

Chemistry 1210 Spring 2024 Test 3

Wednesday, March 27, 2024

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 **43** marks available. Good luck!

1) [11 marks total] A battery was constructed using the following half-reactions:



Platinum electrodes were available where necessary, and 3 litres of solution were used in each half cell. The battery was run at 25°C.

a) [1 mark] Write the overall reaction occurring in the battery.



b) [1 mark] Calculate ε° for the battery.

$$2.36 + 1.36 = \boxed{3.72 \text{ V}}$$

c) [2 marks] Calculate K for the battery.

$$\varepsilon^{\circ} = \frac{0.059159}{2} \log K$$

$$\Rightarrow \log K = 125.762 \dots$$

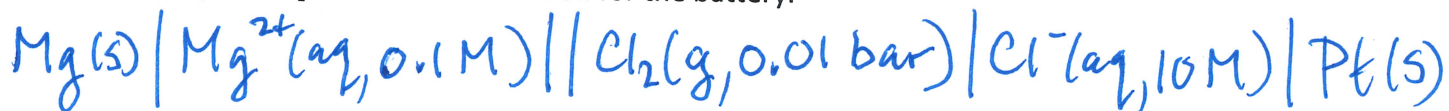
$$\text{So } \boxed{K = 5.79 \times 10^{125}}$$

d) [2 marks] What voltage will the battery generate under the conditions given?

$$E = 3.72 - \frac{0.059159}{2} \log \left(\frac{0.1 \times 10^2}{0.01} \right)$$

$$= \boxed{3.631 \text{ V}}$$

e) [1 mark] Give the cell notation for the battery.



f) [3 marks] A current of 2.0 amperes was drawn from the battery for 16 hours, 4 minutes, and 51.2 seconds. What was the $[\text{Mg}^{2+}]$ after that time?

$$16 \times 3600$$

$$4 \times 60$$

$$51.2$$

$$\hline 57891.2 \text{ s}$$

$$57891.2 \text{ s} \times \frac{2 \text{ coul}}{\text{s}} \times \frac{1 \text{ mol } e^{-}}{96,485.33212 \text{ coul}} \times \frac{1 \text{ Mg}^{2+}}{2 e^{-}}$$

$$= 0.6 \text{ moles Mg}^{2+} \text{ created}$$

$$\text{So } [\text{Mg}^{2+}] = \frac{0.1 \text{ moles}}{\text{L}} \times 3 \text{ L} + 0.6 \text{ moles}$$

$$\hline \text{3 L}$$

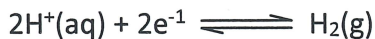
$$= \boxed{0.3 \text{ M}}$$

g) [1 mark] This battery cannot be recharged successfully. Why? (No marks for guessing.

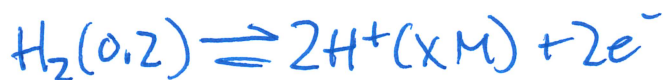


Water will both oxidize before Cl^- and
reduce before Mg^{2+} (more positive E° s for it).

2) [4 marks] A concentration cell was set up using the half-reaction:



Both half-cells had the pressure of H_2 set to 0.20 bar. In one of the half cells the $[\text{H}^+]$ was 0.10 M, and in the other the H^+ was generated by a 0.035 M solution of a weak acid. The concentration cell was run at 10.06°C . If the battery so constructed generated 46.3 mV, what was the K_a of the weak acid?

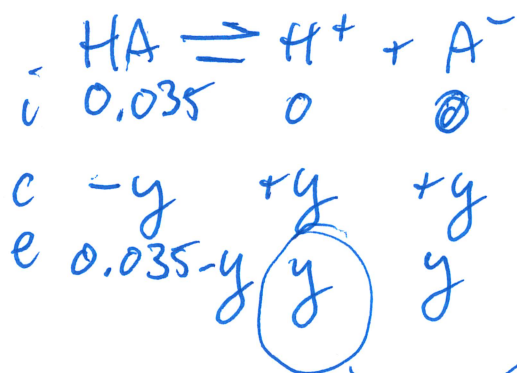


$$46.3 \times 10^{-3} = 0 - \frac{(8.314472 \text{ J mol}^{-1} \text{ K}^{-1})(283.21 \text{ K})}{2 \cdot 96,485.33212} \ln Q$$

$$\Rightarrow Q = 0.022499\dots$$

$$= \frac{x^2}{0.1^2} \Rightarrow x = 0.015 \text{ M H}^+$$

It all came from HA...



$$K_a = \frac{(0.015)^2}{(0.02)} = \boxed{0.01125}$$

3) [1 mark] Which of the following species is most likely to be amphiprotic?

