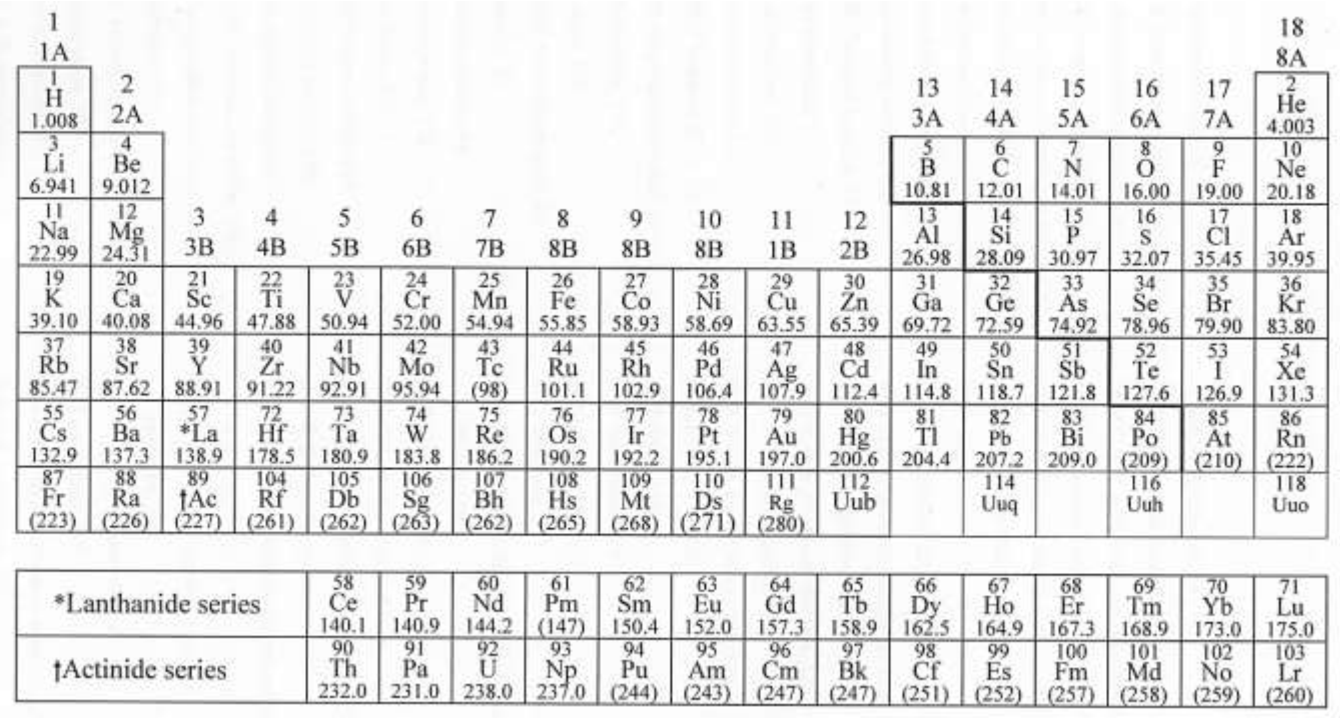
Chemistry II Midterm Exam

18:00-21:00, 15 April, 2016 (Total Score: 106 points)



1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											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 65.39	31 Ga 69.72	32 Ge 72.59	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)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 *La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 †Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (268)	110 Ds (271)	111 Rg (280)	112 Uub		114 Uuq		116 Uuh		118 Uuo

*Lanthanide series	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (147)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
†Actinide series	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	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 (260)

R = 0.08206 atm·L/mol·K = 8.314 J/ mol·K = 0.08314 bar·L/mol·K

F = 96500 C/mol

1. Please answer the following questions. (total 16%)
   - (a) Why are molal and molar concentrations of dilution aqueous solutions approximately equal? (3%)
   - (b) Why are ice cubes (for example, those you see in the trays in the freezer of a refrigerator) cloudy inside? (3%)
   - (c) Why does carbon dioxide escape from a beer when the cap is removed? First, please write the name of the proper physical law which can answer this question. (2%) Then, use it to explain your answer. (3%)
   - (d) If you try to purify ethanol from an ethanol-water mixture by fractional distillation, the maximum purity obtainable is 95%. Please draw a liquid-vapor phase diagram which is roughly close to the phase diagram of an ethanol-water mixture (3%) and then use the diagram to explain your answer (2%).

