Chemistry 2000 Fall 2013 Test 2
Version A

NAME: ________________________________ Student number: _____________

Time: 90 minutes

Aids permitted: calculator

Overflow space: Bottom of pages 8 and 10. If you do need extra space for a question, make sure to give me a clear indication of where I can find the rest of your answer, and label any answers continued in the overflow space with the question number.

Confidentiality agreement: I agree not to discuss (or in any other way divulge) the contents of this exam until **after 5:00 p.m.** Mountain Time on **Wednesday, November 20**. I understand that breaking this agreement would constitute academic misconduct, a serious offense with serious consequences. The minimum punishment would be a mark of zero on this exam and removal of the "overwrite midterm mark with final exam mark" option for my grade in this course; the maximum punishment would include expulsion from this university.

Signature: ________________________________ Date: ___________________

Question	Mark
1	/4
2	/4
3	/2
4	/8
5	/4
6	/14
7	/15
Total:	/51
Percentage:	%

NAME:____

/4 1. Radon (Rn) is a radioactive noble gas formed as a result of the radioactive decay of thorium and uranium. Small quantities of thorium and uranium are found in many materials deriving from mineral sources, such as cement. Radon tends to accumulate in poorly ventilated spaces like basements, and can become a significant health hazard under some conditions.

^{222}Rn is the isotope formed in the ^{238}U decay chain. The isotopic mass of ^{222}Rn is 222.0176 u. What is the root-mean squared speed of the atoms in a ^{222}Rn gas at 20 °C?

/4 2. When gaseous hydrogen chloride reacts with gaseous ammonia, solid ammonium chloride is formed:

$$HCl_{(g)} + NH_{3(g)} \rightarrow NH_4Cl_{(s)}.$$

Since this reaction converts gases into a solid, it will be associated with a large decrease in entropy. This reaction, which is commonly observed when HCl and ammonia are improperly stored together, therefore contradicts the second law of thermodynamics and thus proves that the second law is wrong.

What is wrong with the above argument?

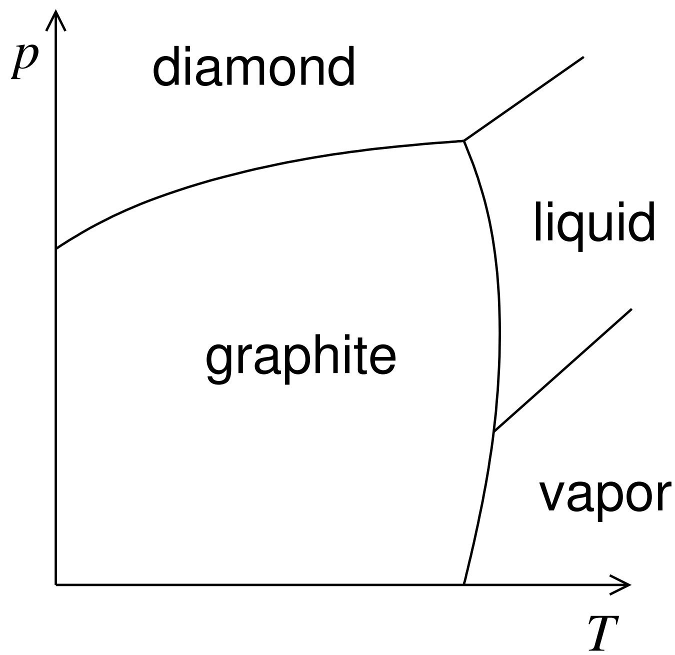
NAME:____

/2 3. When a quartz capillary tube is dipped into an acetone solution, the acetone is drawn up into the capillary. Explain why this happens and what this tells us about the interaction between acetone and quartz.

/8 4. Is the reaction of NO with oxygen to make NO_2 thermodynamically allowed at 25 °C in the presence of 0.0041 bar of NO, 0.21 bar of O_2 and 0.0032 bar of NO_2?

NAME:____________________________________

/4 5. The following is a sketch of part of the phase diagram of carbon:[1]



This phase diagram allows for the synthesis of diamond from graphite in several different ways. We tend to get better quality crystals by solidifying a melted substance than by using other paths through the phase diagram. Keeping this in mind, describe a sequence of temperature and pressure adjustments that would allow for the synthesis of high-quality diamonds from graphite. Clearly indicate how the required temperatures or pressures relate to features of the phase diagram. If it helps, you can show your proposed path on the phase diagram, but make sure to include a written explanation as well. You can also label any features of the phase diagram that are important to your answer.

[1] Adapted from Bundy, *Physica A* **156**, 169 (1989).

