Name ____

CHM 1045
Fall 2015
October 21

EXAMINATION TWO – SOLUTIONS

I _______ II _______ III _______ IV _______ V _______ VI _______ Total ___________

This exam consists of several questions. Rough point values are given. The total will be scaled to 100 points after the exams are marked. For questions with multiple parts, you do not necessarily need the answer to part A in order to work part B, etc. Please glance over the entire exam, and then attempt the questions in the order of your choice. For calculations, draw a box around your final answer given to the correct number of significant figures, and ***be sure to include the correct units***. ***You must show your work to receive any credit for a calculated answer.*** Additional information is provided in a separate information packet, and there should be ample space on the packet for scratch work. Good luck!

I. (2 points) Circle the time above your recitation instructor's name corresponding to the section you attend.

5:00 pm	6:00 pm	7:00 pm	5:00 pm	6:00 pm	7:00 pm	5:00 pm	6:00 pm	7:00 pm
Karin Vallega, 214 HTL			Felipe Andrade, 219 HTL			Lenzi Williams, 520 HTL		

II. (21 points) Write balanced molecular equations (ME) and net ionic equations (NIE) for the following reactions. *Be sure to include the correct states in your final equations and charges for ions in the NIE.*

A. $CuCl_2(aq)$ + $Pb(s)$ →

ME: $CuCl_2(aq) + Pb(s) \rightarrow Cu(s) + PbCl_2(s)$

IE: $Cu^{2+} + 2Cl^- + Pb(s) \rightarrow Cu(s) + Pb^{2+} + 2Cl^-$

NIE: $Cu^{2+}(aq) + 2Cl^-(aq) + Pb(s) \rightarrow Cu(s) + PbCl_2(s)$

B. $K_2SO_4(aq)$ + $CaCl_2(aq)$ →

ME: $K_2SO_4(aq) + CaCl_2(aq) \rightarrow 2KCl(aq) + CaSO_4(s)$

IE: $2K^+ + SO_4^{2-} + Ca^{2+} + 2Cl^- \rightarrow 2K^+ + 2Cl^-\ CaSO_4(s)$

NIE: $Ca^{2+}(aq) + SO_4^{2-}(aq) \rightarrow CaSO_4(s)$

C. $KF(aq)$ + $HI(aq)$ →

ME: $KF(aq) + HI(aq) \rightarrow KI(aq) + HF(aq)$

IE: $K^+ + F^- + H^+ + I^- \rightarrow K^+ + I^- + HF(aq)$

NIE: $H^+(aq) + F^-(aq) \rightarrow HF(aq)$

III. (16 points) We never got a chance to consider the "deflategate" controversy using the ideal gas law, so I thought we might do it here.

Tom Brady and the New England Patriots were accused of deflating footballs used in their AFC championship game against the Indianapolis Colts on January 18, 2015. The NFL requires footballs to be inflated to a pressure between 12.5 and 13.5 "psi." During halftime it was discovered that some of the footballs used by the Patriots were 2 psi below the minimum allowed pressure. Patriots supporters claimed that the drop in pressure was due to the difference in temperature between the locker room and the playing field.

A. Let's assume that the footballs were filled to 12.5 psi before game and checked with a pressure gauge. That's "gauge pressure" (psi-g) – the actual pressure (sometimes called "absolute" pressure) inside the ball would be 27.2 psi.

What's the difference between gauge pressure and absolute pressure? In other words, explain why the numbers are different.

Absolute pressure is the pressure relative to zero, where a perfect vacuum is zero pressure. Gauge pressure is the pressure relative to zero, where the pressure of the atmosphere is defined as zero pressure.

B. According to reports, the temperature in the locker room before the game was 74°F (23°C) and the temperature on the field at halftime was 48°F (9°C). Assuming a pressure of 27.2 psi at 23°C, what would the pressure be after the temperature dropped to 9°C?

