2018 SPRING Semester Final Examination
For General Chemistry I

Date: June 18 (Mon),   Time Limit: 19:00 ~ 21:00

Write down your information neatly in the space provided below; print your Student ID in the upper right corner of every page.

Prof. Name	Class	Student I.D. Number	Name

Problem	points	Problem	points	TOTAL pts
1	/6	**7**	/9	
2	/7	**8**	/7	
3	/9	**9**	/7	
4	/6	**10**	/9	**/100**
5	/12	**11**	/10	
6	/10	**12**	/8	

** This paper consists of 13 sheets with 12 problem sets (pages 11 & 12: constants & periodic table, page 13: claim form). Please check all page numbers before taking the exam. Write down your work and answers in the Answer sheet.

  Please write down the unit of your answer when applicable. You will get 30% deduction for a missing unit.

NOTICE: SCHEDULES on RETURN and CLAIM of the MARKED EXAM PAPER.
(채점 답안지 분배 및 이의신청 일정)

 1. Period, Location, and Procedure

   1)   Return and Claim Period: *June 20 (Wed, 15: 00 ~ 17:00 p.m.)*

   2)   *Location: Room in Creative Learning Bldg. (E11)*

Class	Room	Class	Room	Class	Room
A	*203*	*D*	*207*	*G*	*211*
B	*205*	*E*	*208*		
C	*206*	*F*	*210*		

   3)   Procedure:

   Rule 1: Students cannot bring their own writing tools into the room. (Use a pen only provided by TA)

   Rule 2: With or without claim, you must submit the paper back to TA. (Do not go out of the room with it)

(During the period, you can check the marked exam paper from your TA and should hand in the paper with a FORM for claims if you have any claims on it. The claim is permitted only on the period. Keep that in mind! A solution file with answers will be uploaded on **June 20** on the web.)

2. Final Confirmation

   1) Period: June 21 (Thu)

   2) Procedure: During this period, you can check final score of the examination *on the website* again.

   ** *For further information, please visit General Chemistry website at www.gencheminkaist.pe.kr.*

1. (Total 6 pts)

(a) The air over an unknown liquid is saturated with the vapor of that liquid at 25 °C and a total pressure of 0.980 atm. Suppose that a sample of 6.00 L of the saturated air is collected and the vapor of the unknown liquid is removed from that sample by cooling and condensation. The pure air remaining occupies a volume of 3.75 L at -50 °C and 1.000 atm. Calculate <u>the vapor pressure</u> of the unknown liquid at 25 °C.

(Answer)

(b) Among the seven species below, <u>choose two species</u> whose boiling points are the closest to that of the unknown species above.
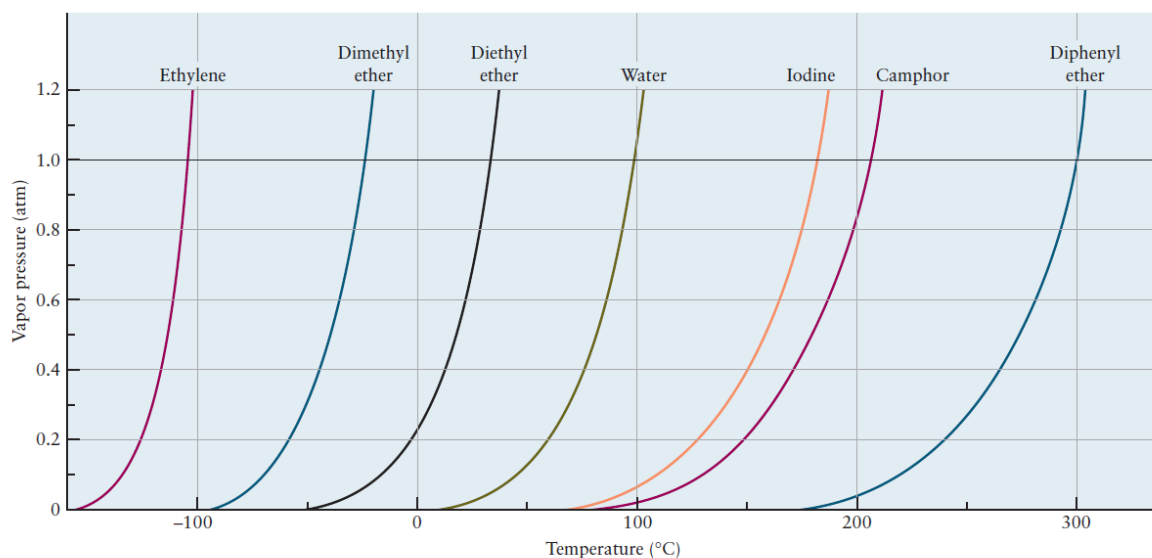

FIGURE 10.17 The vapor pressure of a solid or liquid depends strongly on temperature. The temperature at which the vapor pressure becomes 1 atm defines the normal boiling point of a liquid and the normal sublimation point of a solid.

