First Midterm Examination, CH20B, Winter 2014

Thursday, February 6, 5:00 to 6:50 pm

NAME: [redacted]

CIRCL[redacted]TION: 9 [redacted]

This examination is composed of four proble[redacted] parts of all the problems. You have one hour and fifty minutes to complete the exam. You may use your textbook, one page of notes (front and back), and a noncommunicating calculator of your choice in working the exam.

Problem 1:	25	of 25 points
Problem 2:	25	of 25 points
Problem 3:	30	of 30 points
Problem 4:	20	of 20 points

+25

1. For this problem assume all gases behave as ideal gases.

(a) (15 points) The metabolic oxidation of glucose ($C_6H_{12}O_6$) proceeds according to the balanced reaction equation

$$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

Calculate the volume of $CO_2(g)$ produced at 37 °C and 1.0 atm when 25.0 g of glucose is consumed in this reaction.

(b) (10 points) A piece of $CO_2(s)$ having mass of 6.00 g is placed in a 10.0-L container in which $N_2(g)$ is already present at 750 Torr and 25 °C. The CO_2 undergoes complete sublimation, leaving a mixture of $N_2(g)$ and $CO_2(g)$ at the new temperature of 20 °C. Determine the total pressure of the final mixture.

a) $\frac{25.0\text{g } C_6H_{12}O_6}{} \cdot \frac{1\text{mol } C_6H_{12}O_6}{180.06\text{g } C_6H_{12}O_6} \cdot \frac{6\text{mol } CO_2}{1\text{mol } C_6H_{12}O_6} = 0.833 \text{ mol } CO_2$

$PV = nRT$

$V = \frac{nRT}{P} = \frac{0.833\text{mol } CO_2 \cdot 0.08206 \text{ L atm mol}^{-1} \text{K}^{-1} \cdot (37+273)\text{K}}{1.0\text{atm}}$

$V = 21.2 \text{ L } CO_2$ ✓

b) (CO_2 6.00g ; N_2 750torr 25°C) → P_{total} 20°C

10.0L

N_2: $\frac{PV}{nRT} = \frac{PV}{nRT}$

$\frac{P}{T} = \frac{P}{T}$

$\frac{750\text{torr}}{(25+273)\text{K}} = \frac{x \text{ torr}}{(20+273)\text{K}}$

$x \text{ torr} = 737.4 \text{ torr}$

CO_2:

$6.00\text{g } CO_2 \cdot \frac{1\text{mol } CO_2}{44.1\text{g } CO_2} = 0.136\text{mol } CO_2$

$PV = nRT$

$P = \frac{nRT}{V} = \frac{0.136\text{mol} \cdot 0.0820574 \text{ L atm mol}^{-1} \text{K}^{-1} \cdot (20+273)\text{K}}{10.0\text{L}}$

$= 0.327 \text{atm}$

$0.327 \text{atm} \cdot \frac{760\text{torr}}{1\text{atm}} = 248.5\text{torr}$

$P_{total} = P_{CO_2} + P_{N_2}$

$= 248.5 + 737.4 \text{ torr}$

$= 986 \text{ torr}$ ✓

OR $986 \text{ torr} \cdot \frac{1\text{atm}}{760 \text{ torr}} = 1.30 \text{ atm}$

2. The concentration of hydrogen peroxide (H_2O_2) in an acidic aqueous solution can be determined by titration with a permanganate-ion (MnO_4^-) solution. The **unbalanced** titration reaction involves

$$MnO_4^-(aq) + H_2O_2(aq) \rightarrow Mn^{2+}(aq) + O_2(g)$$

(a) (10 points) Balance the titration reaction equation.

(b) (15 points) Suppose in titrating 12.0 mL of a hydrogen peroxide solution it requires 15.0 mL of a 0.150 mol/L $MnO_4^-(aq)$ solution to reach the endpoint. Determine the H_2O_2 concentration of the original solution.

a) $MnO_4^- + H_2O_2 \rightarrow Mn^{2+} + O_2$

half reactions

$(5e^- + 8H^+ + MnO_4^- \rightarrow Mn^{2+} + 4H_2O) \times 2$

$(H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-) \times 5$

steps: balance Mn first - do nothing

balance O w/ H2O - add 4H2O to top

balance H w/ H+ - add 8H+ to top, add 2H+ to bottom

balance charge w/ e- - add 5e- to top, add 2e- to bottom

multiply by integer to balance e- - multiply top by 2, multiply bottom by 5

$5H_2O_2 + 6H^+ + 2MnO_4^- \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$

check:

Mn balanced ✓

O balanced ✓

H balanced ✓

charge balanced ✓

lowest factor ✓

+10

b) $\frac{0.150 \text{ mol } MnO_4^-}{L} \cdot 0.015 L \cdot \frac{5 \text{ mol } H_2O_2}{2 \text{ mol } MnO_4^-} \cdot \frac{1}{0.012 L}$