Starting with PV = nRT, and moving constants to one side and variables to the other side gives

$$\frac{P}{T} = \frac{nR}{V} \Rightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2} \quad \text{or} \quad \frac{P_i}{T_i} = \frac{P_f}{T_f}$$

We have use absolute temperatures and pressures, so we have to change ^{o}C to K, but because the expression is set up as ratios, we can use psi without converting to atm. (But converting to atm is fine; you get the same answer.)

23 ^{o}C + 273.15 = 296 K   9 ^{o}C + 273.15 = 282 K

Rearranging this expression, the final pressure at halftime would be $P_f = \frac{P_i\,T_f}{T_i}$.

$$P_f = \frac{P_i\,T_f}{T_i} = \frac{27.2 \text{ psi} \times 282 \text{ K}}{296 \text{ K}} = 25.9 \text{ psi}$$

What is another assumption you make in the above calculation?

Possible answers include: 1. volume remains constant
2. no air escaped football

C. Would a temperature drop from 23°C to 9°C account for the footballs being 2 psi below the minimum allowed pressure?

Explain your reasoning.

According to the calculations in Part B, the pressure should have dropped 27.2 psi – 25.9 psi = 1.3 psi. That is a significant drop in pressure (5%), but not the 2 psi drop reported for some of the footballs.

IV. (28 points) We carried out the thermite reaction way back in Chapter 3 and used that reaction to talk about limiting reagents and percent yield. Since then, it showed up in a recitation exercise and a homework problem. It's a pretty impressive reaction. A large part of the driving force in the thermite reaction is based on the stability of aluminum oxide, as reflected in ΔH° of the following reaction.

$$2Al(s) + {}^{3}/_{2}O_2(g) \rightarrow Al_2O_3(s) \qquad \Delta H° = -1669.8 \text{ kJ/mol}$$

If 27 g of aluminum reacts with oxygen to form $Al_2O_3(s)$, how much heat is released assuming the reaction goes to completion?

$$27 \text{ g Al}\left(\frac{1 \text{ mol Al}}{26.98 \text{ g Al}}\right)\left(\frac{1669.8 \text{ kJ released}}{2 \text{ mol Al}}\right) = 835.5 \text{ kJ}$$

Researchers at Purdue University have exploited this reactivity to develop a novel type of rocket fuel consisting of aluminum nanoparticles dispersed in H_2O(*s*). They nicknamed this propellant "ALICE" (get it? Al-ice) and noted that in addition to being environmentally friendly, ALICE could be produced on any extraterrestrial body that contains water. The recent discovery of water on Mars could draw new attention to this intriguing fuel. (*International Journal of Aerospace Engineering*, **2012**)

One can speculate that the reaction that causes ALICE to act as a propellant is

$$2Al(s) + 3H_2O(s) \rightarrow Al_2O_3(s) + 3H_2(g)$$

where the hydrogen gas is subsequently burned.

A. Given the molar enthalpies for the following reactions

$$2Al(s) + {}^{3}/_{2}O_2(g) \rightarrow Al_2O_3(s) \qquad \Delta H° = -1669.8 \text{ kJ/mol}$$
$$H_2(g) + {}^{1}/_{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H° = -285.8 \text{ kJ/mol}$$
$$H_2O(s) \rightarrow H_2O(l) \qquad \Delta H° = 6.01 \text{ kJ/mol}$$

determine ΔH° for the ALICE reaction

$$2Al(s) + 3H_2O(s) \rightarrow Al_2O_3(s) + 3H_2(g)$$

$$2Al(s) + {}^{3}/_{2}O_2(g) \rightarrow Al_2O_3(s) \qquad \Delta H° = -1669.8 \text{ kJ/mol}$$

times 3

$$3H_2O(s) \rightarrow 3H_2O(l) \qquad \Delta H° = +3(6.01 \text{ kJ/mol})$$

flip, times 3

$$3H_2O(l) \rightarrow 3H_2(g) + {}^{3}/_{2}O_2(g) \qquad \Delta H° = -3(-285.8 \text{ kJ/mol})$$

$$2Al(s) + 3H_2O(s) \rightarrow Al_2O_3(s) + 3H_2(g)$$

$$\Delta H° = -1669.8 \text{ kJ/mol} + 3(6.01 \text{ kJ/mol}) + [-3(-285.8 \text{ kJ/mol})] = -794.4 \text{ kJ/mol}$$

Is the ΔH° you calculated consistent with Al-ice serving as a fuel? ________________

Give ~~two reasons~~ one reason to support your answer.

