Name ____

CHM 1045
Spring 2018
February 28

EXAMINATION TWO – TENTATIVE SOLUTIONS

	I	II	III	IV	V		
____ /2	____ /12	____ /14	____ /29	____ /24	____ /14	____ /95	x $^{100}/_{95}$ = Total ______

This exam consists of several problems. 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, Part B to Part C, etc. If you do need a previous answer, the next question will be marked assuming the previous question is correct; however, if you were unable to answer the previous part, make up a reasonable answer and use that for subsequent calculations. Glance over the entire exam, and then attempt the problems in the order of your choice. For calculations, give your answer to the correct number of ***significant figures***, and be sure to include the ***correct units*** for your answer. ***You must show your work to receive any credit for a calculated answer.*** Additional information is provided in a separate information packet; you can use the back for scratch work.

(2 points) Circle the recitation section you are attending.

Chengqi Zhang	Dallas Mann	Matt Donohue
22, 2:00-2:50 pm, HTL 213	25, 2:00-2:50 pm, HTL 214	28, 1:00-1:50 pm, HTL 219
23, 3:00-3:50 pm, HTL 213	26, 3:00-3:50 pm, HTL 214	29, 2:00-2:50 pm, HTL 219
24, 4:00-4:50 pm, HTL 213	27, 4:00-4:50 pm, HTL 214	30, 3:00-3:50 pm, HTL 219

I. (12 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. $HNO_3(aq) + KNO_2(aq) \rightarrow$

ME: $HNO_3(aq) + KNO_2(aq) \rightarrow HNO_2(aq) + KNO_3(aq)$

IE: $H^+ + \cancel{NO_3^-} + \cancel{K^+} + NO_2^- \rightarrow HNO_2(aq) + \cancel{K^+} + \cancel{NO_3^-}$

(HNO2 is a weak acid ⇒ mostly unionized)

NIE: $H^+(aq) + NO_2^-(aq) \rightarrow HNO_2(aq)$

B. $Na_2SO_4(aq) + AgNO_3(aq) \rightarrow$

ME: $Na_2SO_4(aq) + 2AgNO_3(aq) \rightarrow Ag_2SO_4(s) + 2NaNO_3(aq)$

IE: $\cancel{2Na^+} + SO_4^{2-} + 2Ag^+ + \cancel{2NO_3^-} \rightarrow Ag_2SO_4(s) + \cancel{2Na^+} + \cancel{2NO_3^-}$

NIE: $2Ag^+(aq) + SO_4^{2-}(aq) \rightarrow Ag_2SO_4(s)$

II. (14 points) Balance the following chemical equations:

A. $Fe_2O_3 + CO \rightarrow Fe + CO_2$

$^1/_3Fe_2O_3 + CO \rightarrow {}^2/_3Fe + CO_2$ => $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

B. $SF_4 + H_2O \rightarrow H_2SO_3 + HF$

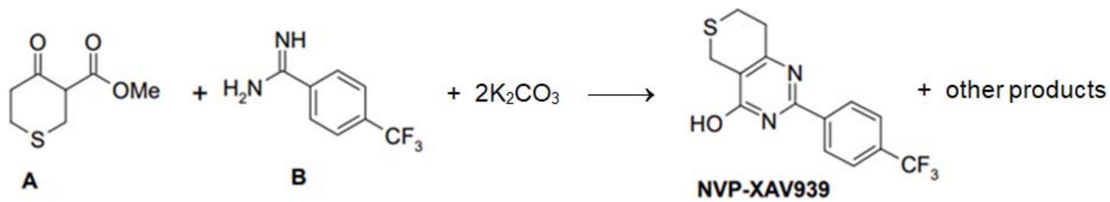
$SF_4 + 3H_2O \rightarrow H_2SO_3 + 4HF$

Now name the two acids produced in the above reactions.

H_2SO_3 sulfurous acid

HF hydrofluoric acid

III. (29 points) Tankyrases (TNKSs) are enzymes that catalyze (increase the rate) of some protein reactions. Several studies have shown that TNKSs may serve as anti-cancer drugs; see *Scientific Reports*, **2018**, *8*, 1-10. The synthesis of one of the first TNKSs to show potential as an anti-cancer drug, NVP-XAV939, is shown below (*Nature*, **2009**, *461*, 614–620).



