JOHN ABBOTT COLLEGE
CHEMISTRY OF SOLUTIONS: 202-NYB-05

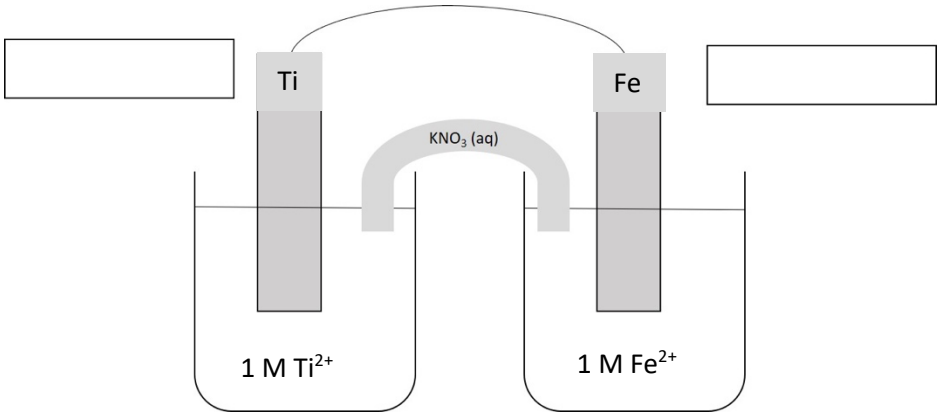
2-hour FINAL EXAMINATION Fall 2020

Chemical equations must be balanced and include physical states.
ALL WORK MUST BE SHOWN FOR FULL MARKS
(Except for Multiple Choice Questions)

1. Consider the reaction that occurs when a sample of magnesium iodide is added to an aqueous solution of sodium hydroxide.

a) Write the balanced molecular and net ionic equations for this reaction making sure to include the physical states (phases) of all species.
   MOLECULAR
   NET IONIC
b) Calculate the theoretical mass of precipitate that forms after 0.0169 moles of magnesium iodide are added to 200.0 mL of 0.124 mol/L sodium hydroxide solution. Show all work for full marks.
c) What is the concentration in mol/L of the spectator **anion** remaining in the solution after the reaction is complete? Assume no change in volume.

2. Consider the following galvanic (voltaic) cell:



Standard Reduction Potentials at 25 °C

$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$ $\quad E° = -0.447$ V

$Ti^{2+}(aq) + 2e^- \longrightarrow Ti(s)$ $\quad E° = -1.630$ V

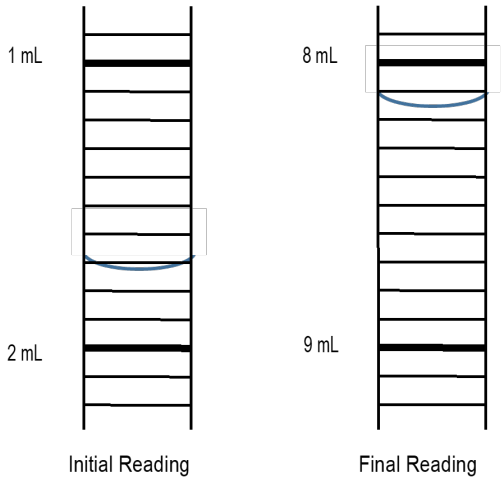
a) Write the balanced oxidation half-reaction.
b) Write the balanced reduction half-reaction.
c) Write the net/overall equation for the cell reaction.
d) Calculate the standard cell potential.
e) Label the anode and the cathode (in the boxes provided above).
f) Identify the oxidizing agent in this reaction.

3. A 25.0-mL solution containing 0.100 g of a diprotic acid, $H_2A(aq)$, was titrated with 0.209 mol/L sodium hydroxide.

a) Write a balanced molecular equation for the reaction between the acid, $H_2A(aq)$, and sodium hydroxide.

b) Shown below are the initial and final burette volumes for the titration of the acid solution. Record the readings in the table provided and calculate the total volume.