$= 0.46875 \text{ mol } H_2O_2/L$

0.469 M of H_2O_2

+15

30/30

3(a) (15 points) A protein with mass 2.50 g is dissolved in water to yield a solution of volume 120.0 mL at 23 °C. The osmotic pressure of the solution is measured to be 0.0423 atm. Determine the molar mass of the protein. 15/15

(b) (15 points) A solution of 2.3 g of ethanol in 1.00 kg of $H_2SO_4(l)$ has a freezing point that is 0.92 °C lower than that of pure $H_2SO_4(l)$. Determine how many particles are formed as one molecule of ethanol goes into solution in $H_2SO_4(l)$ given that the freezing-point-depression constant for the solvent is 6.12 K-kg/mol. 15/15

a) mass = 2.50g

$V = 0.120L$

$T = 23+273K$

$\pi = 0.0423$ atm

$\pi = CRT$ +3

$\pi = \frac{n}{V}RT$

$\pi = \frac{\frac{m}{MW}}{V}RT$ +3

$0.0423\text{atm} = \frac{\frac{2.50\text{ g}}{MW\text{ g/mol}}}{0.120L} \cdot 0.0820\overline{6}\frac{L\ atm}{mol\ K} \cdot (23+273)K$ +6

$MW = 11963 g/mol$

$MW = \boxed{12.0\ kg/mol}$ +3

b) 2.3g CH_3CH_2OH

in 1.00kg H_2SO_4

$\Delta T = -0.92°C$

$k_f = 6.12k\ kg/mol$

$m = \frac{mol\ solute}{kg\ solvent}$

$m = 2.3g \cdot \frac{1mol}{46g} \cdot \frac{1}{1kg} = 0.05m$ +5

$\Delta T_f = K_f m i$ +5

$0.92\ K = 6.12\frac{K\ kg}{mol} \cdot \frac{0.05\ mol}{kg} \cdot i$

$i = 3.006 \approx 3$

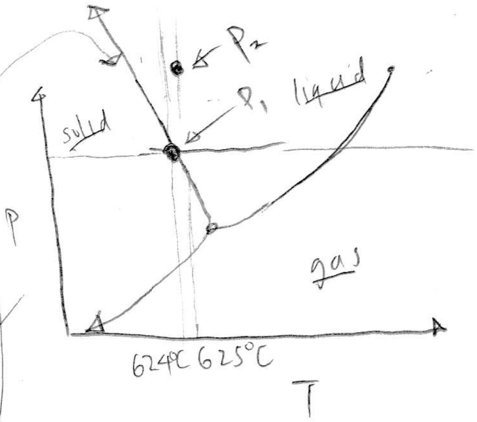
$\boxed{3\text{ particles}}$ +5

4(a) (10 points) At its normal melting point of 624 °C the density of solid plutonium is 16.24 g/cm³ and that of liquid plutonium is 16.66 g/cm³. A sample of liquid plutonium at 625°C is strongly compressed. Predict what phase changes, if any, will occur due to the compression. Explain your answer fully.

(b) (10 points) The triple point of H_2 is at 13.8 K and 0.069 atm. (i) Determine the vapor pressure of $H_2(s)$ at 13.8 K. (ii) Identify the phase change(s), if any, that occur when a sample of $H_2(s)$ at 0.030 atm is heated from 5 K to 300 K. Explain your answer fully.

a) normal melting = 624°C
solid density = 16.24g/cm3
liquid density = 16.66g/cm³

acts like H_2O b/c solid is less dense than liquid, which means the solid/liquid equilibrium line is negatively sloped



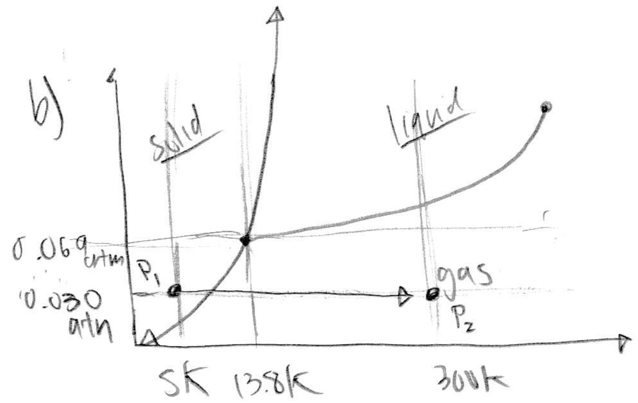
P_1 is the normal melting point at 624°C

P_2 is the point of 625°C, (a higher temperature) and a higher pressure because it is strongly compressed. The solid/liquid equilibrium line is negatively sloped because the solid is less dense than liquid, meaning the liquid phase is more favored at higher pressure. This means the final result is a liquid as seen in the diagram

Therefore

There is no phase change

b)



The vapor pressure for a certain T occurs when the liquid and gas phases are in equilibrium, Because the triple point has liquid/gas/solid equilibrium, the vapor pressure at 13.8K is 0.069atm

P_1 = 5K, 0.030atm
P_2 = 300K, 0.030atm

because 0.030atm is less than the critical point pressure and because going from 5K to 300K passes the critical temperature, there is a phase change from solid to gas as seen in the phase diagram, called sublimation.