(Answer)

2. (Total 7 pts)

(a) <u>Arrange</u> the following substances <u>in order of decreasing</u> critical temperature (T_c) :

   Ar, H$_2$, Kr, CCl$_3$F

(Answer)

(b) Which of the following substances should we expect to have <u>the lower vapor pressure</u> at a given temperature :

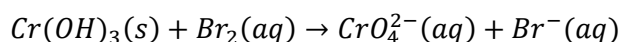(1) CO_2 or SO_2

(Answer)

(2) CH_3OCH_3 or CH_3CH_2OH

(Answer)

3. (Total 9 pts)

(a) <u>Balance the following reaction</u> that takes place in basic solution.

$$Cr(OH)_3(s) + Br_2(aq) \rightarrow CrO_4^{2-}(aq) + Br^-(aq)$$

(Answer)

(b) 103.0 g Cr(OH)$_3$ solid powder is added to the solution that contains 0.3 mol Br$_2$ and 2 mol NaOH dissolved in 1 kg water. Estimate <u>the freezing point of the solution</u> after the reaction is completed, assuming K_f = 1.86 K·kg·mol^{-1}. (Atomic mass: H, 1.008; O, 15.999; Na, 22.990; Cr, 51.996; Br, 79.904).
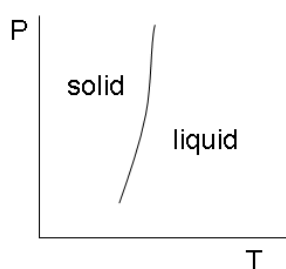
(Answer)

4. (Total 6 pts)

(a) At its melting point (624 °C) at 1 atm, the density of solid plutonium is 16.24 g/cm^3 while the density of the liquid is 16.66 g/cm^3. Predict <u>what phase changes</u>, if any, will occur when a small sample of liquid plutonium at 625 °C is strongly compressed isothermally.

(Answer)

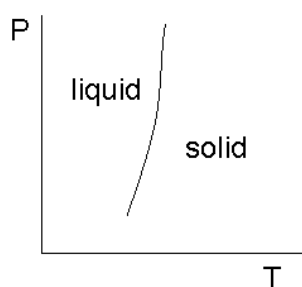(b) If the phase diagram is drawn for plutonium at the liquid-solid boundary around 1 atm and 624 °C, what will <u>it look like</u>?
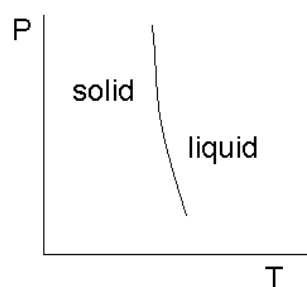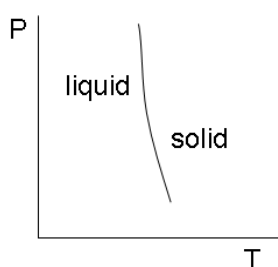
(1)

(2)

(3)

(4)

Give <u>a reasoning</u> for your answer as briefly as possible.

(Answer)

5. (Total 12 pts) One mole of liquid water is allowed to equilibrate with its vapor inside a one-liter vessel. The vapor pressure at 20 ℃ is then found to be 17.5 torr.

(a) <u>How many moles</u> of water exist in the vapor state? Assume ideal behavior.
(Answer)

(b) Suppose that the volume of the vessel is doubled to 2L. What is <u>the new vapor pressure</u>?
(Answer)

(c) <u>How many moles</u> of water vapor are present in the larger container?
(Answer)

(d) Water's vapor pressure falls from 17.5 torr at 20 ℃ to 9.2 torr at 10 ℃. If equilibrium is first established at 20 ℃ in a volume of 1 L, then approximately <u>how many mL of water</u> will condense when the temperature is lowered to 10 ℃? Assume that liquid water has a density of 1 g/mL.
(Answer)

(e) The vapor pressure of water/ sucrose solution ($C_{11}H_{22}O_{11}$, table sugar) is found to be 16.1 torr at 20 ℃, lower by 1.4 torr compared with pure water. The solution, presumed to be ideal, contains 500 g of water. Compute <u>the molality</u>.
(Answer)

6. (Total 10 pts) A sample of pure solid naphthalene ($C_{10}H_8$) weighing 0.6410 g is burned completely with oxygen to $CO_2(g)$ and $H_2O(l)$ in a constant-volume calorimeter at 25°C. The amount of heat evolved is observed to be 25.79 kJ. (the M_w of $C_{10}H_8$ is 128.17g/mol, R = 8.3145J K^{-1} mol^{-1})

(a) Write and <u>balance the chemical equation</u> for the combustion reaction.