Titration Data	
Final Volume	
Initial Volume	
Total Volume	



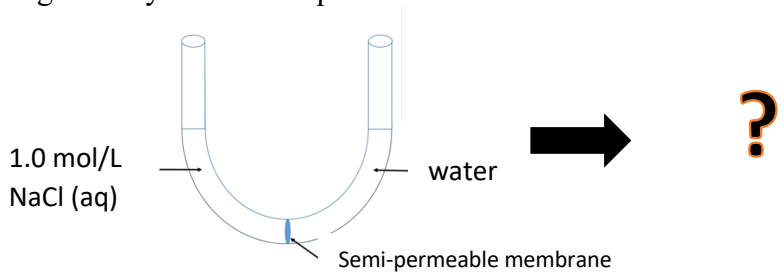
c) Calculate the molar mass of the acid. Show all your work for full marks.

4. Which molecular compound conducts electricity very well when dissolved in water?

i. Ammonia
ii. Ammonium nitrate
iii. Hydrochloric acid
iv. Hypochlorous acid
v. Sodium chloride

Answer: ☐

5. In the lab you are given an empty U-shaped tube. The two halves of the tube are separated by a semi-permeable membrane, as shown below. To the left side you add 30 mL of 1.0 mol/L sodium chloride. To the right side you add an equal volume of water. After a few minutes what will you observe?



i. The liquid level on the left will be higher
ii. The liquid level on the left will be lower
iii. The water level on the right won't change
iv. The liquid level on both sides will be significantly higher

Answer: ☐

6. Nitrogen dioxide decomposes into nitrogen monoxide and oxygen gas according to the reaction:

$$2NO_2(g) \rightarrow 2NO(g) + O_2(g)$$

The rate constant for the reaction is 0.54 $M^{-1} \cdot s^{-1}$ at 300 °C. If the initial concentration of NO_2 is 0.65 mol/L, how much time would it take for the concentration to decrease to half its initial value?

7. The following reaction mechanism is proposed:

I. $C_3H_6(aq) + Br_2(aq) \rightarrow C_3H_6Br^+(aq) + Br^-(aq)$ slow (k_1)

II. $C_3H_6Br^+(aq) + CH_4O(aq) \rightarrow C_4H_{10}OBr^+(aq)$ fast (k_2)

III. $C_4H_{10}OBr^+(aq) + CH_4O(aq) \rightarrow C_4H_9OBr(aq) + CH_5O^+(aq)$ fast (k_3)

a) Write the balanced equation of the overall chemical reaction.

b) Based upon the proposed mechanism above, write the predicted rate law for this reaction.

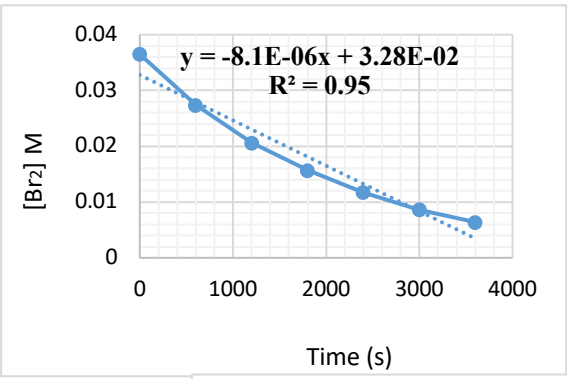
$Rate_{rxn}$ =

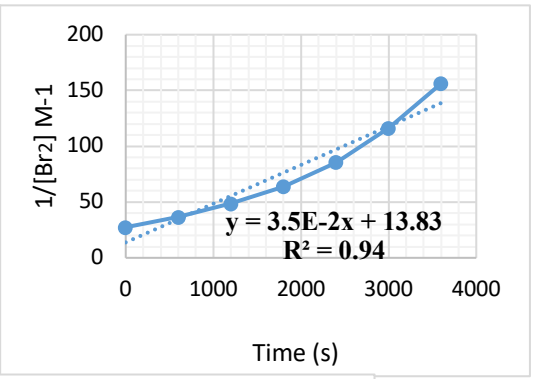
Based on what you wrote above:

