

Chemistry 1210 Spring 2023 Test 3

Wednesday, March 29, 2023

Time: 1 hour 50 minutes

Name: ANSWERS

Student #: _____

This test consists of **ten** pages of questions, the formula sheet, and a periodic table. Please ensure that you have a complete test and, if you do not, obtain one from me **immediately**. There are **51** marks (and four bonus marks) available. Good luck!

1) [2 marks] A solution has a pH of 7.1. This solution is:

- a) Acidic
- b) Neutral
- c) Basic
- d) There is not enough information to answer this question.

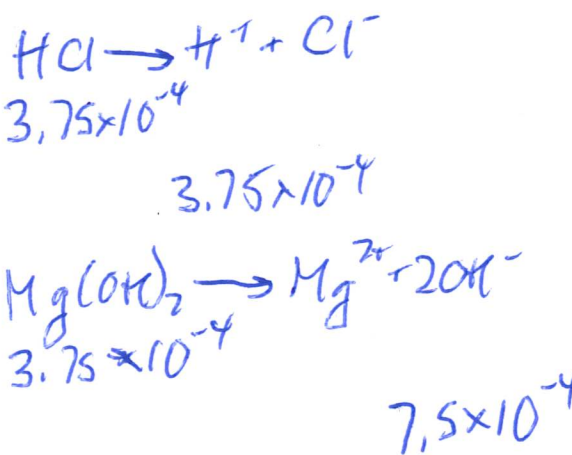
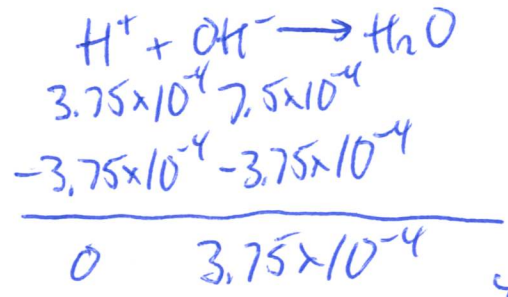
2) [2 marks] At 25°C, the pH of a 5×10^{-10} M solution of Ca(OH)_2 should be:

- a) 4.70
- b) 5.00
- c) 9.00
- d) 9.30
- e) None of these

3) [4 marks] Calculate the pH (at 25°C) of 15.00 mL of 1.00×10^{-3} M HCl mixed with 25.00 mL of 6.00×10^{-4} M Mg(OH)_2 .

$$[\text{HCl}] = \frac{15}{40} \times 1 \times 10^{-3} = 3.75 \times 10^{-4} \text{ M}$$

$$[\text{Mg(OH)}_2] = \frac{25}{40} \times 6 \times 10^{-4} = 3.75 \times 10^{-4} \text{ M}$$

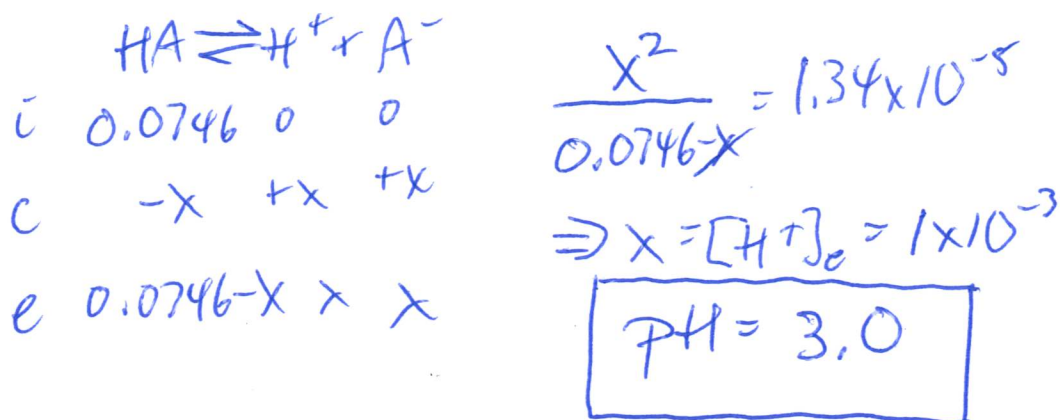


$\text{pOH (by DCS)} = 3.426$

$\text{pH} + \text{pOH} = 14 \Rightarrow \boxed{\text{pH} = 10.574}$

4) [9 marks total] Calculate the pH (at 25°C) of the following solutions, all made with propionic acid ($\text{HC}_3\text{H}_5\text{O}_2$) and/or its salts. Propionic acid is a weak acid with a $K_a = 1.34 \times 10^{-5}$.