2. The melting point of a fictional substance X is 28.5℃ at 1000 bar. The density of the solid phase of X is 5.6 g/cm^3 and the density of the liquid phase is 6.14 g/cm^3 at 1000 bar. The molar enthalpy of fusion of X, ΔH_{fus} is 5.6 kJ/mol at 1000 bar. The molecular mass of X is 70.0 g/mol. (total 10%)
   (a) Please use the Clapeyron equation to predict whether the increase of pressure would increase the melting point or decrease. (5%)
   (b) Please estimate the normal melting point of X. (5%)

3. Consider the following data for naphthalene $C_{10}H_8$

   Normal melting point = 80.26℃ ; Normal boiling point = 218.0℃

   The equilibrium vapor pressure P_{vap} of naphthalene $C_{10}H_8$ is listed in the following table. Here, it is assumed that the molar enthalpy of vaporization $\Delta H_{\text{vap}}°$ and the molar enthalpy of sublimation, $\Delta H_{\text{sub}}°$ are independent of temperature. (total 13%)

Temperature (K)	P_{vap} (kPa)
292	0.006
333	0.25
404	8.34

   (a) Is there enough information to calculate $\Delta H_{\text{vap}}°$ of $C_{10}H_8$? If yes, please calculate $\Delta H_{\text{vap}}°$ of $C_{10}H_8$. If not, please list the additional required physical properties of $C_{10}H_8$ to assist this calculation. (5%)
   (b) Is there enough information to calculate the molar enthalpy of fusion of $C_{10}H_8$, $\Delta H_{\text{fus}}°$ If yes, please calculate $\Delta H_{\text{fus}}°$ of $C_{10}H_8$. If not, please list the additional required physical properties of $C_{10}H_8$ to assist this calculation. (8%)

4. (a) Use the following thermodynamic data to determine the equilibrium constant K_P for the reaction $2\,NaHCO_3(s) \rightleftharpoons Na_2CO_3(s) + CO_2(g) + H_2O(g)$ at 350 K. (6%)
   (b) What is the value of equilibrium constant K_c for this reaction at 350 K? (3%)
   (c) What is the temperature at which the K_P = 1. (3%)

substance	$\Delta H_f°$ (kJ·mol^{-1})	$C_P°$(J·K^{-1}·mol^{-1})	$S°$ (J·K^{-1}·mol^{-1})
$NaHCO_3(s)$	-950.8	87.6	101.7
$Na_2CO_3(s)$	-1130.7	112.3	135
$CO_2(g)$	-393.5	37.1	213.7
$H_2O(g)$	-241.8	33.6	188.8

5. The decomposition of ammonium hydrogen sulfide $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$ is an endothermic process. A 3.08 g of sample of the solid is placed in an evacuated 2.00 L vessel at 24℃. After equilibrium has been established, the total pressure inside is 0.732 bar. Some solid NH_4HS remains in the vessel.

   (a) What is the K_P for this reaction? (3%)

   (b) What percentage of the solid remains? (3%)

   (c) If the volume of the vessel were doubled at a constant temperature, what would happened to the amount of the solid? (increase, decrease, or disappear?) (3%)

   (d) If the vessel were heated and all the solid disappeared, would this system be in equilibrium? And please give a brief explanation for your answer. (3%)

6. The reaction $Cl_2(g) \rightleftharpoons 2\,Cl(g)$ reaches its equilibrium in a vessel. (3% each, total 9 %)

   (a) What will happen to the value of K if the temperature is raised from 300 K to 800 K?

   (b) What will happen to the partial pressure of Cl_2 and Cl if the volume of the reaction vessel is doubled?

   (c) What will happen to the partial pressure of Cl_2 and Cl if some H_2 is introduced into the reaction vessel?

7. For the complete redox reaction given here, write the half-reactions and identify the oxidizing and reducing agents: (3% each, total 6%)

   (a) $2\,Li + H_2 \rightarrow 2\,LiH$

   (b) $Cl_2 + 2\,Br^- \rightarrow 2\,Cl^- + Br_2$

8. Calculate the standard emf of a cell that uses $Fe|Fe^{2+}$ (anode) and $Cr|Cr^{3+}$ (cathode) half-cell reactions. Write the overall cell reaction that occurs under standard-state conditions (4%)

