic energy does not change]
C) kinetic energy increases, potential energy does not change
D) potential energy increases, kinetic energy does not change
E) potential and kinetic energy remain unchanged

3. If 10.0 moles (1.80×10^2 g) of H_2O undergo the above changes, what is the total heat released in going from point Q→R→S?

A) 3.32×10^2 kJ
B) 4.07×10^2 kJ
C) 75.3 kJ
D) 1.35×10^2 kJ
[✓ E) 4.82×10^2 kJ]

$$\boxed{\begin{aligned} &Q \rightarrow R \\ &q = n\Delta H \\ &q = (10.0\,\mathrm{mol})(-40.7\,\mathrm{kJ \cdot mol^{-1}}) \\ &q = -407\,\mathrm{kJ} \end{aligned}}$$

$$S \rightarrow T$$

$$q = mc\Delta T$$

$$q = (1.80 \times 10^2\,\mathrm{g})(4.184\,\mathrm{J\,g^{-1}\,{}^\circ C^{-1}})(0^\circ C - 100^\circ C)$$

$$q = -7.53 \times 10^4\,\mathrm{J}$$

$$= -7.53 \times 10^1\,\mathrm{kJ}$$

$$q_{Total} = (-407\,\mathrm{kJ}) + -75.3\,\mathrm{kJ}$$

$$= -4.82 \times 10^2\,\mathrm{kJ}$$

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4. The standard enthalpy of formation (ΔH_f^o) of NH_4Cl (s) is -315.4 kJ/mol. Which of the following equations corresponds to this ΔH_f^o?

A) NH_4^+ (aq) + Cl^- (aq) → NH_4Cl (s)

B) ½ N_2 (g) + ½ Cl_2 (g) + ½ H_2 (g) → NH_4Cl (s)

C) N_2 (g) + H_2 (g) + Cl_2 (g) → 2 NH_4Cl (s)

[✓ D) ½ N_2 (g) + 2 H_2 (g) + ½ Cl_2 (g) → NH_4Cl (s)]

E) N_2 (g) + Cl_2 (g) + 4 H_2 (g) → 2 NH_4Cl (s)

5. What is the enthalpy change for the following reaction?

$$2/3\ H_2S\ (g) + O_2\ (g) \rightarrow 2/3\ SO_2\ (g) + 2/3\ H_2O\ (l)$$

ΔH_f^o [H_2O (l)] = -285.8 kJ/mol
ΔH_f^o [H_2S (g)] = -20.63 kJ/mol
ΔH_f^o [SO_2 (g)] = -296.8 kJ/mol

$$\Delta H^\circ = \left(\textstyle\sum n \Delta H_f^\circ\right)_{prod} - \left(\textstyle\sum n \Delta H_f^\circ\right)_{react}$$

$$= \left[\left(\frac{2\text{ mol } SO_2}{3}\right)\left(\frac{-296.8\text{ KJ}}{1\text{ mol } SO_2}\right) + \left(\frac{2\text{ mol } H_2O}{3}\right)\left(\frac{-285.8\text{ KJ}}{1\text{ mol } H_2O}\right)\right] - \left[\left(\frac{2\text{ mol } H_2S}{3}\right)\left(\frac{-20.63\text{ KJ}}{1\text{ mol } H_2S}\right)\right] \boxed{= -375\text{ KJ}}$$

[✓ A) -375 kJ]
B) -402 kJ
C) -562 kJ
D) 375 kJ
E) 402 kJ

6. Use Plank's equation to determine the energy, in J/photon, of radiation with frequency 5.8×10^{15} Hertz.

$$E_{photon} = h\nu = (6.626\times10^{-34}\text{ Js})(5.8\times10^{15}\text{ s}^{-1})$$

$$= 3.8\times10^{-18}\text{ J}$$

A) 1.7×10^{24}
B) 5.8×10^{-25}
C) 1.7×10^{-16}
D) 5.2×10^{-8}
[✓ E) 3.8×10^{-18}]

7. What is the smallest allowed value for n, given:

$$n = ?,\ \ell = 2,\ m_\ell = 0,\ m_s = +½$$

A) 1
[✓ B) 3]
C) 5
D) 2
E) 4

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8. What is the orbital designation for $n = 2$, $\ell = 1$, $m_\ell = 0$, $m_s = +½$

[✓ A) 2p]
B) 2s
C) 3s
D) 3p
E) 3d

2p

9. Which of the following could be the quantum numbers corresponding to the highest energy electron in ground state nickel?