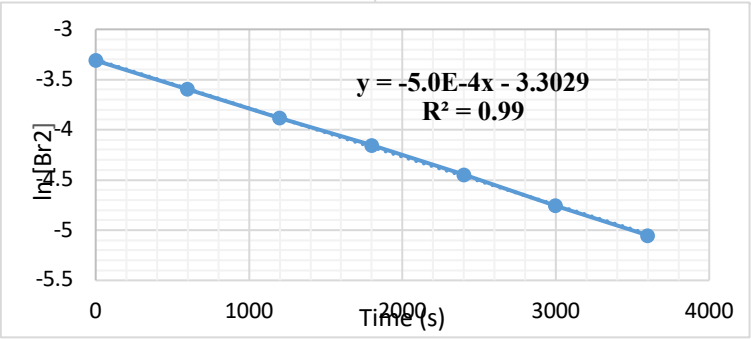
i) What is the order of the reaction with respect to Br_2?

ii) What is the order of the reaction with respect to CH_4O?

c) **Circle** the graph from which the rate constant with respect to Br_2 could be obtained. (Assume that the concentration of the other reactants are constant or hardly change as the reaction proceeds.)





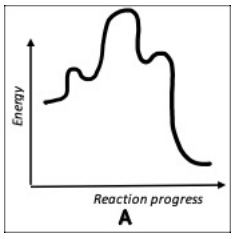


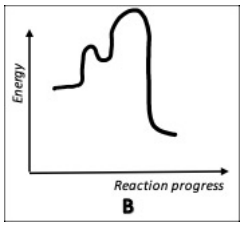
d) Write the rate constant, k, with units.

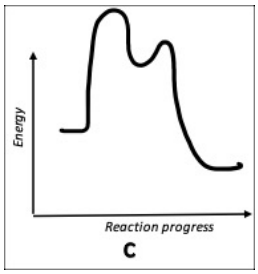
e) If the concentration of CH_4O is increased by a factor of three, how will this affect the rate of the reaction? Assume that the concentrations of the other reactants are essentially constant.

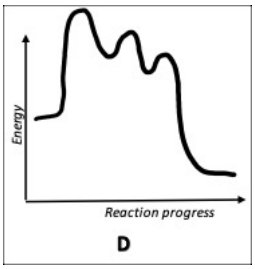
f) What is the role of $C_3H_6Br^+$ in the reaction?

g) Circle the reaction progress diagram below which best describes this reaction. Assume the reaction is <u>exothermic</u>.









8. Solution A is an aqueous solution of glucose ($C_6H_{12}O_6$) which was prepared by adding 150.0 g glucose (180.16 g/mol) into 800.0 mL deionized water.

a) Calculate the boiling point of Solution A.
(K_b of water = 0.512 °C kg mol^{-1}; density of water = 1.000 g/mL; boiling point of water = 100.0 °C)

b) Solution B is 0.2 m aqueous glucose solution. Solution C is 0.2 m aqueous sodium sulfate solution. Explain why the boiling point of Solution C is greater than the boiling point of Solution B.

c) Beaker B contains the glucose solution (Solution B) and beaker C contains the same volume of the sodium sulfate solution (Solution C). Both beakers are stored at room temperature. After a week one beaker contains a larger volume of liquid than the other beaker. Predict which beaker contains the greater volume of liquid and give an appropriate explanation for this phenomenon.

Beaker:

Explanation:

9. Observe the following reaction at equilibrium, occurring inside a sealed container:

$$3\ A(g) + 2\ B(s) + C(g) \rightleftharpoons 2D\ (g) + 2\ E(l)$$

The forward reaction is endothermic.

Which of the following changes can cause the reaction to favor the production of more products (shift right)?

i. Increasing the amount of B(s)
ii. Reducing the volume of the container
iii. Cooling the container (removing heat)
iv. All of the options i, ii, and iii
v. None of the options above

Answer: ☐

10. Which species is the conjugate base of the dihydrogen phosphate ion ($H_2PO_4^-$)?

i. HPO_4^-
ii. H_3PO_4
iii. PO_4^{3-}
iv. HPO_4^{2-}
v. H_2PO_4

Answer: ☐

11. Other than water, a solution of 0.10 mol/L hydrofluoric acid contains which chemical species in the greatest concentration?