a) NH_3

b) H_3PO_4

c) $\text{C}_2\text{H}_3\text{O}_2^{-1}$

d) $\text{H}_2\text{AsO}_4^{-1}$

4) [2 marks] When $K_w = 1.0 \times 10^{-13}$, the pH of a 3×10^{-10} M solution of $\text{Mg}(\text{OH})_2$ is closest to:

a) 3.48

c) 6.50

e) 9.52

b) 3.78

d) 9.22

f) None of these

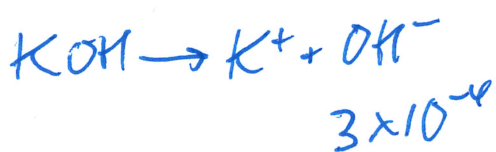
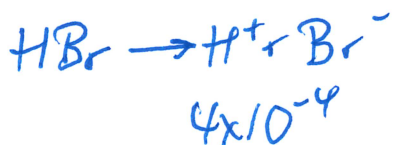
5) [11 marks total] Calculate the pH of the following solutions, all made at 25°C :

a) [3 marks] 10.0 mL of 1.0×10^{-3} M HBr mixed with 15.0 mL of 5.0×10^{-4} M KOH.

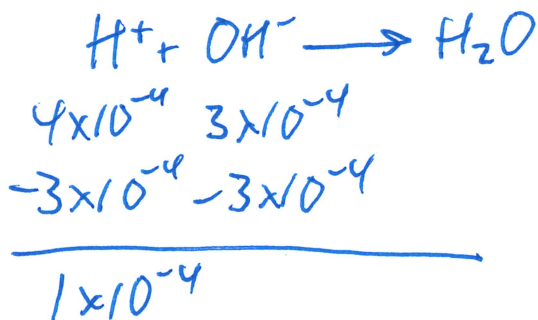
~~Example~~

$$[\text{HBr}] = \frac{10}{25} \times 1 \times 10^{-3} = 4 \times 10^{-4} \text{ M}$$

$$[\text{KOH}] = \frac{15}{25} \times 5 \times 10^{-4} = 3 \times 10^{-4} \text{ M}$$



$$\text{pH (by Desc)} = -\log(1 \times 10^{-4})$$
$$= \boxed{4.0}$$

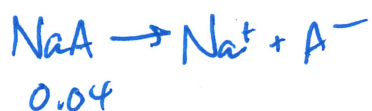
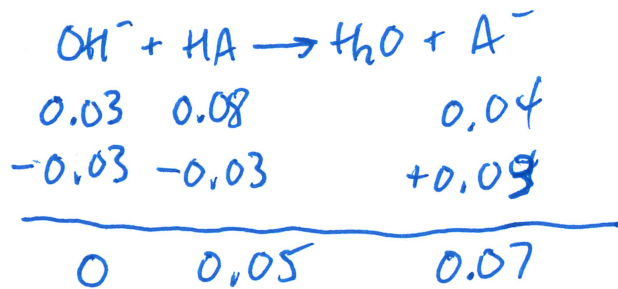


b) [3 marks] 10.0 mL of a solution that has $[HA] = 0.20 \text{ M}$ and $[NaA] = 0.10 \text{ M}$ mixed with 15.0 mL of 0.05 M NaOH. HA is a weak acid with a $K_a = 1.40 \times 10^{-4}$

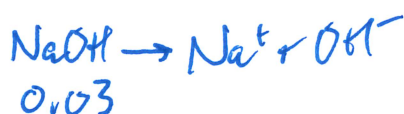
$$[HA] = \frac{10}{25} \times 0.2 = 0.08 \text{ M}$$

$$[NaA] = \frac{10}{25} \times 0.1 = 0.04 \text{ M}$$

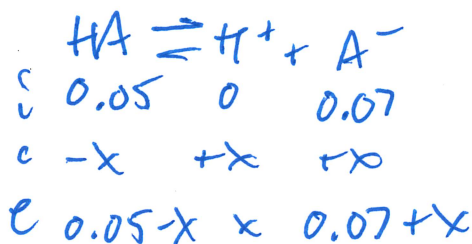
$$[NaOH] = \frac{15}{25} \times 0.05 = 0.03 \text{ M}$$



$$0.04 \qquad \qquad \qquad 0.04$$



$$0.03 \qquad \qquad \qquad 0.03$$

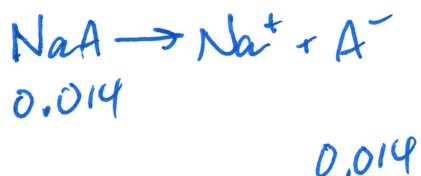


$$x = [H^+]_e = 1 \times 10^{-4}$$

$pH = 4.0$

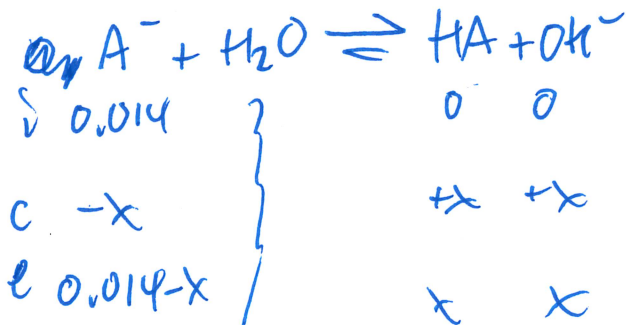
$$\frac{x(0.07+x)}{(0.05-x)} = 1.4 \times 10^{-4}$$

c) [3 marks] 0.014 M NaA (same weak acid as in (b)).



