

LAST NAME: \_\_\_\_\_

FIRST NAME: \_\_\_\_\_

Student Number: \_\_\_\_\_

# CHM 1311 Midterm #2 Fall 2019

## STAGE 1 – 60 min

Please keep your work covered at all times and keep your eyes on your own paper! Cheating or any appearance of cheating will result in an F in the course and possible expulsion from the university.

There are 6 pages in this test. A periodic table, data tables, and a formula sheet are provided separately. Please show your work to receive partial credit.

Cellular phones, unauthorized electronic devices or course notes (unless an open-book exam) are not allowed during this exam. Phones and devices must be turned off and put away in your bag. Do not keep them in your possession, such as in your pockets. If caught with such a device or document, the following may occur: academic fraud allegations will be filed which may result in you obtaining a 0 (zero) for the exam.

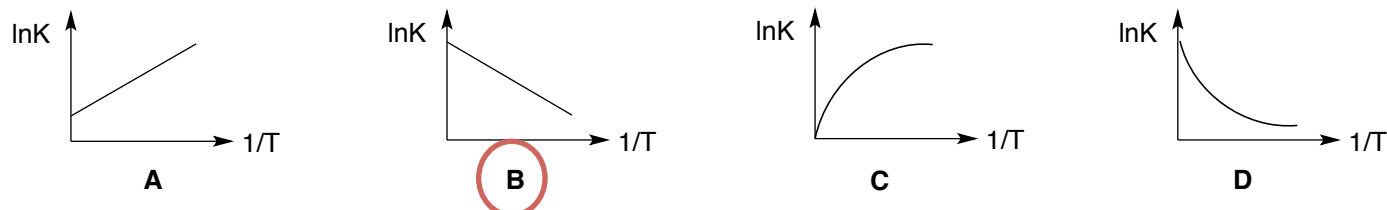
By signing below, you acknowledge that you have ensured that you are complying with the above statement.

Signature: \_\_\_\_\_

## 1. Short Answer Questions

a. (1 pt) The conjugate acid and conjugate base of  $\text{H}_2\text{PO}_4^-$  are  $\text{H}_3\text{PO}_4$  and  $\text{HPO}_4^{2-}$  respectively.

b. (0.5 pt) Which of the following would be the correct van't Hoff plot for an endothermic reaction?

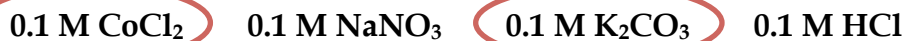


c. (0.5 pt) Which of the following ions is the strongest base?  $\text{N}_3^-$   $\text{NO}_2^-$   $\text{F}^-$   $\text{HO}_2^-$

d. (1 pt) Circle the two 'ingredients' you would use to prepare a buffer of pH = 7.80.



e. (1 pt) The solubility of  $\text{Co}(\text{OH})_2$  will decrease in the presence of (circle all that apply):



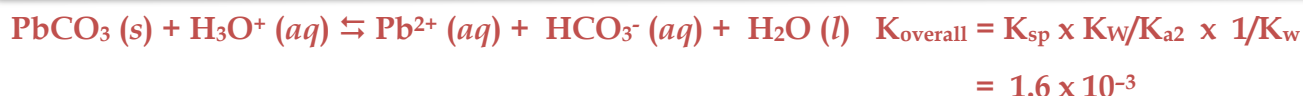
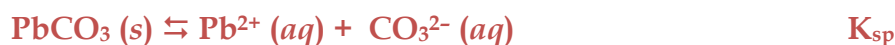
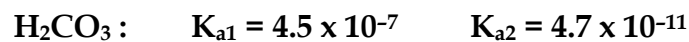
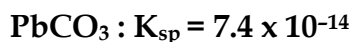
f. (1 pt) Exactly 2.00 mol of A, 2.00 mol of B, and 2.00 mol of C are placed in a sealed 1.00 L flask at 600K.



The reaction will proceed towards (circle one) REACTANTS PRODUCTS

because  $Q = 0.25$ , which is less than  $K$

## BONUS:



2. Consider the following reaction:  $2A(g) + B(g) \rightleftharpoons C(g)$

To a 2.50 L flask, A and B are added at initial pressures of 0.200 bar each. The mixture was allowed to equilibrate at 1000 K and the flask was found to contain 0.00289 mol of C.