i. hydrofluoric acid(aq)
ii. hydronium ion(aq)
iii. hydroxide ion(aq)
iv. hydronium ion(aq) and fluoride ion(aq) equally
v. hydrofluoric acid(aq), hydronium ion(aq) and fluoride ion(aq) equally

Answer: ☐

12. Consider the following solutions:

Acid	Concentration	Ka
Acetic acid	0.350 mol/L	1.8×10^{-5}
Hydrofluoric acid	0.350 mol/L	6.5×10^{-5}
Nitrous Acid	0.350 mol/L	4.6×10^{-5}

a) Which solution will have the highest pH value? No calculations are necessary.

b) Calculate the pH of 1.00 L of the solution from a. Write a relevant chemical equation for the dissociation in water. State and verify any assumptions or approximations you make.

13. A solution contains 0.113 mol/L benzoic acid (C_6H_5COOH) and 0.0612 mol/L sodium benzoate (NaC_6H_5COO). The Ka of benzoic acid is 6.3×10^{-5}.

a) Write the chemical equation for the equilibrium governing the pH of this solution.

b) Calculate the pH of the solution.

c) Write a chemical equation showing the reaction which occurs when nitric acid is added to the original solution.

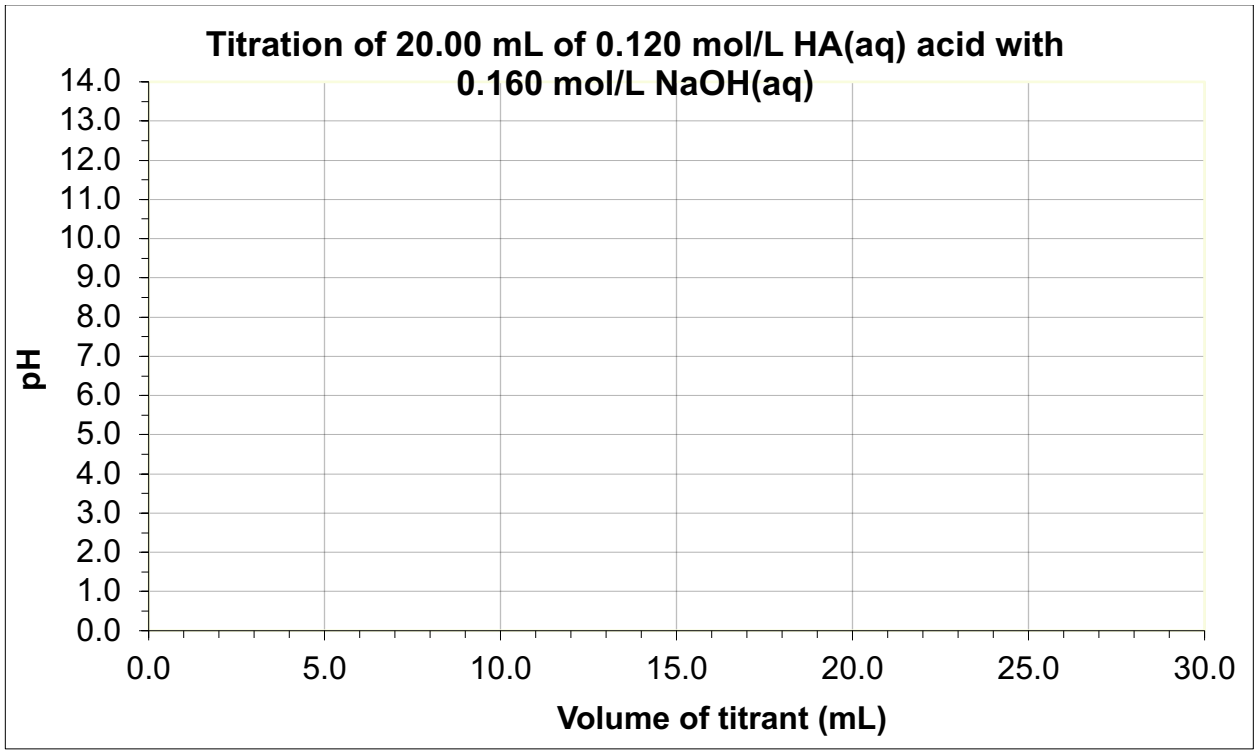
14. 20.00 mL of 0.120 mol/L "HA" (a weak acid with Ka = 1.5×10^{-5}) was titrated with 0.160 mol/L NaOH.