$$\frac{x^2}{0.014-x} = \frac{1 \times 10^{-14}}{1.4 \times 10^{-4}}$$

$$\Rightarrow x = [OH^-]_e = 1 \times 10^{-6}$$

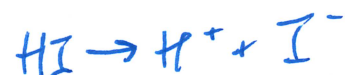


$pOH = 6, \quad pH = pK_w - pOH = 8$

d) [2 marks] 10.0 mL of 0.20 M NH_3 ($K_b = 1.74 \times 10^{-5}$) mixed with 15.0 mL of 0.1335 M HI.

$$[\text{NH}_3] = \frac{10}{25} \times 0.2 = 0.08 \text{ M}$$

$$[\text{HI}] = \frac{15}{25} \times 0.1335 = 0.0801 \text{ M}$$



0.0801

0.0801



0.08 0.0801

-0.08 -0.08 +0.08

0 1×10^{-4} 0.08

By DCSC, $[\text{H}^+]_e = 1 \times 10^{-4}$

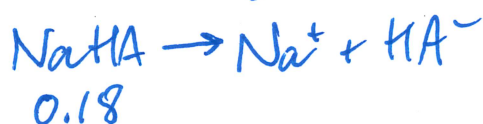
$$\boxed{\text{pH} = 4.0}$$

6) [14 marks total] H_2A is a weak acid with $K_{a1} = 2.5 \times 10^{-4}$ and $K_{a2} = 4.0 \times 10^{-9}$. Calculate the pH of the following solutions made using H_2A and/or its salts at $25^\circ C$.

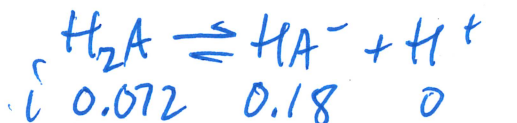
a) [3 marks] 10.0 mL of 0.18 M H_2A mixed with 15.0 mL of 0.30 M NaHA.

$$[H_2A] = \frac{10}{25} \times 0.18 = 0.072 \text{ M}$$

$$[NaHA] = \frac{15}{25} \times 0.3 = 0.18 \text{ M}$$



0.18



$$\frac{(0.18+x)(x)}{0.072-x} = 2.5 \times 10^{-4}$$

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

$pH = 4.0$

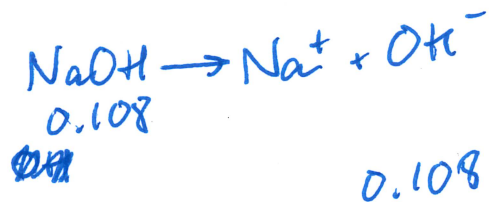
b) [2 marks] 15.0 mL of 0.30 M NaHA

$$pH = \frac{1}{2}(pK_{a1} + pK_{a2}) = 6$$

c) [4 marks] 10.0 mL of 0.21 M H₂A mixed with 15.0 mL of 0.18 M NaOH

$$[H_2A] = \frac{10}{25} \times 0.21 = 0.084 M$$

$$[NaOH] = \frac{15}{25} \times 0.18 = 0.108 M$$



0.108	0.084	0
-0.084	-0.084	+0.084
0.024	0	0.084

rxn continues...



0.024	0.084	0
-0.024	-0.024	+0.024
0	0.06	0.024



i	0.06	0	0.024
c	-x	+x	+x
e	0.06-x	x	0.024+x

$$\frac{x(0.024+x)}{(0.06-x)} = 4.0 \times 10^{-9}$$

$$x = [H^+]_e = 1 \times 10^{-8}$$

$$pH = 8.0$$

d) [1 mark] What would be the pK_a for an indicator that you would use for the titration of H₂A? How do you know? (No marks for guessing. 😊)

Pick an indicator whose colour changes at the 1st equiv. point, for which the pH=6. ∴ pK_a for indicator should be 6.

e) [4 marks] Sketch the titration curve you would expect to see for H_2A being titrated by $NaOH$. On your graph, indicate:

- The equivalence point or points
- The buffer region or regions
- The region or regions on the graph where the pH is controlled by OH^-
- The point or points on the graph where the pH is controlled by one amphiprotic species.

