Name ________________________________

CHM 3120
Spring 2011
February 3

EXAMINATION ONE

I _______ II _______ III _______ IV _______ V _______ Total _________

This exam consists of five questions spread out over four pages. Please glance over the entire exam, and then attempt the questions in the order of your choice. ***You must <u>show your work</u> to receive any credit for a calculated answer.*** Draw a box around your final answer given to the correct number of ***<u>significant figures</u>***, and ***be sure to include the <u>correct units</u>***. A periodic table and some additional information are provided with the exam. Good luck!

I. (22 points) Acids and Bases

A. Identify the following compounds as strong acids, weak acids, strong bases, weak bases, or essentially neutral when dissolved in water.

1. $NaNO_3$ essentially neutral
2. HNO_3 strong acid
3. HF weak acid
4. KF weak base
5. NH_4Cl weak acid

B. In the following chemical equilibrium

$H_2NNH_2(aq) + H_2O(l) \rightleftharpoons H_3NNH_2^+(aq) + OH^-(aq)$

1. What reactant is acting as the acid? H_2O
2. What product is acting as the conjugate acid? $H_3NNH_2^+$

C. Determine the pH of the following solutions:

1. 0.045 M NaOH(*aq*)
(0.048)

$\Rightarrow pOH = -\log(0.045) = 1.35$

$pH = 14.00 - 1.35 = \boxed{12.65}$

(12.68)

2. 7×10^{-5} M HCl(*aq*)
(3×10^{-4})

$\Rightarrow pH = -\log(7 \times 10^{-5})$

$= \boxed{4.2}$

(3.5)

II. (20 points) Scientists at the University of Nottingham have created "the world's smallest periodic table" on a human hair using a gallium ion beam in a scanning electron microscope (*Chemistry and Engineering News*, January 24, 2011). The dimensions of the periodic table are 100 μm by 50 μm. For the purposes of this problem, let's assume the following errors in those dimensions: 100 ± 8 μm by 50 ± 6 μm.

A. Of course we recall from our middle school math class that the perimeter of a rectangle is given by the equation

perimeter = length + length + width + width

So the perimeter of the world's smallest periodic table in μm would be

perimeter = 100 (± 8) + 100 (± 8) + 50 (± 6) + 50 (± 6) μm

Calculate the perimeter and its absolute error (i.e. absolute uncertainty), and give your answers in the boxes provided below.

$$S_y = \sqrt{\sum S_{x_i}^2}$$

$$= \sqrt{8^2 + 8^2 + 6^2 + 6^2} = \sqrt{200} = 14$$

$$\Downarrow$$

$$10$$

perimeter = 300 ± 10 μm

B. The area of the periodic table in μm^2 would be given by

area = length × width = 100 (± 8) μm × 50 (± 6) μm

Calculate the area and its <u>absolute error</u>, and give your answers in the boxes provided below.

$$\frac{S_y}{y} = \sqrt{\sum \left(\frac{S_i}{x_i}\right)^2}$$

$$= \sqrt{\left(\frac{8}{100}\right)^2 + \left(\frac{6}{50}\right)^2} = 0.144\ldots$$

$$\Rightarrow S_y = 0.144\ldots \times 5000 = 721$$

$$\Downarrow$$

$$700$$

area = 5000 ± 700 μm^2

III. (20 points) HMG-CoA reductase inhibitors (commonly called statins) are a class of drug used to lower cholesterol. Lipitor and Zocor are two common examples of statin drugs, but there are many others. A common dose for statins is 20.0 mg of the active ingredient per tablet (in reality the mass of active ingredient per table would probably not be known to this precision, but we are assuming three significant figures for this problem).

A. Following the release of a new generic form of Lipitor, some concerns were raised about its potency. A sample of seven tablets taken from one batch of the generic gave the following results:

Sample 1 (lot #2011-01-12a)	
mean mass	19.4 mg
standard deviation	0.3 mg

$d.f. = N-1 = 7-1 = 6$

Calculate the 95% confidence limits for the mean mass of the drug.

