Chemistry 100 Final Exam (ALL SECTIONS) **April 15, 2009**

M. Aquino; G. Orlova; B. MacLean

Name:_____ **ID**: _____

This exam has a three-hour (3 hour) time limit.

Read over the entire exam before beginning. Do those questions that you find easiest in the beginning. Proceed through the exam from the easier questions to the harder ones. Ration your time according to the value of each question.

There should be twenty-eight different questions. A periodic table and an equation sheet are also provided (attached to the back of your exam). If your exam does not contain 28 questions (16 total pages), notify the instructor immediately.

Answer all questions on this exam paper.

Read all questions carefully!! Please write legibly!!

Question	*Full Marks*	*Marks Earned*	*Question*	*Full Marks*	*Marks Earned*
Multiple Choice	32		**22**	8	
17	4		**23**	8	
18	4		**24**	8	
19	4		**25**	8	
20	4		**26**	8	
21	4		**27 or 28**	8	
			Total	100	

Have you put your name and ID at the top of this page?

PART (I). Multiple Choice (32 marks, 2 marks each)

Please clearly circle the letter of your answer. If two or more answers are circled, the question will be marked wrong regardless of whether the correct answer is circled. Wrong answers will not be penalized, so guess if you have to!

1. Which substance in the reaction below either appears or disappears the fastest?

$$4\ NH_3 + 7\ O_2 \longrightarrow 4\ NO_2 + 6\ H_2O$$

a) NH_3

b) O_2

c) NO_2

d) H_2O

e) The rates of appearance/disappearance are the same for all of these.

2. The rate law of a certain reaction is rate = k[A][B]. The units of the rate constant are _____.

a) mol L^{-1} s^{-1} b) L mol^{-1} s^{-1} c) mol^2 L^{-2} s^{-1} d) mol L^{-1} s^{-2} e) L^2 mol^{-2} s^{-1}

3. The rate constant of a first-order process that has a half-life of 225 s is _____ s^{-1}.

a) 0.693 b) 3.08×10^{-3} c) 1.25 d) 12.5 e) 4.44×10^{-3}

4. Which of the following ionic compounds should possess the greatest lattice energy?

a) LiBr b) LiF c) MgO d) NaCl e) MgF_2

5. Which of the following molecules possesses the shortest N-N bond length?

a) N_2O b) N_2H_4 c) N_2 d) N_2O_4 e) NO_2

6. Hydrocarbons containing carbon-carbon triple bonds are called _____.

a) alkanes b) aromatic hydrocarbons c) alkynes d) alkenes e) olefins

7. For the compound shown on the right, the bond angle indicated would most correctly be described as:

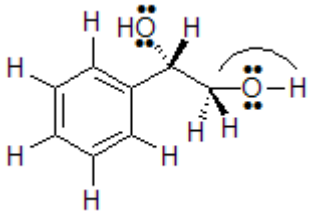
a) 180^o

b) 109.5^o

c) A little greater than 120^o

d) A little greater than 109.5^o

e) A little less than 109.5^o



8. From the correct Lewis structure for formaldehyde (H_2CO), how many σ-bonds, π-bonds, and non-bonding pairs can be found?

a) 2, 2, 2 b) 2, 1, 2 c) 3, 1, 1 d) 3, 1, 2 e) 1, 3, 2

9. Which of the following is false?

a) ΔH is an extensive property

b) ΔH^o_f for $H_2(l)$ is zero

c) The enthalpy change for a reaction is equal in magnitude, but opposite in sign, to ΔH for the reverse reaction

d) The enthalpy change for a reaction depends on the states of the reactants and products

e) Enthalpy is a state function

10. Pentane has _____ structural isomers.

a) 0 b) 1 c) 2 d) 3 e) 4

11. The following reaction would produce a(n) _____.

$$\text{R-OH} + \text{R}'\text{COOH} \longrightarrow$$

a) ketone b) ether c) aldehyde d) alcohol e) ester

12. The equilibrium constant for a reaction is 0.48 at 25°C. What is the value of ΔG^o (kJ/mol) at this temperature?

a) 1.8 b) -4.2 c) 1.5×10^2 d) 4.2 e) -1.8

13. For a reaction to be spontaneous under standard conditions at all temperatures the signs of ΔH^o and ΔS^o must be _____and _____ respectively.