A. NVP-XAV939 was synthesized by reacting 0.876 g of A with 1.42 g of B. Which of these reactants is the limiting reagent?

Compound	molar mass
A	172.22 g/mol
B	176.14 g/mol
K_2CO_3	138.21 g/mol
NVP-XAV939	300.30 g/mol

0.876 g A (1 mol A/172.22 g A) = $5.08_7 \times 10^{-3}$ mol A

1.42 g B (1 mol A/176.14 g B) = $8.06_2 \times 10^{-3}$ mol B

A is the limiting reagent

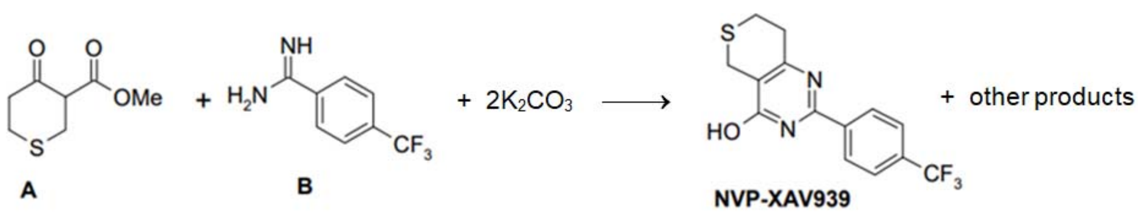
B. Assuming the reaction goes to completion, what would be the yield of NVP-XAV939 in grams?

$5.08_7 \times 10^{-3}$ mol A (1 mol NVP-XAV939/1 mol A) (300.30 g NVP-XAV939/mol NVP-XAV939) = **1.52_7 g**

C. After purification and drying, 1.24 g of NVP-XAV939 was obtained. What was the percent yield for this reaction?

$$\text{percent yield} = \left(\frac{\text{experimental yield}}{\text{theoretical yield}}\right)100\% = \left(\frac{1.24\text{ g}}{1.52_7\text{ g}}\right)100\% = \boxed{81.2\%}$$

D. Taking another look at the reaction we see that K_2CO_3 is also required.



1. Is K_2CO_3 acidic or basic? Explain your reasoning.

basic — Several ways to explain:
- CO_3^{2-} is the conj. base of H_2CO_3
- no ionizable H atoms on CO_3^{2-}
- CO_3^{2-} can accept H^+, so it is a base
- $CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^-$

2. What mass of K_2CO_3 is required for the reaction based on the information given in Part A.

$5.08_7 \times 10^{-3}$ mol A (2 mol K_2CO_3/1 mol A) (138.21 g K_2CO_3/mol K_2CO_3) = **1.41 g K_2CO_3**

III. (24 points) Another important reaction in organic synthesis, polymers, and the food industry is hydrogenation. These reactions are typically carried out in "generators" at temperatures and pressures higher than ambient conditions. Sometimes, however, you can get away with milder conditions using a balloon generator, as shown in the image on the right. The balloon is filled with the desired amount of H_2 gas (often determined by a stoichiometric calculation), and then attached to a flask containing the reaction mixture.

A. Calculate the moles of $H_2(g)$ contained in the balloon on the right. We can assume they used dry hydrogen, so we do not need to correct for water vapor. The temperature in the lab is 24.5°C. The pressure inside the inflated balloon was measured to be 15 mmHg gauge pressure. Based on the 5 L round bottom flask in the photo, we can estimate* the volume of the balloon to be around 11 L.

$24.5\ ^\circ C + 273.15 = 297.6_5\ K$

Assuming an atmospheric pressure of 1 atm = 760 mmHg, the pressure inside the balloon would be 760 + 15 = 775 mmHg

775 mmHg x (1 atm/760 mmHg) = 1.02 atm

$$PV = nRT \Rightarrow n = \frac{PV}{RT} = \frac{1.02\ \text{atm} \times 11\ \text{L}}{(0.08206\ \text{L}\cdot\text{atm/K}\cdot\text{mol}) \times 297.6_5\ \text{K}}$$

= 0.48 mol

*See last page to see how the volume of the balloon was estimated to be 11 L.