$t^{95\%}_{df=6} = 2.45$

$$\mu = \bar{x} \pm \frac{ts}{\sqrt{N}}$$

$$= 19.4 \pm \frac{2.45(0.3\text{ mg})}{\sqrt{7}} = \boxed{19.4 \pm 0.3\text{ mg}}$$

Does the sample differ from the expected value of 20.0 mg at the 95% confidence level? (To receive credit you must explain how you arrived at your answer.)

20.0 mg is not within the 95% confidence level (19.1 – 19.7 mg) ⇒ the sample does differ from the expected value

B. A second sample of five generic tablets was taken from a different lot off the production line and analyzed, giving the following results:

Sample 2 (lot #2011-01-18c)	
mean mass	20.1 mg
standard deviation	0.3 mg

Do the two samples differ from each other at the 95% confidence level?

yes

Show your work below, including the information you used to answer the above question.

$s_{sample\ 1} = s_{sample\ 2} = s_{pooled} = 0.3\text{ mg}$

$$t_{calc} = \frac{|\bar{x}_1 - \bar{x}_2|}{s_{pooled}\sqrt{\frac{N_1+N_2}{N_1 N_2}}} = \frac{|19.4-20.1|}{0.3\sqrt{\frac{7+5}{7\cdot 5}}} = 4.0$$

$d.f. = N_1 + N_2 - 2 = 5+7-2 = 10$ $\qquad t^{95\%}_{df=10} = 2.23$

$t_{calc}(4.0) > t_{table}(2.23)$ ⇒ the samples differ

IV. (24 points) Trimethylamine, $N(CH_3)_3$, is a gas that responsible for the "fishy smell" as seafood starts to go bad, but when dissolved in water it acts as a weak base.

A. Write a chemical equation showing how $N(CH_3)_3$ acts as a weak base in water.

$$N(CH_3)_3(aq) + H_2O(l) \rightleftharpoons H\overset{\oplus}{N}(CH_3)_3(aq) + OH^-(aq)$$

Write an equilibrium expression for that chemical equation.

$$K_{eq} = \frac{[H\overset{+}{N}(CH_3)_3][OH^-]}{[N(CH_3)_3]}$$

B. Determine the pH of 0.25 M $N(CH_3)_3(aq)$. K_b for trimethylamine is 6.3×10^{-5}.

	$N(CH_3)_3$	+ H_2O	$\rightleftharpoons$ $H\overset{\oplus}{N}(CH_3)_3$	+ OH^-
init	0.25		–	–
eq	0.25 – x		x	x

$$6.3\times10^{-5} = \frac{x^2}{0.25-x} \approx \frac{x^2}{0.25} \Rightarrow x = 4.0\times10^{-3} = [OH^-]$$

another iter $\Rightarrow$ $3.9\times10^{-3} = [OH^-]$

$$pOH = -\log[OH^-] = -\log(3.9\times10^{-3}) = 2.41$$

$$pH = 14.00 - pOH = 14.00 - 2.41 = \boxed{11.59}$$

C. What is the conjugate acid of $N(CH_3)_3$? $H\overset{\oplus}{N}(CH_3)_3$

What is the value of K_a for the conjugate acid?

$$K_a = K_w/K_b = \frac{1.0\times10^{-14}}{6.3\times10^{-5}} = \boxed{1.6\times10^{-10}}$$

V. (14 points) Calculate the ionic strength of 0.025 M $MgBr_2(aq)$.

$$MgBr_2(aq) \rightarrow Mg^{2+} + 2Br^-$$

0.025 → 0.025, 0.050

$$\mu = \frac{1}{2}\left(0.025(2)^2 + 0.050(1)^2\right) = \boxed{0.075\ M}$$

We generally assume that molar concentration is a good approximation of activity, but as we discussed in class, that is not always the case. Does that assumption get better or worse if we (circle one)

A. replace 0.025 M $MgBr_2(aq)$ with 0.025 M $NaBr(aq)$? **(better)** worse

Why? lower charge and fewer ion w/ NaBr ⇒ lower μ ⇒ activity coeff closer to 1

B. replace 0.025 M $MgBr_2(aq)$ with 0.025 M $BeCl_2(aq)$? better **(worse)**

Why? smaller ion ⇒ activity coeff decreases