BACHELOR OF SCIENCE (B.Sc.)

IN ENGINEERING DISCIPLINES

Spring Semester 2013

FIRST MIDTERM EXAMINATION PAPER

Course: General Chemistry for Engineering Majors (CHEM-115)

Examiners: Assist. Profs. Kyriaki Polychronopoulou, Ibrahim Yildiz, Deborah Gater and Abdel F. Isakovic

Date: March 10th, 2013, 5:30 PM – 6:30 PM **Duration: 60 minutes**

PLEASE READ THESE INSTRUCTIONS:

- This is a closed book, no notes exam. There will be no bathroom breaks allowed.
- There are total of four (4) questions and one bonus question; bonus question you do not have to answer to obtain a full mark on this exam, but it will help you increase your overall score, if you answer it correctly.
- You can use a non-graphing calculator, but you **cannot** borrow or lend one during the exam
- Please plan your time and do not invest too much time into any individual problem
- Please write clearly in blue or black ink and do not use red pen or a pencil of any color
- This 1st midterm exam contributes 10% to your final grade in this course
- Some constants you might find helpful are below:

$N_A = 6.023 \times 10^{23}\ mol^{-1}$
$R_H = 1.097 \times 10^{7}\ m^{-1}$
$c = 3 \times 10^{8}\ m/s$
$h = 6.626 \times 10^{-34}\ Js$

_**MODEL ANSWERS**________________________

STUDENT NAME (PRINT)

_**100000042**_______________________________

KU STUDENT ID Number

PROBLEM	POINTS PER QUESTION	YOUR POINTS
1	20	20
2	30	30
3	30	30
4	20	20
BONUS QUESTION	10	10
POINTS TOTAL	100 + 10	110

LECTURE SECTION → CIRCLE ONE (9:00 AM – Abdel, 10:00 AM - Deborah, 10:00 Ibrahim, 11:00 AM – Kyriaki, 11:00 AM – Abdel, 1:00 PM - Deborah)

QUESTION 1 (20 marks, 6 + 2 + 4 + 8)

1.1 Classify each of the following as element, compound, or mixture.

(a) air _mixture____ (b) iron ___element__

(c) milk _ mixture ____ (d) table salt ___compound_

1.2 A pure substance composed of two or more different elements is a(n) ___C_________.

(a) ion
(b) heterogeneous mixture
(c) chemical compound
(d) solid
(e) solution

1.3 A glass of lukewarm milk is suggested for people who cannot sleep. Milk at 52°C can be characterized as lukewarm. What is the temperature of lukewarm milk in °F? In K? SHOW YOUR WORKING.

__125.6_______ °F ___325.15_____ K

$(°C \times 9/5) + 32 = °F$

$K = °C + 273.15$ or 273

1.4 The following data refer to the element phosphorus. Classify each as a physical or a chemical property.

(a) It exists in several forms, for example, white, black, and red phosphorus. ______ Physical property __

(b) It is a solid at 25°C and 1 atm. _______ Physical property __

(c) It is insoluble in water. ______ Physical property ___

(d) It burns in chlorine to form phosphorus trichloride. _______Chemical property__

QUESTION 2 (30 marks, 15 + 15)

2.1 Please determine the mass percent of each element in propane, C_3H_8.

See textbook worked example 2.8, page 86

First, calculate the molar mass of propane using atomic weights in periodic table:

mw (C) = 12.011g/mol   mw (H) = 1.0079 g/mol
mw (C_3H_8) = 3 x (12.011g/mol) + 8 x (1.0079 g/mol) = 44.097 g/mol

Second, calculate the mass percent of C and H in C_3H_8:

$$\frac{3\ mol\ C}{1\ mol\ C_3H_8} \times \frac{12.011\ g\ C}{1\ mol\ C} = 36.033\ g\ C/mol\ C_3H_8$$

$$mass\ percent\ of\ C\ in\ C_3H_8 = \frac{36.033\ g\ C}{44.097\ g\ C_3H_8} \times 100\% = 81.713\%$$

$$\frac{8\ mol\ H}{1\ mol\ C_3H_8} \times \frac{1.0079\ g\ H}{1\ mol\ H} = 8.0632\ g\ H/mol\ C_3H_8$$

$$mass\ percent\ of\ H\ in\ C_3H_8 = \frac{8.0632\ g\ H}{44.097\ g\ C_3H_8} \times 100\% = 18.285\%$$

5 s.f. based on atomic/molar weights in periodic table

2.2 What is the mass of carbon contained in 400 grams of propane?

$$mass\ of\ C\ in\ 400\ g\ C_3H_8 = 400\ g\ C_3H_8 \times \frac{81.713 g\ C}{100\ g\ C_3H_8} = 326.85\ g = 327 g\ or\ 300 g\ to\ 1\ s.f.$$

QUESTION 3 (30 marks, 10 + 6 + 6 + 8)

3.1 Write a complete balanced equation (including state symbols for all reactants and products) for the reaction between zinc carbonate and hydrochloric acid to produce zinc chloride and two other products.

$ZnCO_3$ (s) + 2 HCl (aq) → $ZnCl_2$ (aq) + H_2O (l) + CO_2 (g)

3.2 Specify the oxidation states of all of the elements in each compound in the reactants and of all of the elements each compound in the products. Identify any species that have been oxidized or reduced.

Reactants: $ZnCO_3$ [Zn (+2), C (+4), O (-2)], HCl [H (+1), Cl (-1)]
Products: $ZnCl_2$ [Zn (+2), Cl (-1)], H_2O [H (+1), O (-2)], CO_2 [C (+4), O (-2)]

3.3 Identify any of the reactants that are acting as acids and briefly explain why you made this choice. Describe (with reference to the Arrhenius definition) whether they might be expected to be strong or weak acids.