(Answer)

(b) Calculate <u>the standard change in internal energy</u> ($\Delta U°$) for the combustion of 1.000 mol naphthalene to $CO_2(g)$ and $H_2O(l)$.

(Answer)

(c) Calculate <u>the standard enthalpy change</u> ($\Delta H°$) for the same reaction as in part (b).

(Answer)

7. (Total 9 pts) Suppose 2.00 mol of a monatomic ideal gas is initially at a pressure of 3.00 atm and a temperature T = 350 K. It is expanded irreversibly and adiabatically (q = 0) against a constant external pressure of 1.00 atm until the volume has doubled.

(a) Calculate <u>the final volume</u>.

(Answer)

(b) Calculate <u>w and ΔU</u> for this process, in joules.

(Answer)

(c) Calculate <u>the final temperature</u> of the gas.

(Answer)

8. (Total 7 pts)

(a) Calculate the entropy of crystal made of 1 mol carbon monoxide (CO) at T = 0K when CO molecules are in random, but parallel arrangement.

(Answer)

(b) Dichloromethane (CH_2Cl_2) is one of the methane (CH_4) derivatives. If 1 mol of CH_2Cl_2 adopts a random arrangement in its crystal form, what would be its entropy value at T = 0K?

(Answer)

9. (Total 7 pts) Calculate ΔS_{sys}, ΔS_{surr}, and ΔS_{tot} for the irreversible isothermal expansion at 298 K of 5.00 mol of an ideal gas from a pressure of 10.0 atm to constantly held external pressure of 1.00 atm.

(Answer)

10. (Total 9 pts) For the reaction equilibrium,

$$4 \text{ NH}_3 \text{ (g)} + 7 \text{ O}_2 \text{ (g)} \leftrightharpoons 4 \text{ NO}_2 \text{ (g)} + 6 \text{ H}_2\text{O (g)}$$
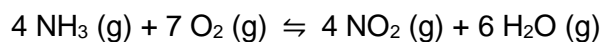
(a) Calculate $\Delta G°$ and the equilibrium constant K at 25°C for the reaction with the standard free energies of formations, $\Delta G_f°$, in kJ/mol: H_2O, -228.59; NH_3, -16.48; NO_2, 51.29.

(Answer)

(b) Calculate $\Delta G°$ and the equilibrium constant K at 0 °C for the reaction with the standard enthalpy of formations, $\Delta H_f°$, in kJ/mol: H_2O, -241.82; NH_3, -46.11; NO_2, 33.18. Assume that standard reaction enthalpy ($\Delta H°$) and entropy ($\Delta S°$) do not change at different temperatures.

(Answer)

(c) Calculate the standard entropy of O_2 at 25°C given with the other standard entropies at the same temperature in J/K·mol: H_2O, 188.72; NH_3, 192.34; NO_2, 239.95.

(Answer)

11. (Total 10 pts) Explain <u>the effect</u> of each of the following stresses <u>(from right to left, from left to right, or no effect)</u> on the position of the following equilibrium:

$$3NO(g) \rightleftharpoons N_2O(g) + NO_2(g)$$
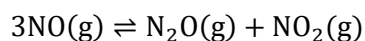
The reaction as written is exothermic.

(a) $N_2O(g)$ is added to the equilibrium mixture without change of volume or temperature.

(Answer)

(b) The volume of the equilibrium mixture is reduced at constant temperature.

(Answer)

(c) The equilibrium mixture is cooled.

(Answer)

(d) Gaseous argon (which does not react) is added to the equilibrium mixture while both the total gas pressure and the temperature are kept constant.

(Answer)

(e) Gaseous argon is added to the equilibrium mixture without changing the volume.

(Answer)

12. (Total 8 pts) Below equation is Van't Hoff equation, which explains the relationship between temperature and equilibrium constants.

$$\ln\left(\frac{K_2}{K_1}\right) = -\frac{\Delta H°}{R}\ \left[\ \frac{1}{T_2} - \frac{1}{T_1}\ \right]$$

(a) Calculate <u>the equilibrium constant</u> of next reaction at standard condition. Is the reaction at this condition <u>forward favored or backward favored</u>?

$$CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g), \ \Delta G°_{reaction} = 113.63 \text{ kJ/mol}$$
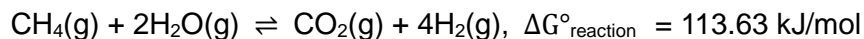
(Answer)

(b) Compute <u>the new equilibrium constant</u> when the reaction temperature was elevated to 1000 K. Use next value of given table. Is the new equilibrium <u>forward favored or backward favored</u>?