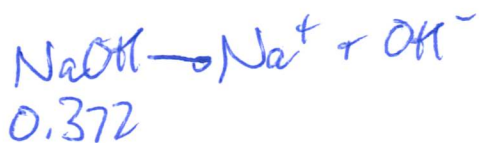
a) [2 marks] 0.0746 M propionic acid



b) [4 marks] 10.00 mL of 1.00 M propionic acid mixed with 15.00 mL of 0.620 M NaOH

$$[\text{HA}] = \frac{10}{25} \times 1 = 0.4 \text{ M}$$

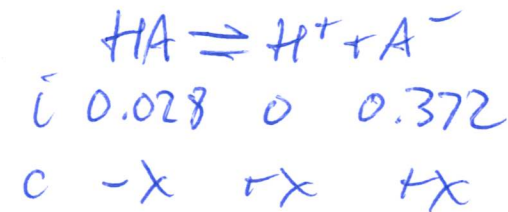
$$[\text{NaOH}] = \frac{15}{25} \times 0.62 = 0.372 \text{ M}$$



0.372	0.372
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0.372	0.4	0
-0.372	-0.372	$+0.372$
0	0.028	0.372

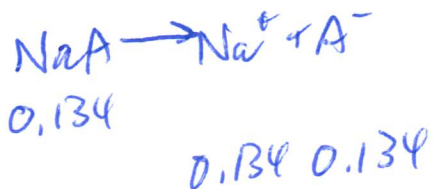


$$\frac{x(0.372 + x)}{0.028 - x} = 1.34 \times 10^{-5}$$

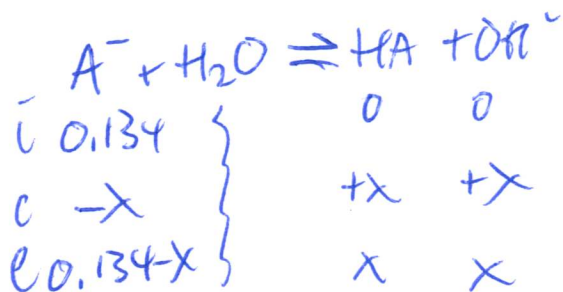
$$\Rightarrow x = [\text{H}^+]_e = 1.00 \times 10^{-6}$$

$\text{pH} = 6.0$

c) [3 marks] 0.134 M sodium propionate



$$\frac{x^2}{0.134} = \frac{1 \times 10^{-14}}{0.134 \times 10^{-5}}$$



$$\Rightarrow x = [\text{OH}^-]_e = 1 \times 10^{-5}$$

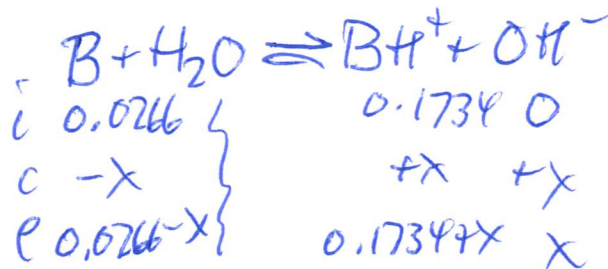
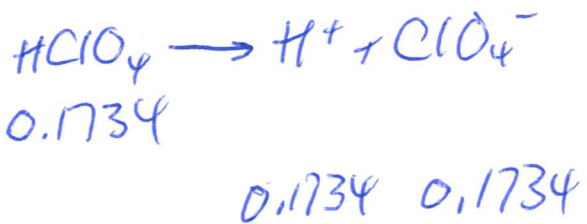
pOH = 5, so pH = 9.0

5) [8 marks total] Calculate the pH (at 25°C) of the following solutions, all made with trimethylamine ((CH₃)₃N) and/or its salts. Trimethylamine is a weak base with a K_b = 6.5 × 10⁻⁵.