THIS QUESTION IS FROM MIDTERM 2 2015 AND IS SIMILAR TO AN EXAMPLE FROM CLASS

a) (4 pts) What is the value of  $K_P$  for the reaction?

$$P_C \text{ at EQM} = \frac{n_C RT}{V} = \frac{(0.00289 \text{ mol})(0.083145 \text{ L} \cdot \text{bar/mol} \cdot \text{K})(1000 \text{ K})}{2.50 \text{ L}}$$

$$= 0.0961 \text{ bar}$$

	2A(g)	+ B(g)	$\rightleftharpoons$	C(g)
I	0.200	0.200		0
C	-2(0.0961)	-0.0961		+0.0961
E	0.0078	0.1039		0.0961

$$K_P = \frac{P_C}{(P_A)^2 \times P_B} = \frac{0.0961}{(0.0078)^2 (0.1039)} = 1.52 \times 10^4$$

α

b) (1 pt) If the equilibrated gas mixture was then transferred to a container of larger volume, what would be the on the equilibrium?

SHIFT TOWARDS REACTANTS

SHIFT TOWARDS PRODUCTS

NO EFFECT

3. A student mixes 31.0 mL of 2.74 M  $\text{Pb}(\text{NO}_3)_2$  (aq) with 20.0 mL of 0.00163 M  $\text{NaI}$  (aq).

a) (1 pt) Identify the expected precipitate:  $\text{PbI}_2$

b) (8 pts) What are the values of  $[\text{Pb}^{2+}]$ ,  $[\text{Na}^+]$ ,  $[\text{NO}_3^-]$  and  $[\text{I}^-]$  after the solution has reached equilibrium at 25°C? You may assume volumes are additive.

$$? \text{ mol Pb}^{2+} = \frac{2.74 \text{ mol Pb}(\text{NO}_3)_2}{\text{L}} \times \frac{1 \text{ mol Pb}^{2+}}{1 \text{ mol Pb}(\text{NO}_3)_2} \times 0.0310 \text{ L} = 8.494 \times 10^{-2} \text{ mol}$$

$$? \text{ mol NO}_3^- = \frac{2.74 \text{ mol Pb}(\text{NO}_3)_2}{\text{L}} \times \frac{2 \text{ mol NO}_3^-}{1 \text{ mol Pb}(\text{NO}_3)_2} \times 0.0310 \text{ L} = 0.1699 \text{ mol}$$

$$? \text{ mol Na}^+ = \frac{0.00163 \text{ mol NaI}}{\text{L}} \times \frac{1 \text{ mol Na}^+}{1 \text{ mol NaI}} \times 0.0200 \text{ L} = 3.26 \times 10^{-5} \text{ mol}$$

$$? \text{ mol I}^- = \frac{0.00163 \text{ mol NaI}}{\text{L}} \times \frac{1 \text{ mol I}^-}{1 \text{ mol NaI}} \times 0.0200 \text{ L} = 3.26 \times 10^{-5} \text{ mol}$$

	$\text{Pb}^{2+}$	+	$2 \text{ I}^-$	$\rightarrow$	$\text{PbI}_2 (\text{s})$
B	$8.494 \times 10^{-2}$				0
A			$3.26 \times 10^{-5}$		
M	$-\frac{1}{2} \times (3.26 \times 10^{-5})$		$-3.26 \times 10^{-5}$		$+\frac{1}{2} \times (3.26 \times 10^{-5})$
A	$8.492 \times 10^{-2}$		0		$1.63 \times 10^{-5}$

$$? [\text{Pb}^{2+}] = \frac{8.494 \times 10^{-2} \text{ mol}}{0.0510 \text{ L}} = 1.665 \text{ M}$$

$$? [\text{NO}_3^-] = \frac{0.1699 \text{ mol}}{0.0510 \text{ L}} = 3.33 \text{ M}$$

$$? [\text{Na}^+] = \frac{3.26 \times 10^{-5} \text{ mol}}{0.0510 \text{ L}} = 6.39 \times 10^{-4} \text{ M}$$

$$? [\text{I}^-] = \frac{0 \text{ mol}}{0.0510 \text{ L}} = 0 \text{ M}$$

	$\text{PbI}_2 (\text{s})$	$\rightleftharpoons$	$\text{Pb}^{2+}$	+	$2 \text{ I}^-$
I	$(1.63 \times 10^{-5} \text{ mol})$		1.665		0
C	$(-s)$		$+s$		$+2s$
E	$(1.63 \times 10^{-5} \text{ mol} - s)$		$1.665 + s$		$2s$