9. What is the equilibrium constant for the following reaction at 298 K?

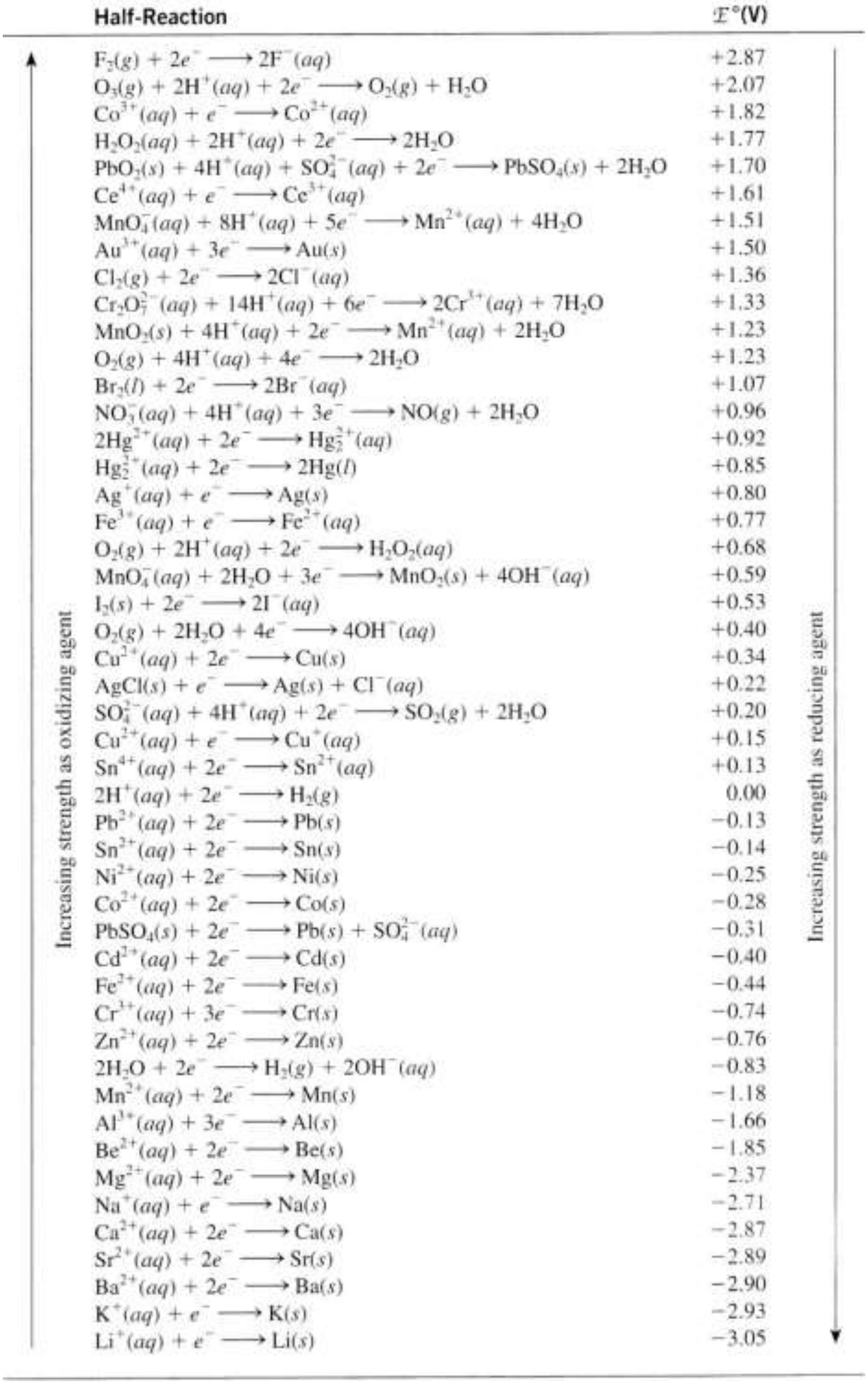
   $Mg^{2+}(aq) + Zn(s) \rightleftharpoons Mg(s) + Zn^{2+}(aq)$ (4%)

10. Given that $E° = 0.52$ V for the reduction $Cu^+(aq) + e^- \rightarrow Cu(s)$, calculate (a) $E°$, (b) $\Delta G°$, and (c) K for the following reaction at 298 K:

    $2\,Cu^+(aq) \rightarrow Cu^{2+}(aq) + Cu(s)$ (4+3+3%)