NAME:____________________________________

/14

6. You may recall that HCl is a strong acid.

   (a) Calculate the equilibrium constant for the reaction

   $$HCl_{(g)} \rightleftharpoons H^+_{(aq)} + Cl^-_{(aq)}$$

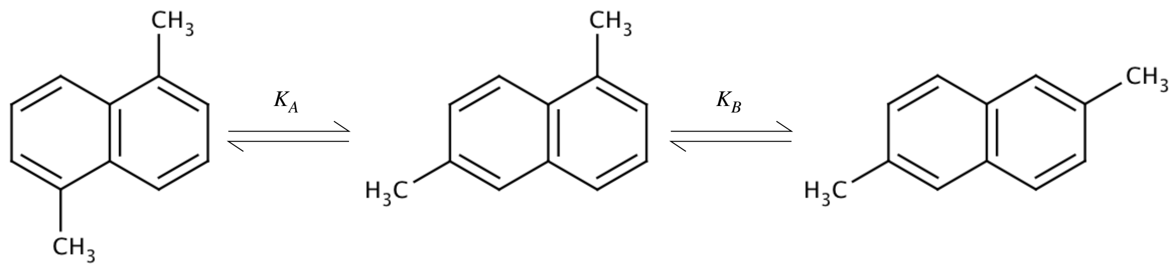
   at 25 °C. /6

   (b) Does the size of the equilibrium constant you calculated agree with the idea that HCl is a strong acid? Explain briefly. /2

   (c) Concentrated HCl has a concentration of $12\,\mathrm{mol\,L^{-1}}$. Neglecting the fact that such a solution will be far from ideal, what would you estimate the equilibrium pressure of HCl to be over a concentrated HCl solution? /6

NAME:____

/15 7. Dimethylnaphthalene has several isomers, all of which are liquids over the range of temperatures studied below. The 1,5, 1,6 and 2,6 isomers,[2] respectively numbered **1**, **2** and **3** below, participate in the following equilibrium:



1 **2** **3**

(a) At 235 °C, the equilibrium mixture contains 34.79% of compound **1**, 35.10% of **2**, and 30.11% of **3**. Calculate the equilibrium constants K_A and K_B at this temperature. /3

Hint: Since these compounds are liquid, what we have here is a mixture of solvents. What is the relevant measure of activity for a solvent?

[2] The numbering specifies positions of the methyl groups around the naphthalene core. All data in this question are from Kraikul et al., *Chem. Eng. J.* **114**, 73 (2005).

NAME:____

(b) At 265 °C, $K_A = 4.665$. What is the standard enthalpy change for the first reaction? Is this reaction exothermic or endothermic? /6

NAME:____

(c) From these data, we can estimate that K_A would be 4.00×10^{-9} at 25 °C. What is the standard free energy change for this reaction? /2

(d) What is the standard entropy change for the first reaction? Which compound has the higher entropy, compound **1** or compound **2**? /4

NAME:____

Constants and conversion factors

Atomic mass unit (u)	$1.6605 \times 10^{-27}\,\mathrm{kg}$	$0\,\mathrm{K} = -273.15\,^\circ\mathrm{C}$
Avogadro's number (N_A)	$6.0221 \times 10^{23}\,\mathrm{mol^{-1}}$	$1\,\mathrm{bar} = 100\,\mathrm{kPa}$
Boltzmann's constant (k_B)	$1.3806 \times 10^{-23}\,\mathrm{J\,K^{-1}}$	$1\,\mathrm{atm} = 1.013\,25\,\mathrm{bar}$
Ideal gas constant (R)	$8.3145\,\mathrm{J\,K^{-1}mol^{-1}}$	

Standard thermodynamic data

Species	$\dfrac{\Delta_f G^\circ}{\mathrm{kJ\,mol^{-1}}}$
$Cl^-_{(aq)}$	−131.218
$HCl_{(g)}$	−95.30
$NO_{(g)}$	86.60
$NO_{2(g)}$	51.32

Formulas

$$pV = nRT \qquad \left(p + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

$$\overline{K} = \tfrac{1}{2}m\overline{v^2} = \tfrac{3}{2}k_BT \qquad \overline{K}_m = \tfrac{3}{2}RT \qquad v_{\mathrm{rms}} = \sqrt{\overline{v^2}} = \sqrt{\frac{3RT}{M}}$$

$$S = k_B \ln \Omega \qquad \Delta S = \frac{q_{\mathrm{rev}}}{T}$$

$$\Delta G = \Delta H - T\Delta S \qquad \Delta_r G_m = \Delta_r G_m^\circ + RT \ln Q \qquad \Delta_r G_m^\circ = -RT \ln K$$

$$\ln\left(\frac{K_2}{K_1}\right) = \frac{\Delta_r H_m^\circ}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$X = \frac{n}{\sum n} \qquad p_A = X_A p_A^\bullet \qquad [\mathrm{A}] = k_H p_A$$

$$\mathrm{pH} = -\log_{10}(a_{\mathrm{H^+}})$$

Activities

State	**Activity (a)**
Solid	1
Pure liquid	1
Ideal solvent	X
Ideal solute	c/c°
Ideal gas	p/p°

NAME:____

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											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 65.41	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	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	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg							

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm	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	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr