Chemistry 2000 Fall 2017 Test 2
Version A

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.

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 ethene ($C_2H_{4(g)}$) 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 positive $\Delta_r H$ value, and a negative $\Delta_r S$. Is there a temperature at which such a reaction would be thermodynamically allowed? Explain briefly. [3 marks]

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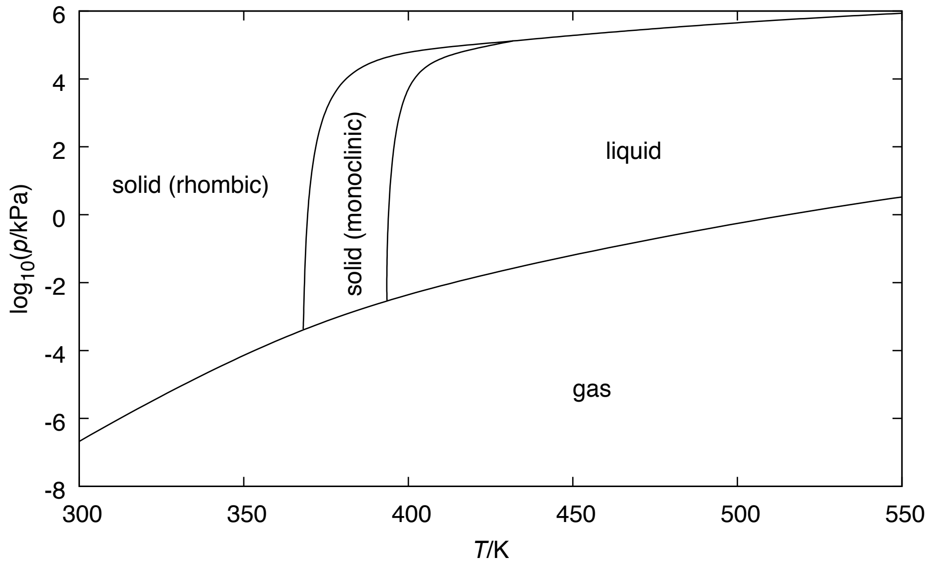
/6 3. The following is a part of the phase diagram of sulfur:[1]



There are two distinct solid phases, distinguished by different crystal structures, as noted in the diagram. For the purpose of this question, it's not important what "rhombic" and "monoclinic" mean. Note the logarithmic scale of the ordinate. The notation used for this axis label means that the pressure was in units of kPa prior to taking the logarithm.

(a) Circle all triple points on the diagram. [2 marks]

(b) Estimate the normal freezing point of sulfur as accurately as you can from the diagram. What solid phase is obtained at the normal freezing point? [4 marks]

[1] Redrawn from A. G. M. Ferreira and L. Q. Lobo, *J. Chem. Thermodyn.* **43**, 95 (2011).

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/6 4. The vapor pressure of liquid nicotinamide (a member of the B_3 vitamin complex) has been measured at several temperatures.[2] Here are two of the points:

T/K	p/bar
396.07	2.388×10^{-4}
433.69	2.206×10^{-3}

What is the enthalpy of vaporization of nicotinamide? [6 marks]

/7 5. Ethylene glycol has a melting point of $-11.5\,^\circ\mathrm{C}$, and an enthalpy of fusion at that temperature of $11\,234\,\mathrm{J\,mol^{-1}}$.

(a) What is the entropy change associated with fusion of ethylene glycol? [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 ethylene glycol will melt in an environment at 0 °C. [5 marks]

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6. The solubility product of calcium fluoride at 25 °C is 1.61×10^{-10}.

(a) Calculate the solubility of calcium fluoride. [10 marks]

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

7. Could nickel react with carbon monoxide at a pressure of 0.15 bar at 25 °C to form $[Ni(CO)_4]$? [7 marks]

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Constants and conversion factors

$0\,\mathrm{K} = -273.15\,°\mathrm{C}$
$1\,\mathrm{atm} = 101.325\,\mathrm{kPa} = 1.013\,25\,\mathrm{bar}$
$R = 8.314\,460\,\mathrm{J\,K^{-1}mol^{-1}}$

Standard thermodynamic data

Species	$\dfrac{\Delta_f G^\circ}{\mathrm{kJ\,mol^{-1}}}$	$\dfrac{S^\circ}{\mathrm{J\,K^{-1}\,mol^{-1}}}$
$C_2H_{4(g)}$	68.36	219.22
$CO_{(g)}$	−137.17	197.5
$CO_{2(g)}$	−394.4	213.7
$CaF_{2(s)}$	−1173.51	68.87
$F^-_{(aq)}$	−281.52	−9.6
$H_2O_{(l)}$	−237.192	69.940
$H_2O_{(g)}$	−228.60	188.72
$[Ni(CO)_4]_{(l)}$	−589.16	319.56
$O_{2(g)}$	0	205.0

Formulas

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

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

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

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	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