11. Consider a Daniel cell operating under non-standard-state conditions. Suppose that the cell reaction is multiplied by 2. What effect does this have on each of the following quantities in the Nernst equation: (a) $E°$, (b) E, (c) Q, (d) ln$Q$, and (e) n? (5%)

12. Use the data in the following table, calculate the solubility product (K_{sp}) of AgCl.
$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$ (5%)



Half-Reaction	$E°$(V)
$F_2(g) + 2e^- \longrightarrow 2F^-(aq)$	+2.87
$O_3(g) + 2H^+(aq) + 2e^- \longrightarrow O_2(g) + H_2O$	+2.07
$Co^{3+}(aq) + e^- \longrightarrow Co^{2+}(aq)$	+1.82
$H_2O_2(aq) + 2H^+(aq) + 2e^- \longrightarrow 2H_2O$	+1.77
$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \longrightarrow PbSO_4(s) + 2H_2O$	+1.70
$Ce^{4+}(aq) + e^- \longrightarrow Ce^{3+}(aq)$	+1.61
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O$	+1.51
$Au^{3+}(aq) + 3e^- \longrightarrow Au(s)$	+1.50
$Cl_2(g) + 2e^- \longrightarrow 2Cl^-(aq)$	+1.36
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O$	+1.33
$MnO_2(s) + 4H^+(aq) + 2e^- \longrightarrow Mn^{2+}(aq) + 2H_2O$	+1.23
$O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O$	+1.23
$Br_2(l) + 2e^- \longrightarrow 2Br^-(aq)$	+1.07
$NO_3^-(aq) + 4H^+(aq) + 3e^- \longrightarrow NO(g) + 2H_2O$	+0.96
$2Hg^{2+}(aq) + 2e^- \longrightarrow Hg_2^{2+}(aq)$	+0.92
$Hg_2^{2+}(aq) + 2e^- \longrightarrow 2Hg(l)$	+0.85
$Ag^+(aq) + e^- \longrightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^- \longrightarrow H_2O_2(aq)$	+0.68
$MnO_4^-(aq) + 2H_2O + 3e^- \longrightarrow MnO_2(s) + 4OH^-(aq)$	+0.59
$I_2(s) + 2e^- \longrightarrow 2I^-(aq)$	+0.53
$O_2(g) + 2H_2O + 4e^- \longrightarrow 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$	+0.34
$AgCl(s) + e^- \longrightarrow Ag(s) + Cl^-(aq)$	+0.22
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \longrightarrow SO_2(g) + 2H_2O$	+0.20
$Cu^{2+}(aq) + e^- \longrightarrow Cu^+(aq)$	+0.15
$Sn^{4+}(aq) + 2e^- \longrightarrow Sn^{2+}(aq)$	+0.13
$2H^+(aq) + 2e^- \longrightarrow H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \longrightarrow Pb(s)$	−0.13
$Sn^{2+}(aq) + 2e^- \longrightarrow Sn(s)$	−0.14
$Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$	−0.25
$Co^{2+}(aq) + 2e^- \longrightarrow Co(s)$	−0.28
$PbSO_4(s) + 2e^- \longrightarrow Pb(s) + SO_4^{2-}(aq)$	−0.31
$Cd^{2+}(aq) + 2e^- \longrightarrow Cd(s)$	−0.40
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	−0.44
$Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s)$	−0.74
$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$	−0.76
$2H_2O + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$	−0.83
$Mn^{2+}(aq) + 2e^- \longrightarrow Mn(s)$	−1.18
$Al^{3+}(aq) + 3e^- \longrightarrow Al(s)$	−1.66
$Be^{2+}(aq) + 2e^- \longrightarrow Be(s)$	−1.85
$Mg^{2+}(aq) + 2e^- \longrightarrow Mg(s)$	−2.37
$Na^+(aq) + e^- \longrightarrow Na(s)$	−2.71
$Ca^{2+}(aq) + 2e^- \longrightarrow Ca(s)$	−2.87
$Sr^{2+}(aq) + 2e^- \longrightarrow Sr(s)$	−2.89
$Ba^{2+}(aq) + 2e^- \longrightarrow Ba(s)$	−2.90
$K^+(aq) + e^- \longrightarrow K(s)$	−2.93
$Li^+(aq) + e^- \longrightarrow Li(s)$	−3.05