a) [3 marks] 10 mL of 0.5 M trimethylamine mixed with 15 mL of 0.289 M HClO₄

$$[\text{B}] = \frac{10}{25} \times 0.5 = 0.2 \text{ M}$$

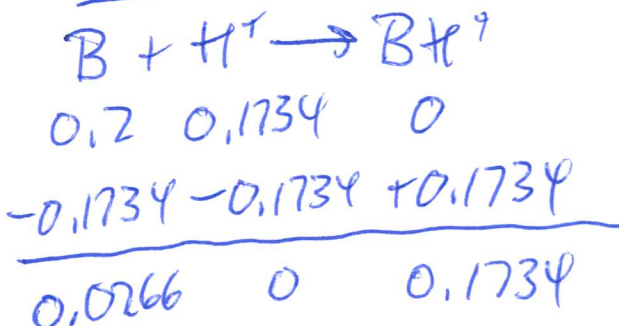
$$[\text{HClO}_4] = \frac{15}{25} \times 0.289 = 0.1734 \text{ M}$$



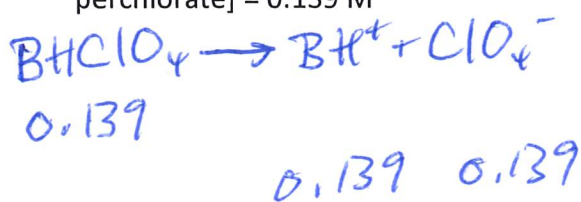
$$x \frac{(0.1734+x)}{(0.0266-x)} = 6.5 \times 10^{-5}$$

$$\Rightarrow x = [\text{OH}^-]_e \approx 1 \times 10^{-5}$$

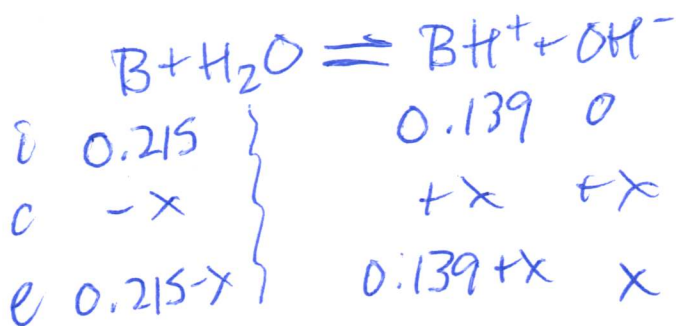
pOH = 5; pH = 9



b) [2 marks] A solution that has [trimethylamine] = 0.215 M and [trimethylammonium perchlorate] = 0.139 M



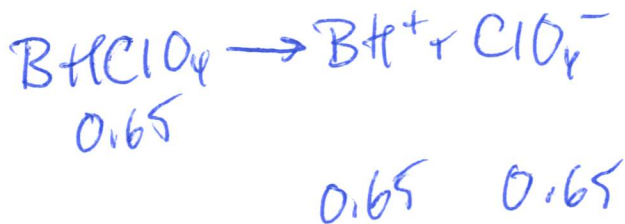
$$\frac{x(0.139)}{0.215} = 6.5 \times 10^{-5}$$



$$\Rightarrow x = [\text{OH}^-]_e = 1 \times 10^{-4}$$

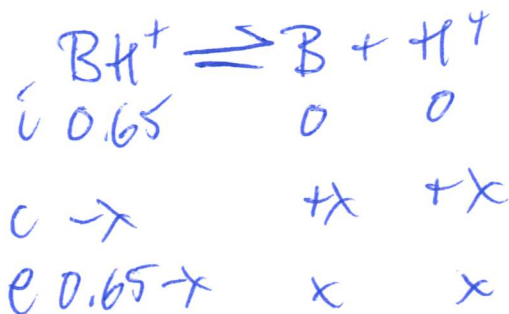
pOH = 4, pH = 10

c) [3 marks] A solution that has [trimethylammonium perchlorate] = 0.65 M



$$\Rightarrow x = [\text{H}^+]_e = 1 \times 10^{-5}$$

pH = 5.0



$$\frac{x^2}{0.65} = \frac{1 \times 10^{-14}}{6.5 \times 10^{-5}}$$

6) [6 marks total] Phosphoric acid (H_3PO_4) is a weak triprotic acid with $\text{p}K_{a1} = 2.12$, $\text{p}K_{a2} = 7.21$, and $\text{p}K_{a3} = 12.32$. Calculate (at 25°C) the pH of the following solutions, all made using phosphoric acid and/or its salts.