	$CH_4(g)$	$H_2O(g)$	$CO_2(g)$	$H_2(g)$
$\Delta H°_{formation}$ (kJ mol^{-1})	−74.9	−241.8	−393.5	0

(Answer)

Physical Constants

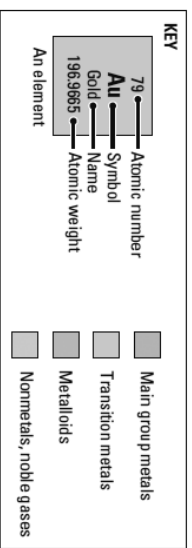|	
Avogadro's number	$N_A = 6.02214179 \times 10^{23}\ \text{mol}^{-1}$
Bohr radius	$a_0 = 0.52917720859\ \text{Å} = 5.2917720859 \times 10^{-11}\ \text{m}$
Boltzmann's constant	$K_B = 1.3806504 \times 10^{-23}\ \text{J K}^{-1}$
Electronic charge	$e = 1.602176487 \times 10^{-19}\ \text{C}$
Faraday constant	$F = 96485.3399\ \text{C mol}^{-1}$
Masses of fundamental particles:	
Electron	$m_e = 9.10938215 \times 10^{-31}\ \text{kg}$
Proton	$m_P = 1.672621637 \times 10^{-27}\ \text{kg}$
Neutron	$m_n = 1.674927211 \times 10^{-27}\ \text{kg}$
Permittivity of vacuum	$\varepsilon_o = 8.854187817 \times 10^{-12}\ \text{C}^{-2}\ \text{J}^{-1}\ \text{m}^{-1}$
Planck's constant	$h = 6.62606896 \times 10^{-34}\ \text{J s}$
Ratio of proton mass to electron mass	$m_P / m_e = 1836.15267247$
Speed of light in a vacuum	$c = 2.99792458 \times 10^8\ \text{m s}^{-1}$ (exactly)
Standard acceleration of terrestrial gravity	$g = 9.80665\ \text{m s}^{-2}$ (exactly)
Universal gas constant	$R = 8.314472\ \text{J mol}^{-1}\ \text{K}^{-1}$ $= 0.0820574\ \text{L atm mol}^{-1}\ \text{K}^{-1}$

Values are taken from the 2006 CODATA recommended values,
as listed by the National Institute of Standards and Technology.

Conversion factors

Ångström	$1\ \text{Å} = 10^{-10}\ \text{m}$
Atomic mass unit	$1\ \text{u} = 1.660538782 \times 10^{-27}\ \text{kg}$
	$1\ \text{u} = 1.492417830 \times 10^{-10}\ \text{J} = 931.494028\ \text{MeV}$ (energy equivalent form $E = mc^2$)
Calorie	$1\ \text{cal} = 4.184\ \text{J}$ (exactly)
Electron volt	$1\ \text{eV} = 1.602177 \times 10^{-19}\ \text{J} = 96.485335\ \text{kJ mol}^{-1}$
Foot	$1\ \text{ft} = 12\ \text{in} = 0.3048\ \text{m}$ (exactly)
Gallon (U. S.)	$1\ \text{gallon} = 4\ \text{quarts} = 3.785412\ \text{L}$ (exactly)
Liter	$1\ \text{L} = 10^{-3}\ \text{m}^{-3} = 10^3\ \text{cm}^3$ (exactly)
Liter-atmosphere	$1\ \text{L atm} = 101.325\ \text{J}$ (exactly)
Metric ton	$1\ \text{t} = 1000\ \text{kg}$ (exactly)
Pound	$1\ \text{lb} = 16\ \text{oz} = 0.4539237\ \text{kg}$ (exactly)
Rydberg	$1\ \text{Ry} = 2.17987197 \times 10^{-18}\ \text{J} = 1312.7136\ \text{kJ mol}^{-1} = 13.60569193\ \text{eV}$
Standard atmosphere	$1\ \text{atm} = 1.01325 \times 10^5\ \text{Pa} = 1.01325 \times 10^5\ \text{kg m}^{-1}\ \text{s}^{-2}$ (exactly)
Torr	$1\ \text{torr} = 133.3224\ \text{Pa}$

PERIODIC TABLE OF THE ELEMENTS

KEY

79	Atomic number
Au	Symbol
Gold	Name
196.9665	Atomic weight

An element

- Main group metals
- Transition metals
- Metalloids
- Nonmetals, noble gases

Period number

Group number, U.S. system

Group number, IUPAC system

Numbers in parentheses are mass numbers of radioactive isotopes.