Increasing strength as oxidizing agent

Increasing strength as reducing agent

104B Chemistry (II) Midterm Exam

Answer

1. **(total 16%)**

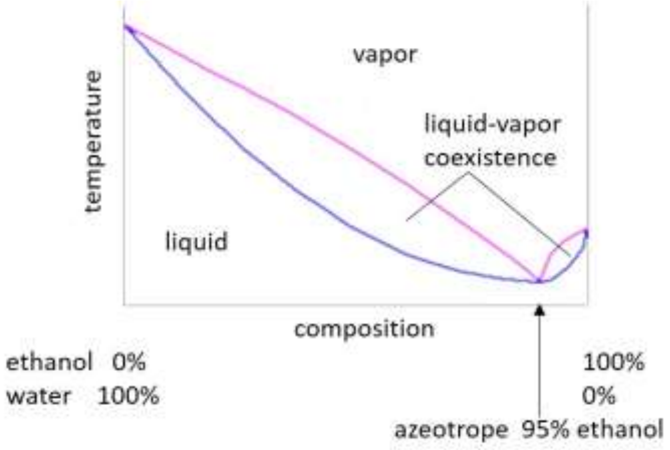
(a) Dilute concentrations molality and molarity are almost the same because the density of the solution is almost equal to that of the pure solvent. **(3%)**

(b) As the water freezes, dissolved minerals in the water precipitate from solution, and dissolved gases in the water can also form minuscule bubbles. The precipitates and tiny bubbles refract light and create an opaque appearance. (The answer which contains either precipitated or bubbles is good enough to get the full credit.) **(3%)**

(c) Henry's law **(2%)**

When one open a beer, the pressure of a beer bottle decreases suddenly. Carbon dioxide escapes from a beer bottle because gases are less soluble in liquids at lower pressure. **(3%)**

(d) The liquid-vapor phase diagram of an ethanol-water mixture is close to the phase diagram drawn below, where the ethanol-water system forms a low-boiling azeotrope and the distillation process will always converge to the azeotrope. **(2%)**



(3%)

2. **(total 10%)**

(a) First, calculate the molar volumes of the solid phase and the liquid phase of X:

$\bar{V}(solid) = 70.0\frac{g}{mol} \div 5.6\frac{g}{cm^3} = 12.5\frac{cm^3}{mol} = 12.5 \times 10^{-6}\frac{m^3}{mol}$ **(1%)**

$\bar{V}(liquid) = 70.0\frac{g}{mol} \div 6.14\frac{g}{cm^3} = 11.4\frac{cm^3}{mol} = 11.4 \times 10^{-6}\frac{m^3}{mol}$ **(1%)**

The Clapeyron equation is $\left(\frac{dP}{dT}\right)_{fus} = \frac{\Delta H_{fus}}{T\,\Delta V}$ **(1%)**

Here, ΔH_{fus} of X is equal to 5.6 kJ/mol. So, $\Delta H > 0$. ΔV is equal to

$[\bar{V}(liquid) - \bar{V}(solid)] = 11.4 \times 10^{-6}\frac{m^3}{mol} - 12.5 \times 10^{-6}\frac{m^3}{mol} = -1.1 \times 10^{-6}\frac{m^3}{mol}$

So, $\Delta V < 0$.

Since T is the absolute temperature, T>0.

Because $\left(\frac{dP}{dT}\right)_{fus} = \frac{\Delta H_{fus}}{T\,\Delta V} < 0$, the increase of pressure would decrease the melting point of X. **(2%)**

(b) $\left(\frac{dP}{dT}\right)_{fus} = \frac{\Delta P}{\Delta T} = \frac{\Delta H_{fus}}{T\,\Delta V} = \frac{5600\frac{J}{mol}}{(28.5+273.15\ K)\times\left(-1.1\times10^{-6}\frac{m^3}{mol}\right)} = -1.688\times10^{7}\frac{J}{K\cdot m^3}$

$\frac{\Delta P}{\Delta T} = \frac{(1000-1.013)\times10^{5}}{301.65-T} = -1.688\times10^{7}\frac{J}{K\cdot m^3}$

T = 307.57 K = 34.42℃ **(5%)**

3. **(total 13%)**

Because the normal melting point of $C_{10}H_8$ is 80.26℃, the table of vapor pressure of $C_{10}H_8$ actually cover the equilibrium conditions of different states, which are listed below

Temperature (K)	P_{vap} (kPa)	State
292	0.006	solid-gas
333	0.25	solid-gas
404	8.34	liquid-gas

