Chemistry 1210 Spring 2024 Test 3

Wednesday, March 27, 2024 Time: 1 hour 50 minutes

Name: _____ 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:

$Mg^{2+}(aq, 0.10\ M) + 2e^{-1} \rightleftharpoons Mg(s)$ $\varepsilon° = -2.36\ V$

$Cl_2(g, 0.010\ bar) + 2e^{-1} \rightleftharpoons 2Cl^{-1}(aq, 10\ M)$ $\varepsilon° = 1.36\ V$

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.

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

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

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 $[Mg^{2+}]$ after that time?

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

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

$2H^+(aq) + 2e^{-1} \rightleftharpoons H_2(g)$

Both half-cells had the pressure of H_2 set to 0.20 bar. In one of the half cells the $[H^+]$ 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?

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

a) NH_3 b) H_3PO_4 c) $C_2H_3O_2^{-1}$ d) $H_2AsO_4^{-1}$

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

a) 3.48
b) 3.78
c) 6.50
d) 9.22
e) 9.52
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.

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

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

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

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°C.

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

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

c) **[4 marks]** 10.0 mL of 0.21 M H_2A mixed with 15.0 mL of 0.18 M NaOH

d) **[1 mark]** What would be the pK_a for an indicator that you would use for the titration of H_2A? How do you know? (No marks for guessing. 😊)

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

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