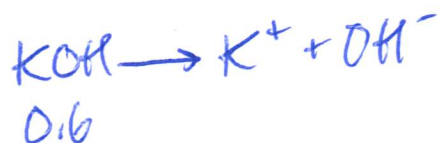
a) [4 marks] 10 mL of 1 M H_3PO_4 mixed with 15 mL of 1 M KOH

$$[\text{H}_3\text{A}] = \frac{10}{25} \times 1 = 0.4 \text{ M}$$

$$[\text{KOH}] = \frac{15}{25} \times 1 = 0.6 \text{ M}$$

$$[\text{H}_2\text{A}^-] = [\text{HA}^{2-}], \text{ so}$$

$$\text{by DCSC } \boxed{\text{pH} = 7.21}$$



0.6

0.6 0.6



0.6 0.4

0

-0.4 -0.4 +0.4

0.2 0

0.4

rxn continues...



0.2 0.4

0

-0.2 -0.2 +0.2

0 0.2

0.2

b) [2 marks] A solution containing only NaH_2PO_4 .

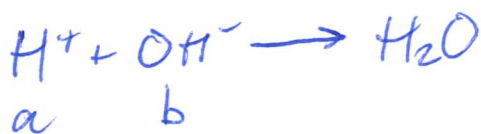
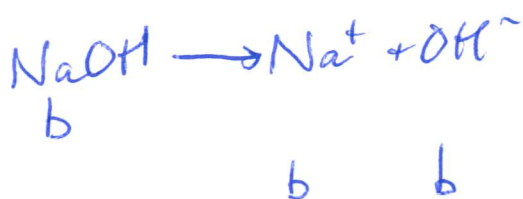
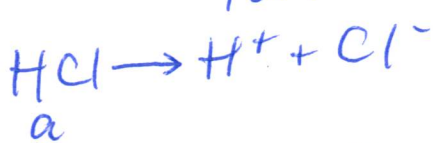
$$\frac{1}{2}(\text{p}K_{a1} + \text{p}K_{a2}) = \boxed{4.665}$$

7) [5 marks total] A 10-mL aliquot of 1.0×10^{-3} M HCl is titrated with 8.0×10^{-4} M NaOH. An indicator with $pK_{in} = 4.00$ is used.

a) [4 marks] At what added volume of NaOH will the end point be reached?

$$[HCl] = \frac{10}{10+V} \times 1 \times 10^{-3} = \frac{0.01}{10+V} \quad (a)$$

$$[NaOH] = \frac{V}{10+V} \times 8 \times 10^{-4} = \frac{8 \times 10^{-4} V}{10+V} \quad (b)$$



$$\begin{array}{r} -b \quad -b \\ \hline a-b \end{array}$$

$$a - b = 10^{-4}$$

$$\left(\frac{0.01 - 8 \times 10^{-4} V}{10+V} = 10^{-4} \right) \times 10^4$$

$$\frac{100 - 8V}{10+V} = 1$$

$$100 - 8V = 10 + V$$

$$90 = 9V$$

$$\boxed{V = 10 \text{ mL}}$$

b) [1 mark] Is the indicator a suitable one for the titration? How do you know? (No marks for guessing. 😊)

want end point when moles acid = moles base:

$$10 \times 10^{-3} = V \times 8 \times 10^{-4}$$

$$\Rightarrow V = 12.5 \text{ mL}$$

$$\text{error: } \frac{2.5}{12.5} \times 100 = 20\% \therefore$$

No good!