Period	1 / 1A / (1)	2 / 2A / (2)	3 / 3B / (3)	4 / 4B / (4)	5 / 5B / (5)	6 / 6B / (6)	7 / 7B / (7)	8 / 8B / (8)	9 / 8B / (9)	10 / 8B / (10)	11 / 1B / (11)	12 / 2B / (12)	13 / 3A / (13)	14 / 4A / (14)	15 / 5A / (15)	16 / 6A / (16)	17 / 7A / (17)	18 / 8A / (18)
1	1 **H** Hydrogen 1.0079																	2 **He** Helium 4.0026
2	3 **Li** Lithium 6.941	4 **Be** Beryllium 9.0122											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.0067	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984	10 **Ne** Neon 20.1797
3	11 **Na** Sodium 22.9898	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.9815	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.9738	16 **S** Sulfur 32.065	17 **Cl** Chlorine 35.453	18 **Ar** Argon 39.948
4	19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.9559	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.9380	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.9332	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.38	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.64	33 **As** Arsenic 74.9216	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.798
5	37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.9058	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.9064	42 **Mo** Molybdenum 95.96	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.9055	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.9045	54 **Xe** Xenon 131.293
6	55 **Cs** Cesium 132.9055	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.9055	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.084	79 **Au** Gold 196.9666	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.9804	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
7	87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (267)	105 **Db** Dubnium (268)	106 **Sg** Seaborgium (271)	107 **Bh** Bohrium (272)	108 **Hs** Hassium (277)	109 **Mt** Meitnerium (276)	110 **Ds** Darmstadtium (281)	111 **Rg** Roentgenium (280)	112 — (285)	113 — (284)	114 — (287)	115 — (288)	116 — (293)	—	118 — (294)

Lanthanides 6	58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.9076	60 **Nd** Neodymium 144.242	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.9254	66 **Dy** Dysprosium 162.500	67 **Ho** Holmium 164.9303	68 **Er** Erbium 167.259	69 **Tm** Thulium 168.9342	70 **Yb** Ytterbium 173.054	71 **Lu** Lutetium 174.9668
Actinides 7	90 **Th** Thorium 232.0381	91 **Pa** Protactinium 231.0359	92 **U** Uranium 238.0289	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Claim Form for General Chemistry Examination

Class:_____, Professor Name:_____, I.D.# :_____, Name:_____

If you have any claims on the marked paper, please write down them on this form and *submit this with your paper in the assigned place*. (And this form should be attached *on the top of the marked paper with a stapler*.) Please, *copy this*

By Student		By TA	
		Accepted? Yes(√) or No(√)	
Question #	Claims	Yes: ☐	No: ☐
		Pts (+/-)	Reasons

sheet if you need more before use.

Problem	points	Problem	points	TOTAL pts
1	4+2/6	**7**	3+3+3/9	
2	3+4/7	**8**	3+4/7	
3	3+6/9	**9**	3+3+1/7	
4	3+3/6	**10**	3+3+3/9	**/100**
5	2x3+3+3/12	**11**	2x5/10	
6	3+3+4/10	**12**	4+4/8	

Missing units in the answer: -1 pt, "-1 pt" means "minus 1 point"

1. (Total 6 pts)

(a) (4 pts) P_{air} 2 pts, $P_{unknown}$ 2 pts

The chemical amount of air that was present in the 6.00 L portion of air mixed with the vapors of the unknown can be computed because its physical state after purification is fully described. Assuming ideality

$$n_{air} = \frac{PV}{RT} = \frac{(1.000 \text{ atm})(3.75 \text{ L})}{(0.08206 \text{ L atm mol}^{-1}\text{K}^{-1})(223.15 \text{ K})} = 0.2048 \text{ mol}$$

$$P_{air} = \frac{n_{air}RT}{V}$$

$$P_{air} = \frac{(0.2048 \text{ mol})(0.08206 \text{ L atm mol}^{-1}\text{K}^{-1})(298.15 \text{ K})}{6.00 \text{ L}} = 0.835 \text{ atm}$$

But the total pressure above the unknown was 0.980 atm. By Dalton's law

$$P_{unknown} = 0.980 - 0.835 = 0.145 \text{ atm}$$

(b) (2 pts) each liquid 1 pt

The unknown liquid has a vapor pressure of 0.145 atm at 25 °C. Thus its vapor pressure curve lies between those of water and diethyl ether. Therefore, **water and diethyl ether** have the boiling points closest to the unknown liquid.

2. (Total 7 pts)

(a) (3 pts)
CCl_3F is a polar molecule (strong dipole-dipole forces)
We expect that CCl_3F will have the highest T_c.
The remaining 3 substances can interact only by way of induced dipole-dipole (London dispersion force)
We would predict T_c to decrease in the order Kr(36 electrons), Ar(18 electrons), and H_2(2 electrons).

(b) (4 pts) each 2 pts
(1) London forces between SO_2 molecules should be greater than CO_2.
Moreover, as SO_2 is polar but CO_2 is not.
Therefore SO_2 has the lower vapor pressure.

(2) Molecular weights are equal.
However, there will be strong hydrogen bonding in ethanol.
We expect ethanol to have the lower vapor pressure.