a) +, + b) +, - c) -, - d) -, + e) +, 0

14. Which set of three quantum numbers; n, l, m_l, corresponds to a 3d orbital?

a) 3,3,2 b) 3,2,2 c) 3,2,3 d) 2,1,0 e) 2,3,3

15. A reaction that is spontaneous as written _____

a) is very rapid

b) will proceed without outside intervention

c) is also spontaneous in reverse direction

d) has an equilibrium position that lies far to the left

e) is very slow

16. The value of ΔG^o (in kJ/mol) at 100 °C for the reaction below is _____

$$S\ (s,\ rhombic) + O_2\ (g) \longrightarrow SO_2\ (g)$$

At 25°C, ΔH^o for this reaction is -269.9 kJ/mol, and ΔS^o is +11.6 J/(mol-K)

a) -300.4 b) +300.4 c) -4.597 d) +4.597 e) -274.2

PART (II). Short Answer (20 marks, each worth 4 marks). Please answer in the space provided.

17. Which of the following molecules/ions will possess a dipole moment? Are any of these planar (flat)? If so, circle each one that is.

CO_3^{2-}

NH_3

BrF_3

18. What is the energy content of 25 g of a breakfast cereal that is 75% carbohydrates, 10% fats, and 15% proteins in its makeup? (energy content: proteins: 17 kJ/g; fats: 38 kJ/g; carbohydrates: 17 kJ/g)

19. Given the data in the table below and ΔH^o_{rxn} for the reaction:

$CaC_2\,(s) + 2\,H_2O(l) \longrightarrow Ca(OH)_2(s) + C_2H_2\,(g) \qquad \Delta H^o_{rxn} = -127.2$ kJ/mol

Calculate ΔH^o_f of $CaC_2(s)$, in kJ/mol.

Substance	ΔH^o_f, kJ/mol
$Ca(OH)_2\,(s)$	-986
$C_2H_2\,(g)$	227
$H_2O\,(l)$	-286

20. Write the electron configuration for the element which is in the 3rd period of the periodic table, which has the following ionization energies: IE_1=786 kJ/mol; IE_2 = 1577 kJ/mol; IE_3 = 3232 kJ/mol; IE_4 = 4356 kJ/mol; IE_5 = 16091 kJ/mol.

21. Draw the structures of the products of the following reactions:

a) cyclohexene + H_2 $\longrightarrow$

b) acetic acid + propanol $\longrightarrow$

PART (III) Long Answers (Answer 6 questions, each is worth 8 marks for a total of 48 marks). Please answer in the space provided.

22. The ΔG^0 for the reaction: $H_2\,(g) + I_2\,(g) \leftrightarrows 2\,HI\,(g)$ is 2.60 kJ/mol at 25^0C.

Calculate ΔG, and predict the direction in which the reaction is spontaneous if the initial pressures are: $P_{H2} = 3.5$ atm; $P_{I2} = 1.5$ atm, $P_{HI} = 1.75$ atm.

23. Urea (NH_2CONH_2) is the end product in protein metabolism in animals. The decomposition of urea in 0.1 M HCl occurs as follows:

$$NH_2CONH_2\,(aq) + H^+\,(aq) + 2\,H_2O\,(l) \longrightarrow 2\,NH_4^+\,(aq) + HCO_3^-\,(aq)$$

The reaction is first-order in urea and first-order overall. When $[NH_2CONH_2] = 0.200$ M, the rate at 61°C is 8.56×10^{-5} M/s.

a) What is the value for the rate constant, *k*? (3 marks)

b) What is the concentration of urea in this solution after 4.00×10^3 s if the starting concentration is 0.500 M? (3 marks)

c) What is the half-life for this reaction at 61°C? (2 marks)