8) [2 marks] Indicate whether each of the following salts acts as an acid, as a base, or neither in aqueous solution. Circle your choice:

NaNO ₂	acid	base	neither
NH ₄ Cl	acid	base	neither
KF	acid	base	neither
KI	acid	base	neither

9) [4 marks] When 1.63 grams of NaOH (40.0 g/mol) was mixed with 100.0 mL of 0.300 M H₂SO₄ (S = 4.184 J/g·°C, D = 1.00 g/mL) at 22.20°C, the temperature of the resulting solution rose to 29.06°C. Given that the H₂SO₄ was contained in a calorimeter with C = 50 J/°C, calculate ΔH° for the reaction:



$$q_{\text{sol'n}} + q_{\text{cal'd}} + q_{\text{rxn}} = 0$$

$$(101.63)(4.184)(29.06 - 22.2) + 50(29.06 - 22.2) + q_{\text{rxn}} = 0$$

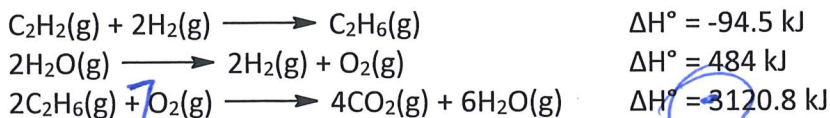
$$\Rightarrow q_{\text{rxn}} = -3260 \text{ J}$$

$$\text{LR check: } 1.63 \text{ g} \times \frac{1 \text{ mol}}{40 \text{ g}} \times \frac{1 \text{ rxn}}{2 \text{ NaOH}} = 0.020375 \text{ moles rxn}$$

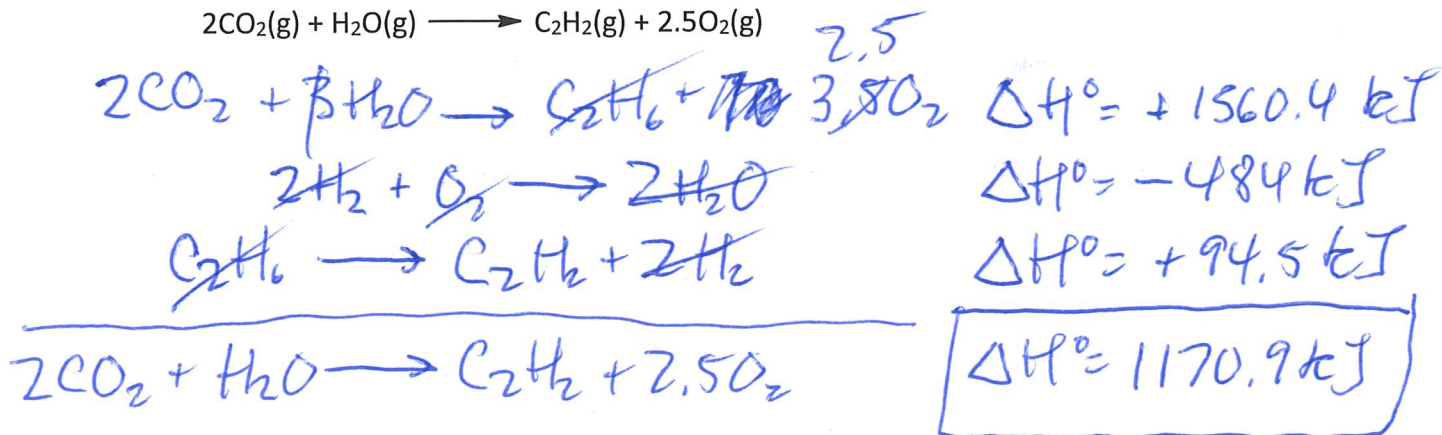
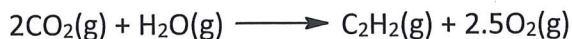
$$100 \times 10^{-3} \text{ L} \times \frac{0.3 \text{ mol}}{1 \text{ L}} \times \frac{1 \text{ rxn}}{1 \text{ H}_2\text{SO}_4} = 0.03 \text{ moles rxn}$$

$$\therefore \Delta H^\circ = \frac{-3260 \text{ J}}{0.020375} = \boxed{-160,000 \text{ J or } -160 \text{ kJ}}$$

10) [3 marks total] Given the following reactions:



a) [2 marks] Calculate ΔH° for the reaction



b) [1 mark] What is the enthalpy of formation of $\text{H}_2\text{O}(\text{g})$? Give your answer in kJ/mol.

$$-242 \frac{\text{kJ}}{\text{mol}}$$

11) [2 marks] Given the reaction

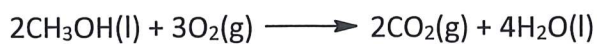


And that the molar enthalpies of formation of CO_2 and H_2O are -393.52 kJ and -285.83 kJ respectively, calculate the molar enthalpy of formation of $\text{CH}_3\text{OH}(\text{l})$.