(a) There are two equilibrium vapor pressures of liquid naphthalene required to fulfill the calculation $\Delta H_{vap}°$ of $C_{10}H_8$ by using the Clausius-Clapeyron Equation. One data is from the above table, which is P_{vap} = 8.34 kPa at 404 K, and another data is the normal boiling point of naphthalene, which P_{vap} = 101.3 kPa at 218.0℃ (491.15 K). **(2%)**

Insert two equilibrium vapor pressures of liquid naphthalene into the Clausius-Clapeyron Equation:

$$ln\frac{101.3\text{ kPa}}{8.34\text{ kPa}} = \frac{-\Delta H^{\circ}_{vap}}{8.314}\left(\frac{1}{491.15\text{ K}} - \frac{1}{404\text{ K}}\right)$$

$$\Delta H^{\circ}_{vap} = -8.314\times ln\frac{101.3}{8.34} \div \left(\frac{1}{491.15} - \frac{1}{404}\right) \cong 46244\frac{J}{mol} = 46.244\frac{kJ}{mol}$$ **(3%)**

(b) Because $\Delta H_{sub}° = \Delta H_{fus}° + \Delta H_{vap}°$, $\Delta H_{vap}°$ and $\Delta H_{sub}°$ are needed first, in order to calculate $\Delta H_{fus}°$. **(1%)**

$\Delta H_{vap}°$ can be obtained in previous question, which is 46.244 kJ/mol. Then, we need two equilibrium vapor pressures of solid naphthalene required to calculate $\Delta H_{sub}°$ of $C_{10}H_8$ by using the Clausius-Clapeyron Equation. There are two equilibrium data of the solid-gas state in the above table, which is P_{vap} = 0.006 kPa at 292 K, and P_{vap} = 0.25 kPa at 333K. **(2 %)**

Insert two equilibrium vapor pressures of solid naphthalene into the Clausius-Clapeyron

Equation:

$$ln\frac{0.25\text{ kPa}}{0.006\text{ kPa}} = \frac{-\Delta H^{\circ}_{sub}}{8.314}\left(\frac{1}{333\text{ K}} - \frac{1}{292\text{ K}}\right)$$

$$\Delta H^{\circ}_{sub} == -8.314 \times ln\frac{0.25}{0.006} \div \left(\frac{1}{333} - \frac{1}{292}\right) \cong 71948\frac{J}{mol} = 71.948\frac{kJ}{mol}$$ **(3%)**

$$\Delta H^{\circ}_{fus} = \Delta H^{\circ}_{sub} - \Delta H^{\circ}_{vap} = 71.948 - 46.244 = 25.704\frac{kJ}{mol}$$ **(2%)**

4. **(total 12%)**

(a) $\Delta H^\circ = (-1130.7)+(-393.5)+(-241.8) - 32\times(-950.8) = 135.6$ (kJ)

$\Delta S^\circ = 135+213.7+188.8-2\times101.7 = 334.1$ ($J\cdot K^{-1}$)

at 350 K, $\Delta G^\circ = 135.6-350\times334.1\times10^{-3} = 18.67$ (kJ) **分段給分 (3%)**

$K_P = -\Delta G^\circ/RT = \exp(-18.67\times10^{3}/(8.314\times350)) = 1.64\times10^{-3}$ **分段給分 (3%)**

(b) $K_P = K_c(RT)^{\Delta n} = 1.64\times10^{-3} = K_c(0.08314\times350)^2$

$K_c = 1.64\times10^{-3}/846.8 = 1.94\times10^{-6}$ **(3%)**

(c) $K_P = 1$, $\Delta G^\circ = 0$, $T = \Delta H^\circ/\Delta S^\circ = 406$ (K)

或

$\ln(1/1.64\times10^{-3}) = (-135.6\times10^{3}/8.314)((1/T)-(1/350))$, $T = 406$ (K) **(3%)**

5. **(total 12%)**

(a) $K_P = P(NH_3) \times P(H_2S) = (0.732/2)^2 = 1.34\times10^{-1}$ **(3%)**

(b) total amount of gases, $n = 2.00\times0.732/(0.08314\times297) = 5.93\times10^{-2}$ (mol)

the amount of solid decomposed = $51.1\times(5.93\times10^{-2})/2 = 1.52$ (g)

the percentage of the solid remains = (3.08-1.52)/3.08 = 50.6% **(3%)**

(c) for the 4.00-L vessel, the amount of NH_3 (or H_2S) =

$(0.732/2)\times4.00/(0.08314\times297) = 5.93\times10^{-2}$ mol

$51.1\times(5.93\times10^{-2}) = 3.03$ (g) of NH_4HS decomposed , 3.03 < 3.08 ➔

more NH_4HS is decomposed, and there is still some NH_4HS solid in the vessel. **(3%)**