24. Calculate the standard enthalpy of formation of gaseous diborane (B_2H_6) using the following thermochemical information:

$$4\ B\ (s) + 3\ O_2\ (g) \longrightarrow 2\ B_2O_3\ (s) \qquad \Delta H^o = -2509.1\ kJ$$

$$2\ H_2\ (g) + O_2\ (g) \longrightarrow 2\ H_2O\ (l) \qquad \Delta H^o = -571.7\ kJ$$

$$B_2H_6\ (g) + 3\ O_2\ (g) \longrightarrow B_2O_3\ (s) + 3\ H_2O\ (l) \qquad \Delta H^o = -2147.5\ kJ$$

25. Ethane, like all hydrocarbons, can be combusted to release heat.

a) Using the bond enthalpies given, calculate ΔH (kJ/mol) for the complete combustion of 1 mol of ethane. (5 marks)

Bond type	**Bond enthalpy (kJ/mol)**
C-H	414
C-C	347
C=C	620
C-O	351
C=O	745
O-O	146
O=O	495
O-H	460

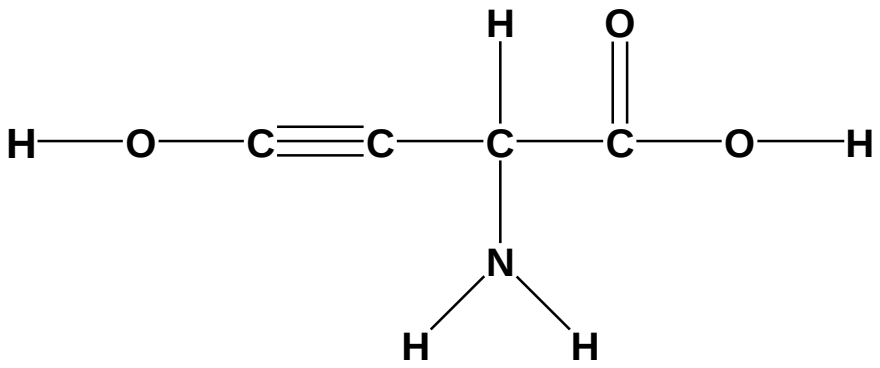
b) A carbon-carbon double bond is stronger than a carbon-carbon single bond (see table above); however, the double bond is not quite twice as strong as a single bond. Explain. (3 marks)

26. Draw correct Lewis structures for each of the following molecules/ions, and indicate both the electron domain geometry and molecular geometry for each:

Molecular/Ionic Formula	Lewis Structure	Electron Domain Geometry	Molecular Geometry
SF_4			
I_3^-			
IF_5			
NO_2^+			
BCl_3			

NOTE: ANSWER QUESTION 27 <u>OR</u> QUESTION 28, NOT BOTH (IF YOU ANSWER BOTH ONLY THE FIRST ONE WILL GET MARKED!)

27. Identify (circle and name) all the functional groups **AND** indicate (with an arrow) what the hybridization is (eg. *sp*, sp^2,sp^3) at each carbon, for the molecule below.



28. For each pair, circle the substance that has the higher boiling temperature and identify its predominant intermolecular force.

a) acetic acid and acetone (2-propanone)

b) pentane and 2-methylbutane

c) Kr and Ar

d) acetonitrile, CH_3CN and propane, C_3H_8

Equations

$$w = -P_{op}\,\Delta V = -P_{op}(V_f - V_i) \quad q_{rxn} + q_{sol'n} + q_{cal} = 0 \quad q_x = C_x \Delta T = C_x(T_f - T_i)$$

$$q_x = C_x \Delta T = m_x s_x (T_f - T_i) \qquad \Delta E = E_f - E_i = q + w$$

$$\Delta_r H^\circ = \Sigma\, n_p \Delta_f H^\circ(\text{products}) - \Sigma\, n_r \Delta_f H^\circ(\text{reactants})$$

$$\Delta_{univ} S = \Delta_{sys} S + \Delta_{surr} S \qquad \Delta_r S^\circ = \Sigma\, n_p S^\circ(\text{products}) - \Sigma\, n_r S^\circ(\text{reactants})$$

$$\Delta_r G^\circ = \Sigma\, n_p \Delta_f G^\circ(\text{products}) - \Sigma\, n_r \Delta_f G^\circ(\text{reactants})$$

$$\Delta_{surr} S = -\frac{\Delta_{sys} H}{T_{surr}} = -\frac{\Delta_r H^\circ}{T_{surr}} \qquad \Delta_r G^\circ = \Delta_r H^\circ - T\Delta_r S^\circ \qquad \Delta_r G^\circ = -RT \ln K_{eq}$$