3. (Total 9 pts)

(a) (3 pts)
$10\ OH^-$ (aq) + 2 $Cr(OH)_3$ (s) + 3 Br_2 (aq) $\rightarrow$ 2 CrO_4^{2-} (aq) + 6 Br^- (aq) + 8 H_2O (l)
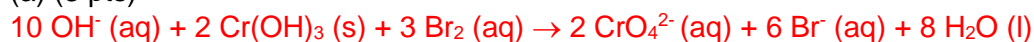
(b) (6 pts) mole change 2 pts, total water mass 1 pt, freezing point depression 3 pts
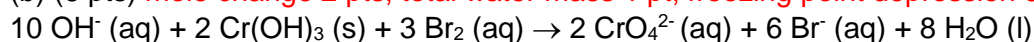
$10\ OH^-$ (aq)	+ 2 $Cr(OH)_3$ (s)	+ 3 Br_2 (aq)	$\rightarrow$ 2 CrO_4^{2-} (aq)	+ 6 Br^- (aq)	+ 8 H_2O (l)
2 mol	1 mol	0.3 mol			
-1 mol	-0.2 mol	-0.3 mol	+0.2 mol	+0.6 mol	+0.8 mol
1 mol	0.8 mol	0 mol	0.2 mol	0.6 mol	0.8 mol

After the reaction, 2 mol Na^+(aq) + 1 mol OH^-(aq) + 0.2 mol CrO_4^{2-} (aq) + 0.6 mol Br^-(aq) = 3.8 moles of solute are left in the aqueous phase. Total water mass is 1 kg + (0.8 mol)*(15.999+1.008*2 g/mol)*(1/1000 kg/g) = 1.014 kg.
Use these to calculate the freezing point depression of
$\Delta T_f = -K_f{}^*m = -(1.86\ K\cdot kg\cdot mol^{-1})*(3.8\ mol/1.014\ kg) = -6.97\ K$
Thus, the freezing point of this solution mixture after the reaction is **-6.97 °C**.

4. (Total 6 pts)

(a) (3 pts)
At 624 °C, both liquid and solid are at equilibrium and the liquid is denser. Therefore, when it is compressed at the same temperature, the equilibrium will shift to the denser side and the solid will melt. Namely, the melting point lowers. At 625 °C (above melting point), plutonium will exist as liquid, and as it gets compressed, the melting point will lower. Thus, because the maintained temperature will be higher than the melting temperature and the sample will remain in the liquid state. (No change will happen.)

(b) (3 pts)
At lower temperature: solid $\rightarrow$ either (1) or (3); melting point lowers at higher pressure $\rightarrow$ (3) or (4). Therefore, (3) is the right shape.

5. (Total 12 pts)

(a) (2 pts)

P= 17.5 torr $\times \frac{1 \text{ atm}}{760 \text{ torr}}$ = 0.023 atm

V= 1L, T= 20℃ = 293 K, R= 0.082 atm L mol^{-1} K^{-1}

n= $\frac{PV}{RT}$ = <u>9.57×10^{-4} mol</u>

(b) (2 pts)

The same as in a 1L container: <u>17.5 torr</u>
The vapor pressure depends only on temperature.

(c) (2 pts)

Since the volume doubles, so must the number of moles.

9.57×10^{-4} moles $\times 2$= <u>1.91×10^{-3} mol</u>

(d) (3 pts)

P= 9.2 torr $\times \frac{1 \text{ atm}}{760 \text{ torr}}$ = 0.012 atm

V=1L, T= 10℃ = 283 K

n= $\frac{PV}{RT}$ = $\frac{0.012 \times 1}{0.082 \times 283}$ = 5.2×10^{-4} mol

9.57×10^{-4} mol $- 5.2 \times 10^{-4}$ mol = 4.4×10^{-4} mol

The difference, 4.4×10^{-4} mol, condensate

4.4×10^{-4} mol $\times \frac{18g}{mol} \times \frac{1mL}{1g}$ = <u>7.9×10^{-3} mL</u>

(e) (3 pts)

n_1=500g H_2O $\times \frac{1 \text{ mol}}{18g}$= 27.8 mol H_2O

$X_1 = \frac{n_1}{n_1 + n_2}$ $X_1(n_1 + n_2) = n_1$

$n_2 = \frac{n_1(1 - X_1)}{X_1}$

$P_1 = X_1 P_1^0$

$X_1 = \frac{P_1}{P_1^0} = \frac{16.1 \text{ torr}}{17.5 \text{ torr}}$ = 0.92

$n_2 = \frac{n_1(1 - X_1)}{X_1} = \frac{(27.8)(1 - 0.92)}{0.92}$ = 2.47 mol

molality= $\frac{2.417 \text{mol sucrose}}{0.5 \text{kg } H_2O}$ = <u>4.83 m</u>

6. (Total 10 pts)

(a) (3 pts)

a) The equation is $\boxed{C_{10}H_8(s) + 12\,O_2(g) \longrightarrow 10\,CO_2(g) + 4\,H_2O(l)}$.