$$K_{\text{sp}} = [\text{Pb}^{2+}][\text{I}^-]^2$$

$$8.7 \times 10^{-9} = (1.665 + s)(2s)^2$$

$$8.7 \times 10^{-9} \approx (1.665)(2s)^2$$

$$s = 3.61 \times 10^{-5} \text{ mol/L}$$

$$\text{CHECK: } \frac{3.61 \times 10^{-5}}{1.665} \times 100\% = 0.002\%$$

$$[\text{Pb}^{2+}] = 1.665 \text{ M} + s$$

$$= 1.665 + 3.61 \times 10^{-5} \text{ M}$$

$$= 1.66 \text{ M}$$

$$[\text{I}^-] = 2s$$

$$= (2)(3.61 \times 10^{-5}) \text{ M}$$

$$= 7.22 \times 10^{-5} \text{ M}$$

$$[\text{Pb}^{2+}] = \underline{1.66 \text{ M}}$$

$$[\text{Na}^+] = \underline{6.39 \times 10^{-4} \text{ M}}$$

$$[\text{NO}_3^-] = \underline{3.33 \text{ M}}$$

$$[\text{I}^-] = \underline{7.22 \times 10^{-5} \text{ M}}$$

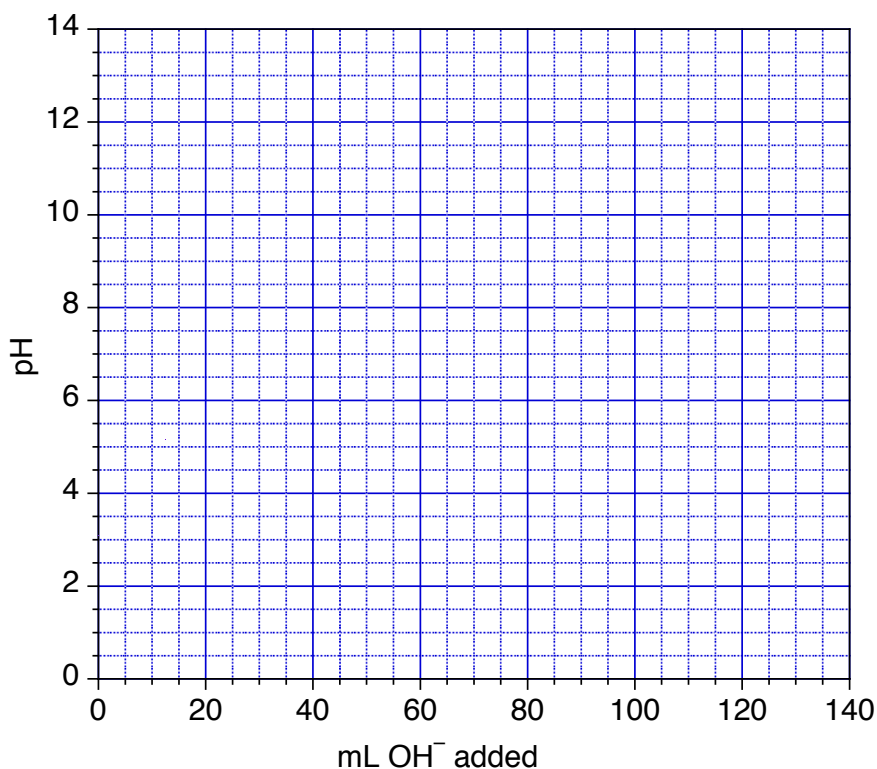
c) (3 pts) What mass (in mg) of solid precipitate is obtained?

$$\begin{aligned}\text{mol PbI}_2 \text{ that dissolves} &= \frac{3.61 \times 10^{-5} \text{ mol}}{\text{L}} \times 0.0510 \text{ L} = 1.84 \times 10^{-6} \text{ mol} \\ \therefore \text{mol PbI}_2 \text{ remaining} &= (1.63 \times 10^{-5} - 1.84 \times 10^{-6}) \text{ mol} = 1.45 \times 10^{-5} \text{ mol} \\ ? \text{ g PbI}_2 &= 1.45 \times 10^{-5} \text{ mol} \times \frac{461 \text{ g}}{\text{mol}} \times \frac{1000 \text{ mg}}{1 \text{ g}} = 6.7 \text{ mg}\end{aligned}$$