A) $n = 3$, $\ell = 2$, $m_\ell = 0$, $m_s = 0$
B) $n = 3$, $\ell = 2$, $m_\ell = 1/2$, $m_s = +½$
[✓ C) $n = 3$, $\ell = 2$, $m_\ell = 0$, $m_s = +½$]
D) $n = 3$, $\ell = 1$, $m_\ell = 0$, $m_s = +½$
E) $n = 4$, $\ell = 2$, $m_\ell = 0$, $m_s = +½$

3d
$n = 3$, $\ell = 2$

10. What is the correct electron configuration for Ar?

A) $3s^2 3p^6$

B) $3p^6$

C) $[Ar]3p^6$

[✓ D) $1s^2 2s^2 2p^6 3s^2 3p^6$]

E) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

Version A & C

n_{KOH}, n_{CA} , LR + 'n' , formula, units, sf

1 1 1

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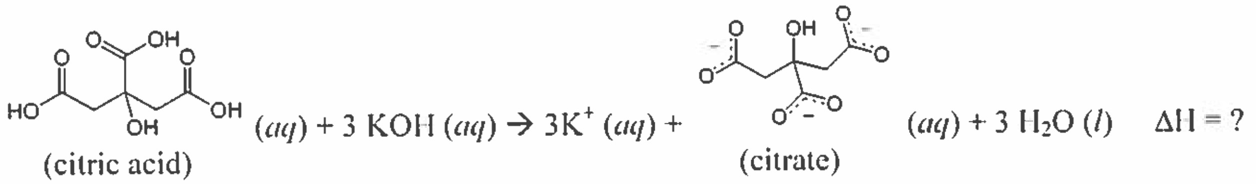
II. Problems **(Show your work and give your answer in the space provided. Use the back of the page if you require extra space.)**

correct values in formula

1

(4 points) **1.** The reaction of citric acid with aqueous potassium hydroxide proceeds according to the following equation:


(citric acid) (aq) + 3 KOH (aq) → 3K$^+$ (aq) + (citrate) (aq) + 3 H_2O (l) ΔH = ?

When 70.0 mL of 0.250 mol/L citric acid is combined with 70.0 mL of 0.250 mol/L KOH in a coffee-cup calorimeter the temperature changes from 23.40 °C to 24.62 °C. Calculate ΔH for the reaction as **written above (in other words, per mole of citric acid consumed.)**
Assume 1.00 g/mL as the density of the solution and 4.184 J g^{-1} °C^{-1} as the specific heat capacity of the solution in the coffee-cup.

$n_{\text{citric acid}} = (0.0700\,L)(0.250\,mol\cdot L^{-1}) = 0.0175\,mol$ citric acid (0.5)

$n_{KOH} = (0.0700\,L)(0.250\,mol\cdot L^{-1}) = 0.0175\,mol$ KOH (0.5)

$n_{\text{citric acid}}$ required to react w/ all KOH:

$$\boxed{= 0.0175\,mol\ KOH \left(\frac{1\,mol\ \text{citric acid}}{3\,mol\ KOH}\right) = 0.00583_3\,mol}$$

(0.5) L.R

$n_{\text{citric acid}}$ required < n available ∴ citric acid does not limit. KOH is limiting

$n\Delta H = -mc\Delta T$

$\Delta T = 24.62°C - 23.40°C = 1.22°C$

$\Delta H = \frac{-mc\Delta T}{n_{\text{citric acid}}}$ (0.5) formula

(0.5) full volume (0.25) (0.25)

$\Delta H = -\frac{(140.0g)(4.184\,J\cdot g^{-1}\cdot °C^{-1})(1.22°C)}{(0.00583_3\,mol)}$ (0.5) for correct 'n'

$$\boxed{\Delta H = -1.23\times10^{5}\,J\cdot mol^{-1}\ \text{citric acid}}$$

(0.25) units throughout

(0.25) sf.

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(2.5 point) **2. (a)** When an electron drops from the n = 7 to the n = 1 level, in an excited state-to-ground state transition in a **hydrogen atom**, a photon of energy is emitted. Determine the wavelength for this photon.

$$\Delta E = -2.179\times10^{-18}\,J\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \quad ①$$

$n_i = 7$

$n_f = 1$

$$= -2.179\times10^{-18}\left(\frac{1}{1^2} - \frac{1}{7^2}\right)$$

$$= -2.134_5\times10^{-18}\,J$$

$$E = \frac{hc}{\lambda}$$

①

$$\lambda = \frac{hc}{|E|} = \frac{(6.626\times10^{-34}\,J\cdot s)(2998\times10^{8}\,m\cdot s^{-1})}{|(-2.134_5\times10^{-18}\,J)|}$$

$\lambda = 9.307\times10^{-8}\,m$ (-0.25) if λ is (−)

0.25 sf
0.25 units } only once for both parts

(1.5 points) **2. (b)** Determine the amount of energy required to ionize the electron from a He^+ ion in its ground state. Does the photon from part (a) have sufficient energy to cause the ground state He^+ ion to be ionized? If yes, determine the kinetic energy of the ejected electron.

$$E = \frac{2.179\times10^{-18}(Z^2)\,J}{n^2}$$

n = 1 (ground state)

Z = 2 for He

$$E = 2.179\times10^{-18}(2^2)\,J \quad ①$$

$$E = 8.716\times10^{-18}\,J$$

$$8.716\times10^{-18}\,J > 2.134_5\times10^{-18}\,J$$

therefore there is insufficient energy for ionization (0.5)