HCl is acting as an acid because it is donating a proton (H^+) to an oxygen atom on the CO_3^{2-} ion (Bronsted Lowry) and/(or) increases the concentration of H^+ (H_3O^+) ions in aqueous solution (Arrhenius). HCl is considered a strong acid in the Arrhenius definition because it dissociates almost completely to form H^+ (H_3O^+) and Cl^- ions in solution (strong electrolyte/good conductor of electricity).

3.4 Circle any of the following descriptions that apply to the reaction between zinc carbonate and hydrochloric acid. Briefly explain your reasoning for choosing/not choosing each option.

Precipitation reaction	NO – not two soluble reactants and no solid product
Acid-base reaction	YES – proton is donated from HCl to O in CO_3^{2-}, salt and water are formed NO – according to Arrhenius no soluble base/OH^- in solution and not simple formation of salt/water (partial credit depending on answer in 3.2)
Gas-forming reaction	YES – CO_2 gas is produced from non-gaseous reactants
Redox reaction	NO – no change in oxidation numbers of any species between reactants and products – electron transfer definition of redox YES – C loses oxygen (reduced) and H gains oxygen (oxidized) – oxygen definition of redox

QUESTION 4 (20 marks, 10 + 10)

4.1 If you were to take a volleyball scuba diving with you what would be its new volume if it started at the surface with a volume of 2.50L, under a pressure of 752.0 mmHg and a temperature of 22.0°C? On your dive you take it to a place where the pressure is 2947 mmHg, and the temperature is 0.245°C.

By applying the $\frac{P1V1}{T1} = constant$ condition for the two states that are given (surface and diving), we get the following: $\frac{P1V1}{T1} = \frac{P2V2}{T2}$ (Eq. 1)

Where,

P1=752 mmHg (or 0.984 atm) V1=2.5 L T1=22^{o}C (295K)

And

P2=2947 mmHg (or 3.877 atm) V2=? L T2=0.245^{o}C (273.24K)

$\left(\frac{T2}{P2}\right) \times \left(\frac{P1V1}{T1}\right) = V2$ (Eq. 2)

By substitution of the above values to eq. 2, we get: $\left(\frac{273.24K}{3.87atm}\right) \times \left(\frac{0.984atm2.5L}{295K}\right) = V2$

Therefore $V2 = 0.591L$

4.2 Which gas has the greatest density at 45^{o}C and the pressure of 2.00 atm?

(a) O_2, (b) N_2, (c) H_2, (d) CO_2, (e) Xe

Two possible solutions

For both solutions, we need first to report all the Molecular weights of the gases involved, showing our working:

O_2-2x16 g/mol=32 g/mol N_2-2x14 g/mol=28 g/mol

H_2-2X1 g/mol=2 g/mol CO_2-12g/mol+2x16g/mol=44 g/mol

Xe-131 g/mol

Numerical solution:

Based on the Ideal Gas Law (PV=nRT) and by applying appropriate transformations, we are getting the following formula which connects the density of the gases with the pressure.

$$d = \frac{P \times M}{R \times T}$$

By substitution of P, M, R, T on the above formula for each one of the above gases we can find the density of the gases. In particular:

P=2.00 atm

M (molecular weight, see above the values in g/mol)

R=0.082 Latm.mol^{-1}K^{-1}

T=273 + 45=318 K

For example, in the case of O_2, we are getting:

$$d(O2) = \frac{2.00atm \times 32g/mol}{0.082Latm/molK \times 318K} = 2.45\frac{g}{L}\ or\ 2.5\ g/L$$

In a similar way, we can find the density for the rest of the gases:

$d(N_2)$=2.1 g/L $d(H_2)$=0.2 g/L
$d(CO_2)$=3.4 g/L d(Xe)=10.1 g/L

Based on the above results, Xe has the highest density for the given conditions.

Alternative solution (much faster):

Based on the molecular weights and on the formula $d = \frac{P\times M}{R\times T}$

We can say that as the molecular weight of a gas increases, density is expected to increase too (proportional relationship of d-M). So, the gas with the highest Molecular weight (Xe) has the highest density, since all the rest of the parameters in the above equation remain constant.

Bonus question (10 marks, 5 + 5)

It is not necessary to answer this question to gain 100% on the exam, but any marks obtained here will be used for additional credit in the midterm grade

Refer to question 3 for the context for this question

B1 Identify any of the reactants that are acting as bases and specify whether they are best described as Arrhenius or Brønsted-Lowry bases. Briefly explain your reasoning.

The CO_3^{2-} ion that is part of the $ZnCO_3$ is acting as a base because it is accepting a proton from the HCl. It is best described as a Bronsted-Lowry base because it is a proton-acceptor and is not (initially) in solution/the reaction does not involve any OH^- ions and the Arrhenius definition of a base specifies the involvement of hydroxide.
There are no other bases on the reactant side of this reaction.

B2 Using the Brønsted-Lowry definition, identify which of the products is the conjugate base, and briefly explain whether you think the equilibrium for this reaction would be product- or reactant-favoured, and why you are of this opinion.

The conjugate base (i.e., the species that remains when the initial acid loses a proton) is Cl^-, which would accept a proton from water to form HCl in the reverse reaction. This is likely a product favoured reaction for two reasons. First, the product acid-base pair is much weaker than the reactant acid-base pair (particular HCl is a much stronger acid than H_2O) and acid-base reactions tend to favour the weaker acid-base pair (according to Bronsted Lowry); and second, the reverse reaction is less likely because the CO_2 would effectively be removed from the reaction as it is emitted as a gas and would thus not be present to react with the other products.