B. You can also hydrogenate with deuterium, $D_2(g)$, where deuterium is the isotope of hydrogen with one neutron in the nucleus. So the mass of a D atom would be roughly 2 amu, and the molar mass of D_2 would be 4 g/mol.

Assuming you did everything else just the same, which balloon...

1. is heavier? H_2 **[D_2]** they're both the same
2. contains the most gas molecules? H_2 D_2 **[they're both the same]**
3. contains molecules with the higher average kinetic energy? H_2 D_2 **[they're both the same]**

C. Do you expect a $D_2(g)$ filled balloon to float in air? yes

Explain.

As noted above, the deuterium nucleus contains one proton and one neutron, so the mass of one D atom is around 2 amu or 2 g/mol. Therefore, the molar mass of D_2 is 4 g/mol, which is seven times less than the molar mass of air, making a deuterium-filled balloon considerably less dense than the same balloon filled with air. (The molar mass of helium is also 4 g/mol.)

V. (14 points) A recent eye-catching article from ScienceDaily, ***Turning Beer into Fuel****, was actually about the use of alcohols as fuels (*www.sciencedaily.com/releases/2017/12/171206100119.htm). The paper states that compared to ethanol, "a much better fuel alternative is butanol but this is difficult to make from sustainable sources"; however, the article does not say why butanol is better. I found this...

> ***In other words, methanol and ethanol are not great fuel sources because they produce more carbon dioxide than their equivalent hydrocarbons for the same amount of energy. ... Butanol produces LESS carbon dioxide than gasoline for the same amount of energy.***
>
> (biofuel.org.uk/bioalcohols.html)

Combustion of a "mole" of gasoline provides around 4800 kJ of energy and produces roughly 350 g of CO_2. Combustion of a mole of butanol provides 2724 kJ of energy.

$$C_4H_9OH(\ell) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(\ell) + 2724\text{ kJ/mol}$$

A. How much butanol would be required to provide 4800 kJ of energy?

4800 kJ x (1 mol butanol / 2724 kJ) = **1.76_2 mol butane**

(Note: We could convert to grams, but not required.)

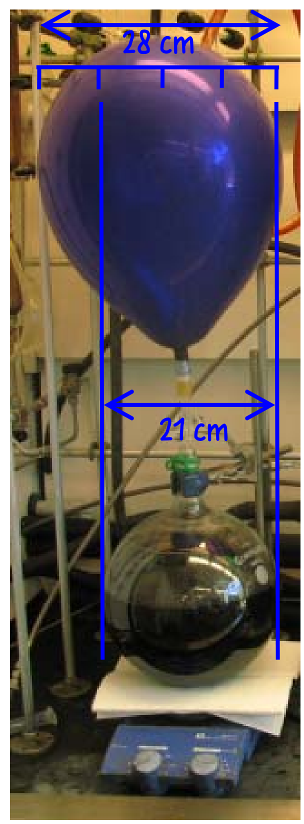
B. How much carbon dioxide (in g) would be produced in Part A?

1.76_2 mol C_4H_9OH x (4 mol CO_2 / 1 mol C_4H_9OH) x 44.01 g/mol CO_2 = **310 g CO_2**

C. So, does butanol produces "LESS" carbon dioxide than gasoline for the same amount of energy? Explain.

Yes. From above "combustion of a mole of gasoline provides around 4800 kJ of energy and produces roughly 350 g of CO_2." Burning the amount of butanol needed to release 4800 kJ of energy produces 310 g of CO_2.

So <u>yes</u>, butanol produces less carbon dioxide than gasoline for the same amount of energy



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*Estimating volume of the balloon.

Volume of the flask = 5 L = 5000 mL = 5000 cm^3

5000 cm^3 = $V = {}^4/_3\pi r^3$

Solving for radius gives r = 10.6 cm, so the diameter of the flask is ~ 21 cm, and the "diameter" of the balloon would be around 28 cm.

Approximating the balloon as a sphere then gives

$V = {}^4/_3\pi r^3 = {}^4/_3\pi({}^{28\text{ cm}}/_2)^3 = 11{,}500\text{ cm}^3 \approx 11._5\text{ L}$