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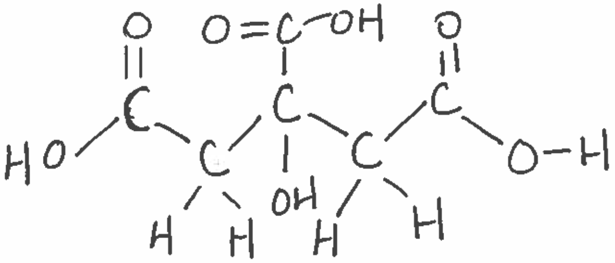
(1 bonus point)

III. "All or Nothing" Bonus For question 1 in the long answer section, determine how much excess reagent is left-over. Express your answer in grams. **You must show your work, but no part marks will be awarded for incorrect answers, so double check that you did question 1 correctly first.**

Citric acid in excess



$C_6O_7H_8$

Molar mass = $192.124\,g \cdot mol^{-}$

$$
\begin{array}{rll}
 & 0.0175 \text{ mol} & \text{available} \\
- & 0.00583_3 \text{ mol} & \text{required} \\
\hline
 & 0.0116_6 \text{ mol} & \text{in excess}
\end{array}
$$

mass in excess $= (0.0116_6\,mol)(192.124\,g \cdot mol^{-1})$

$\boxed{= 2.24g}$

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PERIODIC TABLE OF THE ELEMENTS

KEY: 6 (atomic number) C 12.011 (atomic mass)

s-block ← → | d-block ← → | p-block ← →

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
													1 H 1.0079				2 He 4.0026
3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.0107	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.1797
11 Na 22.9898	12 Mg 24.3050											13 Al 26.9815	14 Si 28.0855	15 P 30.9738	16 S 32.065	17 Cl 35.453	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.9559	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.9380	26 Fe 55.8475	27 Co 58.9332	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.409	31 Ga 69.723	32 Ge 72.61	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.798
37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.224	41 Nb 92.9064	42 Mo 95.94	43 Tc (99)	44 Ru 101.07	45 Rh 102.9055	46 Pd 105.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.75	52 Te 127.60	53 I 126.9045	54 Xe 131.29
55 Cs 132.9054	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.9664	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.9804	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (269)	109 Mt (268)									

f-block ← →

Lanthanides	58 Ce 140.116	59 Pr 140.9077	60 Nd 144.24	61 Pm (147)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.925	66 Dy 162.50	67 Ho 164.9303	68 Er 167.259	69 Tm 168.9342	70 Yb 173.04	71 Lu 174.967
Actinides	90 Th 232.0381	91 Pa 231.0359	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Parenthesis Indicates the most stable isotope

SOME USEFUL CONSTANTS

Quantity and Symbol	Value	Quantity and Symbol	Value
ΔH_{fusion}, $H_2O(s)$ at 273 K	6.01 kJ mol^{-1}	Rydberg constant, R_H	1.097 x 10^{7} m^{-1}
$\Delta H_{vaporization}$, $H_2O(\ell)$ at 373 K	40.7 kJ mol^{-1}	Velocity of light in a vacuum, c	2.998 x 10^{8} m s^{-1}
Specific Heat Capacity of $H_2O(\ell)$	4.184 J g^{-1} K^{-1}	Planck's Constant, h	6.626 x 10^{-34} J s
Specific Heat Capacity of $H_2O(s)$ at 0°C	1.960 J g^{-1} K^{-1}	Density of $H_2O(\ell)$ (near 0°C)	1.000 g mL^{-1}
Avogadro Constant, N_A	6.022 x 10^{23} mol^{-1}		

Ideal Gas Constant, R 8.314 L kPa mol^{-1} K^{-1} = 8.314 J mol^{-1} K^{-1} = 0.08314 L bar mol^{-1} K^{-1}
= 0.08206 L atm mol^{-1} K^{-1}

CONVERSION FACTORS

1 bar = 10^5 Pa = 100 kPa = 750.1 mmHg = 750.1 torr = 0.9860 atm
1 L = 1 dm^3 (exactly) 1 L bar = 100 J
1 cal = 4.184 J (exactly)
1 L atm = 101.3 J

SOME USEFUL FORMULAS

$$\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT \qquad u_{rms} = \sqrt{\frac{3RT}{M}} \qquad \ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$E_n(J) = -2.179 \times 10^{-18}\,\frac{Z^2}{n^2} \qquad r_n = \frac{n^2 a_o}{Z^2}$$

$$PV = nRT \qquad e_k = \frac{1}{2}mu^2 \qquad \lambda\nu = c \qquad C = k_HP_{gas} \text{ or } kP_{gas}$$

$$\lambda = \frac{h}{mu} \qquad \Delta E(J) = Z^2 \times 2.179 \times 10^{-18}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right) \qquad \Delta U = q + w \qquad \pi = iCRT \text{ or } iMRT$$

$$\Delta H = \Delta U + RT\Delta n_{gases}$$

$\Delta T_f = -iK_fm$ $\Delta T_b = iK_bm$ $P_A = x_AP°_A$ $P_T = x$

$\Delta H° = \sum \nu_p \Delta_f H°$ (products) $- \sum \nu_r \Delta_f H°$ (reactants) ${}_AP°_A + x_bP°_b$ (mixture of volatile liquids)