(b) (3 pts)

b) The amount of heat evolved ($-q$) in the combustion of 0.6410 g of naphthalene was observed to equal 25.79 kJ. Since the combustion was performed at constant volume, no work was done on the system ($w = 0$). Therefore, $\Delta U = q + w = -25.79\text{ kJ} + 0 = -25.79\text{ kJ}$. Put this ΔU on a molar basis to correspond to the 1 mol of naphthalene appearing in the balanced equation

$$\Delta U = \left(\frac{-25.79\text{ kJ}}{0.6410\text{ g }C_{10}H_8}\right) \times \left(\frac{128.17\text{ g }C_{10}H_8}{1\text{ mol }C_{10}H_8}\right) = -5157\text{ kJ mol}^{-1}$$

The temperature is 25°C both before and after the reaction. Therefore for the equation written above (which shows 1 mol of naphthalene) $\Delta U° = \boxed{-5157\text{ kJ}}$.

(c) (4 pts)

c) To calculate $\Delta H°$ use the definition

$$\Delta H° = \Delta U° + \Delta(PV)$$

Assume that the gases are ideal and that the volumes of the solids are negligible. Then $\Delta(PV) = (\Delta n_g)RT$, and

$$\Delta H° = \Delta U° + (\Delta n_g)RT$$

The Δn_g is the change in the number of moles of gases during the reaction. The combustion of 1 mol of naphthalene produces 10 mol of gas, while consuming 12 mol of gas. Accordingly

$$(\Delta n_g)RT = (-2\text{ mol})(8.3145\text{ J K}^{-1}\text{mol}^{-1})(298.15\text{ K}) = -4.96\text{ kJ}$$

$$\Delta H° = \Delta U° + (\Delta n_g)RT = -5157\text{ kJ} - 4.96\text{ kJ} = \boxed{-5162\text{ kJ}}$$

7. (Total 9 pts)

(a) (3 pts)

Initially, n = 2.00 mol, P_0 = 3.00 atm, T_0 = 350 K. Thus, V_0 = nRT/P = 19.1 L.
After expansion, V = $2V_0$ = 38.3 L.

(b) (3 pts)

w = $-P_{ext}$ ΔV = -1.00 atm * 19.1 L = -101325 Pa * 0.0191 m³ = -1940 J.
Because the process is adiabatic, ΔU = w = -1940 J.

(c) (3 pts)

For monatomic ideal gas, $\Delta U = \frac{3}{2}nR\Delta T$. Therefore, ΔT = -77.8 K, and the final temperature is 272 K.
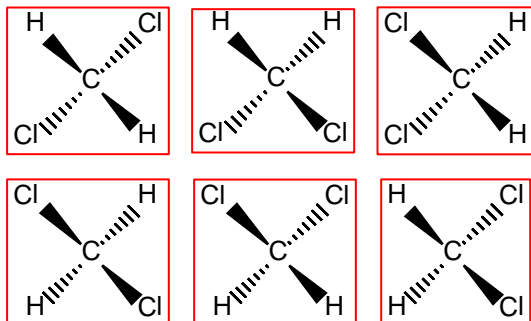
8. (Total 7 pts)

(a) (3 pts)
$S = k_B \ln 2^{N_A} = k_B N_A \ln 2 = 5.76$ J/K

(b) (4 pts) 6 orientations 2 pts; entropy 2 pts
There are six orientations of CH_2Cl_2 molecule as shown below:

$S = k_B \ln 6^{N_A} = k_B N_A \ln 6 = 14.90$ J/K

9. (Total 7 pts) ΔS_{sys} 3 pts, ΔS_{surr} 3 pts, ΔS_{tot} 1 pt

$\Delta S_{tot} = \Delta S_{sys} + \Delta S_{surr}$
Since S is a function of state, ΔS_{sys} for the irreversible process is equal to ΔS_{sys} for the reversible process with the same initial and final states.
Thus, $\Delta S_{sys} = q_{rev}/T = -w/T = -[-nRT \ln (V_2/V_1)]/T = -[-nRT \ln (P_1/P_2)]/T = nR \ln (P_1/P_2)$
$= (5.00$ mol$)(8.315$ J K^{-1} mol$^{-1}) \ln (10.0$ atm$/1.00$ atm$)$
$= 95.7$ J K^{-1}

$\Delta S_{surr} =$ (heat given up by the surrounding)/T = -(heat absorbed by the system)/T
$= -q_{irrev}/T = -(-w_{irrev})/T = (w_{irrev})/T = -P_{ext}\Delta V/T = -(1$ atm$)(V_f-V_i)/T$
$V_i = nRT/P_i = (5.00$ mol$)(0.08206$ L atm K^{-1} mol$^{-1})(298$ K$)/10.0$ atm $= 12.2$ L
$V_f = nRT/P_f = (5.00$ mol$)(0.08206$ L atm K^{-1} mol$^{-1})(298$ K$)/1.00$ atm $= 122$ L
Thus,
$\Delta S_{surr} = -(1$ atm$)(V_f-V_i)/T = -(1$ atm$)(122$ L $- 12.2$ L$)/298$ K $= -(109.8$ L atm$)/298$ K
$= -(109.8$ L atm$)(101.3$ J$/1$ L atm$)/298$ K $= -37.3$ J K^{-1}

