Chemistry 2000 Fall 2017 Test 2
Version B

NAME: _____ Student number: _____

Time: 90 minutes

Aids permitted: calculator (wireless communication capabilities OFF).

Significant figures: I will specifically ask when I want you to track your significant figures. Otherwise, just give me a sensible number of digits in your answer given the precision of the data.

Overflow: If you 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 on another page with the question number.

Confidentiality agreement: I agree not to discuss (or in any other way divulge) the contents of this exam until **after 8:30 p.m.** Mountain Time on **Tuesday, November 7**. 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	/7
2	/3
3	/6
4	/6
5	/7
6	/18
7	/7
Total:	/54
Percentage:	%

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/7 1. When we burn a fuel in open air, the water produced would usually stay in the gas phase because the air is not saturated with water vapor. However, if we burn the same fuel in a closed vessel, the water often condenses on the walls of the vessel. Calculate the entropy change for the combustion of methane in the gas phase producing (a) liquid water or (b) water vapor. Give your answers to the correct number of significant figures. Comment on differences in the size and/or sign of the answer. Do these differences make sense? [7 marks]

/3 2. Suppose that a reaction carried out at constant temperature and pressure has a negative $\Delta_r H$ value, and a positive $\Delta_r S$. What can we say about the temperature range over which this reaction is thermodynamically allowed? Explain briefly. [3 marks]

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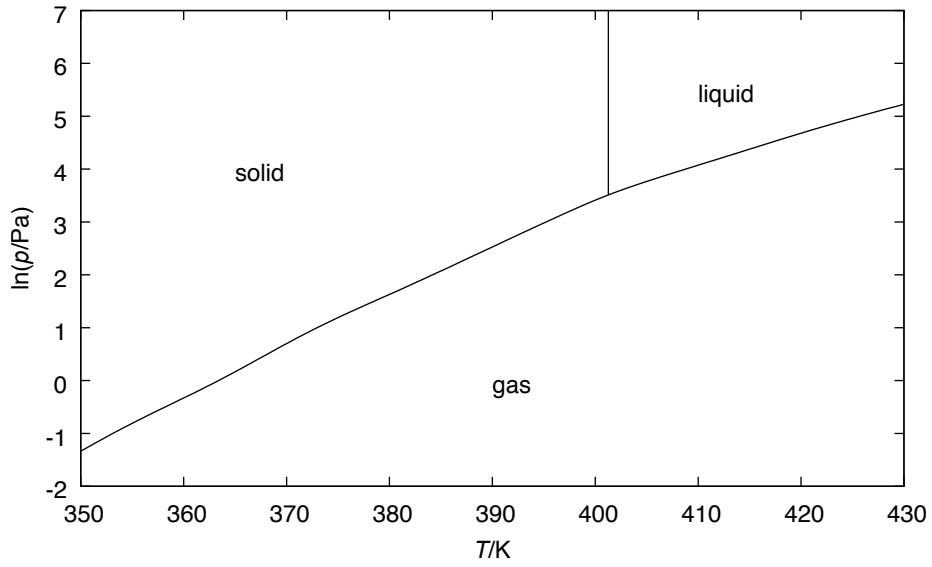
/6 3. Here is the phase diagram of nicotinamide (a member of the vitamin B_3 complex):[1]



Note the logarithmic scale of the ordinate. The notation used for this axis label means that the pressure was in units of Pa prior to taking the logarithm.

(a) Estimate the pressure and temperature at the triple point as accurately as you can. [3 marks]

(b) In practical terms, at least in the range of pressures shown here, would the freezing point of nicotinamide be a good calibration point for a thermometer? Explain briefly. [3 marks]

[1]Redrawn from A. R. R. P. Almeida et al., *J. Chem. Thermodyn.* **82**, 108 (2015).

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/6 4. The vapor pressure of solid N-methylnicotinamide (a compound found in urine) has been measured at several temperatures.[2] Here are two of the points:

T/K	p/bar
347.78	8.5×10^{-6}
377.39	1.496×10^{-4}

What is the enthalpy of vaporization of N-methylnicotinamide? [6 marks]

/7 5. Hydrogen cyanide has a melting point of $-13.4\,^{\circ}\mathrm{C}$, and an enthalpy of fusion at that temperature of $8412\,\mathrm{J\,mol^{-1}}$.

(a) What is the entropy change associated with fusion of hydrogen cyanide? [2 marks]

[2] A. R. R. P. Almeida et al., *J. Chem. Thermodyn.* **82**, 108 (2015).

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(b) Use an argument based on entropy to show that solid hydrogen cyanide will melt in an environment at 5°C. [5 marks]

/18 6. The solubility product of silver(I) sulfate at 25 °C is 1.19×10^{-5}.

(a) Calculate the solubility of silver(I) sulfate. [10 marks]

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(b) Calculate the standard free energy of formation of silver(I) sulfate. In this question, carefully track your significant figures. [8 marks]

7. Could metallic iron react with carbon monoxide at a pressure of 0.23 bar at 25 °C to form $[Fe(CO)_5]$? [7 marks]

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Constants and conversion factors

$0\,\mathrm{K} = -273.15\,^{\circ}\mathrm{C}$
$1\,\mathrm{atm} = 101\,325\,\mathrm{Pa} = 1.013\,25\,\mathrm{bar}$
Ideal gas constant $R = 8.314\,460\,\mathrm{J\,K^{-1}mol^{-1}}$

Standard thermodynamic data

Species	$\Delta_f G^\circ$ / $\mathrm{kJ\,mol^{-1}}$	S° / $\mathrm{J\,K^{-1}\,mol^{-1}}$
$Ag^+_{(aq)}$	77.11	73.93
$CH_{4(g)}$	−50.81	186.1
$CO_{(g)}$	−137.17	197.5
$CO_{2(g)}$	−394.4	213.7
$[Fe(CO)_5]_{(l)}$	−695.0	337.08
$H_2O_{(l)}$	−237.192	69.940
$H_2O_{(g)}$	−228.60	188.72
$O_{2(g)}$	0	205.0
$SO^{2-}_{4(aq)}$	−744.00	17

Formulas

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

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

$$\Delta_r G^\circ_m = -RT \ln K \qquad \ln\left(\frac{K_2}{K_1}\right) = \frac{\Delta_r H^\circ_m}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

Activities

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

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1																	**18**
1 H																	2 He
1.01	**2**											**13**	**14**	**15**	**16**	**17**	4.00
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
6.94	9.01											10.81	12.01	14.01	16.00	19.00	20.18
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
22.99	24.31	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	26.98	28.09	30.97	32.07	35.45	39.95
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
39.10	40.08	44.96	47.88	50.94	52.00	54.94	55.85	58.93	58.69	63.55	65.41	69.72	72.61	74.92	78.96	79.90	83.80
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
85.47	87.62	88.91	91.22	92.91	95.94		101.07	102.91	106.42	107.87	112.41	114.82	118.71	121.76	127.60	126.90	131.29
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
132.91	137.33	138.91	178.49	180.95	183.85	186.21	190.2	192.22	195.08	196.97	200.59	204.38	207.2	208.98			
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg							

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