1. energy was released (ΔH° < 0)
2. the magnitude of ΔH° is fairly large
3. burning the H_2 produced is also exothermic

B. Consider again the following reactions from Part A:

1. $2Al(s) + {}^{3}/_{2}O_2(g) \rightarrow Al_2O_3(s)$ ΔH° = –1669.8 kJ/mol
2. $H_2(g) + {}^{1}/_{2}O_2(g) \rightarrow H_2O(l)$ ΔH° = –285.8 kJ/mol
3. $H_2O(s) \rightarrow H_2O(l)$ ΔH° = 6.01 kJ/mol

For which, if any, reactions does ΔH° correspond to a molar enthalpy of formation? #1 and #2

C. Write the oxidation numbers in the spaces provided.

Al	H	O	Al	O	H
0	+1	-2	+3	-2	0

$$2Al(s) + 3H_2O(s) \rightarrow Al_2O_3(s) + 3H_2(g)$$

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V. (~~24~~ points) We looked at the decomposition of hydrogen peroxide in class. The reaction is slow, but if you add a catalyst, it proceeds rather quickly.

$$2H_2O_2(aq) \longrightarrow 2H_2O(\ell) + O_2(g)$$

A. If a catalyst is added to 154 mL of 0.882 *M* $H_2O_2(aq)$, how many moles of $O_2(g)$ are produced, assuming the reaction goes to completion?

$$154 \text{ mL } H_2O_2(aq)\left(\frac{1 \text{ L}}{1000 \text{ mL}}\right)\left(\frac{0.882 \text{ mol } H_2O_2}{1 \text{ L } H_2O_2(aq)}\right)\left(\frac{1 \text{ mol } O_2}{2 \text{ mol } H_2O_2}\right) = 0.0679 \text{ mol } O_2$$

B. The oxygen gas from the above procedure was collected and dried to remove water vapor. The volume of $O_2(g)$ was 726 mL at 23.9°C and 735 mmHg. Determine the amount (moles) of O_2 gas collected.

726 mL x (1 L / 1000 mL) = 0.726 L

735 mmHg x (1 atm / 760 mmHg) = 0.967 atm

$23.9\ ^oC + 273.15 = 297$ K

$$PV = nRT \Rightarrow n = \frac{PV}{RT} = \frac{(0.967 \text{ atm})(0.726 \text{ L})}{0.08206 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}(297 \text{ K})} = 0.288 \text{ mol } O_2$$

C. What was the percent yield for the reaction?

$$\text{percent yield} = \left(\frac{\text{actual yield}}{\text{theoretical yield}}\right) \times 100\% = \left(\frac{0.0288 \text{ mol } O_2}{0.0679 \text{ mol } O_2}\right) \times 100\% = 42.4\%$$

D. Why was it necessary to remove the water vapor?

Most of us answered something like "removed water vapor because we needed the oxygen sample to be pure," but we will looking for a specific reason why the water vapor needed to be removed for the calculation to give the correct answer. If water vapor is not removed, then $P = P_{O2} + P_{H2O}$, and using PV = nRT to solve for n would actually give moles of O_2 plus moles of $H_2O(g)$. So we have to remove the water vapor before measuring pressure or we have to subtract the vapor pressure of water (which can be looked up as a function of temperature).

That question was not graded. The two points for that question were omitted from the exam total, making the maximum possible 92 instead of 94.

IV. (3 points) Looks like we might finally be getting some fall weather, with cooler and less humid days.

Which is heavier, humid air or dry air?

Briefly explain your reasoning.

Dry air and humid air contains the same number of molecules of gas per volume (at the same temperature and pressure), but H_2O is lighter than N_2 or O_2. Therefore, humid air is lighter (less dense) than dry air.

Humid air only "feels" heavier.