Answer: 6.7 mg

4. You are performing a titration of 100.0 mL of 0.110 M benzoic acid with 0.110 M NaOH. Determine the pH of the solution:

- d) (3 pts) initially
- e) (1 pt) at the half-equivalence point
- f) (4 pts) at the equivalence point
- g) (1 pt) Use these values to sketch a titration curve on the graph provided.



a) initial pH:

	HA	+ H <sub>2</sub> O	⇌	H <sub>3</sub> O <sup>+</sup>	+ A <sup>-</sup>
I	0.110	-		0	0
C	-x	-		+x	+x
E	0.110 - x	-		x	x

$$\text{pH} = -\log(0.0026) = 2.58$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}]}$$

$$6.3 \times 10^{-5} = \frac{x^2}{0.110 - x} \approx \frac{x^2}{0.110}$$

$$\therefore x \approx 0.0026 \text{ M} = [\text{H}_3\text{O}^+]$$

$$\text{Check: } \frac{0.0026}{0.110} \times 100\% = 2.4\% \longrightarrow \text{PASSES}$$

b) At the 1/2 equivalence point:  $\text{pH} = \text{p}K_a = -\log(6.3 \times 10^{-5}) = 4.20$  (after 50 mL added)

c) At the equivalence point:

mol HA = mol OH<sup>-</sup> added = 0.0110 mol (this corresponds to adding 100.0 mL of base)  
 new [A<sup>-</sup>] = 0.0110 mol / (0.100 L + 0.100 L) = 0.0550 M

Benzoate (C<sub>7</sub>H<sub>5</sub>O<sub>2</sub><sup>-</sup>) is the conjugate base of a weak acid, so it hydrolyzes:

	A <sup>-</sup>	+ H <sub>2</sub> O	⇌	HA	+ OH <sup>-</sup>
I	0.0550	-		0	0
C	-x	-		+x	+x
E	0.055 - x	-		x	x

$$\text{pOH} = -\log(5.6 \times 10^{-6}) = 5.53$$

$$\text{pH} = 14 - 5.53 = 8.47$$

$$K_b = \frac{K_w}{K_a} = \frac{[\text{HA}][\text{OH}^-]}{[\text{A}^-]}$$

$$\frac{1.0 \times 10^{-14}}{6.3 \times 10^{-5}} = 1.6 \times 10^{-10} = \frac{x^2}{0.055 - x} \approx \frac{x^2}{0.055}$$

$$\therefore x \approx 2.9 \times 10^{-6} \text{ M} = [\text{OH}^-]$$

$$\text{Check: } \frac{2.9 \times 10^{-6}}{0.055} \times 100\% = 0.005\% \longrightarrow \text{PASSES}$$

5. (4 pts) Smudge the Cat (see photo at right) is displeased with his salad, because he prefers balsamic vinegar for his salad dressing. Balsamic vinegar is an aqueous solution of acetic acid. The legal minimum acetic acid content of true balsamic vinegar is 6.00% by mass. Dr. Fox takes a 5.00 mL sample of *Modeleno* brand vinegar ( $d = 1.01 \text{ g/mL}$ ) and titrates it to completion with 39.55 mL of 0.1000 M NaOH. Does the sample exceed the legal minimum content?



$$\text{mol CH}_3\text{COOH} = 0.03955 \text{ L NaOH} \times \frac{0.1000 \text{ mol NaOH}}{\text{L}} \times \frac{1 \text{ mol CH}_3\text{COOH}}{1 \text{ mol NaOH}} = 0.003955 \text{ mol}$$

$$? \text{ g CH}_3\text{COOH} = 0.003955 \text{ mol CH}_3\text{COOH} \times \frac{60.0 \text{ g CH}_3\text{COOH}}{\text{mol CH}_3\text{COOH}} = 0.2373 \text{ g}$$

$$? \text{ g vinegar} = 5.00 \text{ mL} \times \frac{1.01 \text{ g}}{\text{mL}} = 5.05 \text{ g}$$

$$\therefore \% \text{CH}_3\text{COOH} = \frac{0.2373 \text{ g}}{5.05 \text{ g}} \times 100\% = 4.7\%$$

Circle one: YES

NO

Question	Points Possible	Points Earned	TA Initial
1	5		
2	5		
3	12		
4	9		
5	4		
<b>TOTAL</b>	<b>35</b>		