$$\begin{array}{l} 2(-393.52) + 4(-285.83) - 2x = -1453.56 \\ -1930.36 - 2x = -1453.56 \\ \Rightarrow x = -238.4 \frac{\text{kJ}}{\text{mol}} \end{array}$$

(32.04 g)
mol

12) [4 marks] When 324.4 mg of $\text{CH}_3\text{OH}(\text{l})$ is burned in a bomb calorimeter with $C = 10.0 \text{ kJ}/^\circ\text{C}$, the temperature of the calorimeter increases from 25.0000°C to 25.7346°C . Calculate ΔH° for the reaction



$$q_{\text{cal}} = 10.0(0.7346) = 7.346 \text{ kJ}$$

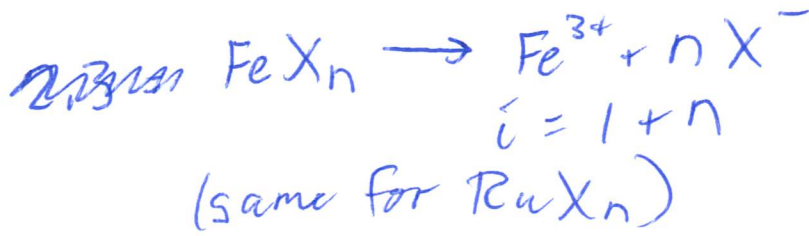
$$\therefore q_{\text{rxn}} = -7.346 \text{ kJ}$$

$$n_{\text{rxn}} = 324.4 \times 10^{-3} \text{ g} \times \frac{1 \text{ mol}}{32.04 \text{ g}} \times \frac{1 \text{ rxn}}{2 \text{ CH}_3\text{OH}} = \frac{5.062 \dots \times 10^{-3}}{\text{mol rxn}}$$

$$\therefore \Delta E^\circ = \frac{-7.346 \text{ kJ}}{5.062 \dots \times 10^{-3}} = -1451.08 \text{ kJ}$$

$$\Delta H^\circ = -1451.08 + (2-3)(8.314 \times 10^{-3})(298.15)$$
$$= \boxed{-1453.56 \text{ kJ}}$$

[BONUS - 4 marks] It takes 5.0144 g of FeX_n to lower the freezing point of 100 g of water ($K_f = 1.86^\circ\text{C/molal}$) by 2.3°C . It takes 6.4125 g of RuX_n (same X, same n) to lower the freezing point of 100 g of water by 2.3°C . What are the element X and the value of n? You may assume that both FeX_n and RuX_n ionize completely in water.



$$2.3 = (n+1)(1.86) \frac{\text{moles}}{0.1 \text{ kg}}$$

$$\Rightarrow \text{moles} = \frac{0.23}{1.86(n+1)} \text{ for both.}$$

$$n+1 = \frac{bc - cf}{ad - ed}$$

$$= 4$$

$$n = 3$$

$$\text{So: } \frac{5.0144 \leftarrow a}{55.845 + nX \leftarrow b} = \frac{0.23 \leftarrow c}{1.86(n+1) \leftarrow d}$$

and

$$\frac{6.4125 \leftarrow e}{101.07 + nX \leftarrow f} = \frac{0.23 \leftarrow c}{1.86(n+1) \leftarrow d}$$

$$\frac{a}{b + nX} = \frac{c}{d(n+1)}$$

$$\frac{e}{f + nX} = \frac{c}{d(n+1)}$$

$$ad(n+1) = bc + enX$$

$$ed(n+1) = cf + enX$$

$$(ad - ed)(n+1) = bc - cf$$

$$\text{So: } \frac{5.0144 \leftarrow a}{55.845 + 3X \leftarrow b} = \frac{0.23 \leftarrow c}{1.86(4) \leftarrow d}$$

$$= 3.09 \dots \times 10^{-2}$$

$$\frac{a}{b + 3X} = c$$

$$a = cb + 3cX$$

$$a - cb = 3cX$$

$$X = \frac{a - cb}{3c} = 35.453 \text{ Cl.}$$

So: $X = \text{Cl}$
 $n = 3$