Hence, $\Delta S_{tot} = \Delta S_{sys} + \Delta S_{surr} = 95.7$ J K$^{-1} + (-37.3$ J K$^{-1}) = 58.4$ J K^{-1}

10. (Total 9 pts)

(a) (3 pts)

$\Delta G°$/(kJ/mol) = 4 * 51.29 + 6 * (-228.59) − 4 * (-16.48) − 7 * 0 = -1100.46

From $\Delta G = \Delta G° + RT° \ln Q = 0$, when Q = K, we get

$$K = \exp\left(-\frac{\Delta G°}{RT°}\right) = 6._2 \times 10^{192}.$$

(b) (3 pts)

At 25°C,

$\Delta H°$/(kJ/mol) = 4 * 33.18 + 6 * (-241.82) − 4 * (-46.11) − 7 * 0 = -1133.76

$$\Delta S° = -\frac{\Delta G° - \Delta H°}{T°} = -111.7 \text{ J/mol} \cdot \text{K}$$

Therefore, at T = 273.15 K,

$$\Delta G° = \Delta H° - T\Delta S° = -1103.25 \text{ kJ/mol}$$

$$K = \exp\left(-\frac{\Delta G°}{RT}\right) = 9._3 \times 10^{210}.$$

(c) (3 pts)

$\Delta S°$/(J/K·mol) = 4 * 239.95 + 6 * 188.72 − 4 * 192.34 − 7 x = -111.7

Therefore, x = 204.9 and the standard entropy is 204.9 J/K·mol.

* exp(443.9) = exp(192.8 * ln 10) = (exp (ln 10))^192.8 = 10^192.8 = 10^0.8 * 10^192
  = 6.3 * 10^192

11. (Total 10 pts) for each, 2 pts

Chemical systems always tend toward equilibrium.[2] If a stress is applied to a system at equilibrium, the system reacts to minimize the stress and to reach a new equilibrium.

a) The stress is the addition of $N_2O(g)$. The system reacts to decrease the concentration of N_2O. The reaction proceeds from ⌈right to left⌉ until a new equilibrium is reached.

b) The stress is the reduction in volume. The partial pressures of all the compounds will momentarily rise. The equilibrium will then shift in such a way as to reduce the number of molecules of gas (chemical amount of gas) in the container and reduce the total pressure. There are three moles of gas on the reactant side of the equation and two moles of gas on the product side. The equilibrium will thus shift from ⌈left to right⌉.

c) The reaction is exothermic. Cooling the mixture shifts the equilibrium from ⌈left to right⌉ (to favor the products).

d) In order to maintain a constant pressure, the volume of the system must have increased. Thus, the reaction will shift from ⌈right to left⌉.

e) The partial pressures of the reacting gases are unchanged by the addition of an inert gas, and the equilibrium law is independent of total pressure. There is ⌈no effect⌉ on the position of the equilibrium.

12. (Total 8 pts)

(a) (4 pts) K 3 pts, backward 1 pt
$\ln K = -\Delta G°/RT$ = - 113.63 x 1000 J mol^{-1} / (8.314 J K^{-1} mol^{-1} x 298 K) = - 45.86
∴ K = 1.21 x 10^{-20}
Because Equilibrium constant is smaller than one, it is backward favored at 298K.

(b) (4 pts) K 3 pts, forward 1 pt
Let equilibrium constant K_1 for 25 °C(298K), and K_2 for 1000K
$\Delta H°_{reaction} = \Delta H°_{formtaion}(\text{product}) - \Delta H°_{formtaion}(\text{reactant})$
= [(- 393.5 kJ/mol) x 1mol + (0 kJ/mol) x 3mol)] – [(-74.9 kJ/mol) x 1mol + (-241.8 kJ/mol) x 2mol]
= 165 kJ
Let the reaction is proceeded for 1mol CO_2 (g). Then $\Delta H°_{reaction}$ can be considered as 165 kJ/mol.
$\ln\left(\frac{K_2}{K_1}\right) = -\frac{\Delta H°}{R} \left[\frac{1}{T_1} - \frac{1}{T_2} \right] = -\frac{165 \text{ kJ/mol}}{8.314 \text{ J/K mol}} \left[\frac{1}{1000 \text{ K}} - \frac{1}{298 \text{ K}} \right] = 46.75$
∴ $K_2 = K_1$ x $e^{46.75}$ = 2.4324
New equilibrium constant is larger than one. Therefore, it is forward favored at 1000K.