(d) No. The reaction quotient Q may be smaller than equilibrium constant K, but there is no more solid to decompose into the products. **(3%)**

因題目未提供 NH_4HS 相關資料以及最終溫度，若同學討論更多，如 NH_4HS 可能昇華、融化…等，只要合理即可得 3 分，並可斟酌給予額外加分。

6. **(total 9%)**

(a) This reaction must be endothermic. K will increase. **(3%)**

(b) Both of $P(Cl_2)$ and $P(Cl)$ will decrease. **(3%)**

(c) Introducing H_2 will produce HCl. Both of $P(Cl_2)$ and $P(Cl)$ will decrease. **(3%)**

7. **(total 6%)**

(a) Li $\rightarrow$ $Li^+ + e^-$ **(1%)** ; $H_2 + 2\,e^- \rightarrow 2\,H^-$ **(1%)**

H_2 is the oxidizing agent; Li is the reducing agent. **(1%)**

(b) $2Br^- \rightarrow Br_2 + 2e^-$ **(1%)** ; $Cl_2 + 2e^- \rightarrow 2Cl^-$ **(1%)**

Cl_2 is the oxidizing agent; Br^- is the reducing agent. **(1%)**

8.

Anode (oxidation): $3\ Fe(s) \rightarrow 3\ Fe^{2+}(aq) + 6\ e^-$

Cathode (reduction): $2\ Cr^{3+}(aq) + 6\ e^- \rightarrow 2\ Cr(s)$

Overall: $3\ Fe(s) + 2\ Cr^{3+}(aq) \rightarrow 3\ Fe^{2+}(aq) + 2\ Cr(s)$

$$E^o_{cell} = E^o_{cathode} - E^o_{anode} = E^o_{Cr^{3+}/Cr} - E^o_{Fe^{2+}/Fe}$$

$$\mathbf{E^\circ_{cell}} = -0.74\text{ V} - (-0.44\text{ V}) = \mathbf{-0.30\text{ V}}$$ **(4%)**

9. $E°(cell) = E°(cath) - E°(anod) = -2.37-(-0.76) = -1.61$ V

$$E^o_{cell} = \frac{0.0257\text{ V}}{n}\ln K, \qquad \ln K = \frac{nE^o_{cell}}{0.0257\text{ V}}, \qquad K = e^{\frac{nE^o_{cell}}{0.0257\text{ V}}}$$

$K = e^{[(2)(-1.61V)/0.0257V]} = 3.86 \times 10^{-55}$ **(4%)**

10.

Anode (oxidation): $Cu^+(aq) \rightarrow Cu^{2+}(aq) + e^-$

Cathode (reduction): $Cu^+(aq) + e^- \rightarrow Cu(s)$

Overall: $2\ Cu^+(aq) \rightarrow Cu^{2+}(aq) + Cu(s)$

(a) $$E^o_{cell} = E^o_{cathode} - E^o_{anode} = E^o_{Cu^+/Cu} - E^o_{Cu^{2+}/Cu^+}$$

$$E^\circ_{\mathbf{cell}} = 0.52\text{ V} - 0.15\text{ V} = \mathbf{0.37\text{ V}}$$ **(4%)**

(b) $\Delta G° = -nFE° = -1\times96500\times0.37 = -36\times10^3$ (J) = -36 (kJ) **(3%)**

(c) $K = \exp(-\Delta G°/RT) = \exp(36\times10^3/(8.314\times298)) = 2.0\times10^6$ **(3%)**

11. (a)unchanged (b) unchanged (c) squared (d) doubled (e) doubled **(各 1%，共 5%)**

12.

$Ag(s) \rightarrow Ag^+(aq) + e^-$

$AgCl(s) + e^- \rightarrow Ag(s) + Cl^-(aq)$

$AgCl(s) \rightarrow Ag^+(aq) + Cl^-(aq)$

$E° = 0.22 - 0.80 = -0.58$ (V)

$K_{sp} = \exp(-\Delta G°/RT) = \exp(-1\times96500\times0.58/(8.314\times298)) = 1.5\times10^{-10}$ **(5%)**