For the reaction $aA + bB \rightarrow cC + dD$

$$rate = k[A]^x [B]^y$$

$$rate = -\frac{1}{a}\frac{\Delta[A]}{\Delta t} = -\frac{1}{b}\frac{\Delta[B]}{\Delta t} = +\frac{1}{c}\frac{[C]}{\Delta t} = +\frac{1}{d}\frac{[D]}{\Delta t}$$

$$\ln\left(\frac{A}{A_o}\right) = -kt \qquad t_{1/2} = \frac{0.693}{k} \qquad \frac{1}{[A]} = \frac{1}{[A]_o} + kt \qquad t_{1/2} = \frac{1}{k[A]_o}$$

$$\ln k = \ln A - E_a/RT \qquad \ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$\Delta E = h\nu \qquad c = \lambda\nu \qquad \lambda = \frac{h}{mv}$$

$$r_n = \frac{\varepsilon_0 h^2}{\pi m e^2 Z} \times n^2 \quad \text{where } n = 1, 2, 3\ldots \qquad -\frac{h^2}{8\pi^2 m}\frac{d^2\psi}{dx^2} + V\psi = E\psi$$

$$E_n = -\left(\frac{me^4}{8\varepsilon_0^2 h^2}\right)\left(\frac{Z^2}{n^2}\right)$$

$$E_{ionic} = \frac{kq_1 q_2}{r} \qquad pH = -\log[H^+] \qquad pK_a = -\log K_a$$

$$A_x B_y(s) \leftrightarrow xA^{y+}(aq) + yB^{x-}(aq)$$

$$pH = pK_a + \log\frac{[A^-]}{[HA]} \qquad K_{sp} = [A^{y+}]^x [B^{x-}]^y$$

$$pOH = -\log[OH^-] \qquad pH + pOH = 14.00$$

$$K_w = [H_3O^+][OH^-] = [H^+][OH^-] = 1.0 \times 10^{-14}$$

$$1\ J = kg\frac{m^2}{s^2}\ ;\ 1\ cal = 4.184\ J;\ 1\ Cal = 4.184\ kJ = 4184\ J$$

PERIODIC TABLE OF ELEMENTS

IA												IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H 1.01	IIA																2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.1	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.30	IIIB	IVB	VB	VIB	VIIB		VIIB		IB	IIB	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	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 [98.91]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 *La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [210.0]	85 At [210.0]	86 Rn [222.0]
87 Fr [223.0]	88 Ra [226.0]	89 †Ac [227.0]	104 Rf [261.1]	105 Db [262.1]	106 Sg [263.1]	107 Bh [262.1]	108 Hs [265.1]	109 Mt [266.1]									

At. No.
X
At. Wt.

58 *Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [146.92]	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 †Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237.0]	94 Pu [239.0]	95 Am [241.1]	96 Cm [244.1]	97 Bk [249.1]	98 Cf [252.1]	99 Es [252.1]	100 Fm [257.1]	101 Md [258.1]	102 No [259.1]	103 Lr [262.1]

Avogadro's N = 6.022×10^{23} /mol
Plank's constant h = 6.626×10^{-34} J/s
Speed of light c = 3×10^{8} m/s

1 atm = 760 Torr = 101.325 kPa = 760 mm Hg = 1.013 bar
R = 8.314 J / (K mol); 0.08206 L atm / (K mol)
Molar volume of an ideal gas at STP = 22.414 L

For a quadratic equation $ax^2 + bx + c$, quadratic formula $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

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