a) What volume of NaOH was required to reach the equivalence point?

b) Explain why at the equivalence point the pH will be greater than 7.0? Back up your explanation with a relevant chemical equation. No calculations are necessary.

c) Calculate the pKa of this weak acid.

d) Sketch in the graph provided below what the titration curve would look like. The initial starting pH is 2.87.



Answer Key:

1.

a) MOLECULAR $MgI_2(s \text{ or } aq) + 2NaOH(aq) \rightarrow Mg(OH)_2(s) + 2NaI(aq)$

NET IONIC $Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$

b) = 0.723 g (3 sf)

c) *[I-] = 0.169 mol/L*

2.

a) $Ti(s) \longrightarrow Ti^{2+}(aq) + 2e^-$

b) $Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$

c) $Ti(s) + Fe^{2+}(aq) \longrightarrow Ti^{2+}(aq) + Fe(s)$

d) $E°_{cell}$ = 1.183 V (3 decimals)

e) Anode left box, cathode right box

f) $Fe^{2+}(aq)$

3.

a) $H_2A(aq) + 2NaOH(aq) \rightarrow Na_2A(aq) + 2H_2O(l \text{ or } aq)$

b) Final volume = 8.15

Initial = 1.73

Total = 6.42

c) molar mass (H_2A) = 149 g/mol (3 sf)

4.

iii. Hydrochloric acid

5.

i. The liquid level on the left will be higher

6. t = 2.8 s

7. a) $C_3H_6 + Br_2 + 2\ CH_4O \rightarrow 2\ C_4H_9OBr + Br^- + CH_5O^+$

b) $Rate_{rxn} = Rate = k[C_3H_6][Br_2]$

i) 1

ii) 0

c) The last graph D

d) $5.0 \times 10^{-4}\ s^{-1}$

e) *No change*

f) An intermediate

g) The last graph

8.

a) boiling point = 100.5 °C (rounded to 1 decimal)

b) It will come down to the i factor. Sodium sulfate has an i factor = 3, whereas glucose has an I factor = 1. Since both solutions are the concentration, sodium sulfate will have higher BP due to larger i factor.

c) Beaker: C because as discussed in part b), solution C has a higher concentration of particles due to its larger i factor.

This will lower the vapor pressure of solution C more than B. Lower vapor pressure means less evaporation will take place, so beaker C will have a larger volume of liquid over time.

9.

ii) Reducing the volume of the container

10.

iv) HPO_4^{2-}

11.

i) Hydrofluoric acid(aq)

12.

a) acetic acid

b) $CH_3COOH(aq) + H_2O(l) \leftrightarrows CH_3COO^-(aq) + H_3O^+(aq)$

assumption is that x is small x = [H3O+] = 2.5 x 10^{-3} M pH = 2.60

% error = 0.71% so assumption is valid

13.

a) Write the chemical equation for the equilibrium governing the pH of this solution. (*2 marks*)

$C_6H_5COOH(aq) + H_2O(l) \leftrightarrows C_6H_5COO^-(aq) + H_3O^+(aq)$

Or $C_6H_5COO^-(aq) + H_2O(l) \leftrightarrows C_6H_5COOH + OH^-(aq)$

b) Calculate the pH of the solution. (*6 marks*)

pH = 3.93

c) $C_6H_5COO^-(aq) + HNO_3(aq) \rightarrow C_6H_5COOH(aq) + NO_3^-(aq)$

or $C_6H_5COO^-(aq) + H_3O^+(aq) \rightarrow C_6H_5COOH(aq) + H_2O(aq)$

or $C_6H_5COO^-(aq) + H^+(aq) \rightarrow C_6H_5COOH(aq)$

Sodium ion can be in the equation as long as equation is balanced.

14.

a) 0.0150 L

b) At the equivalence point, the HA and NaOH have fully neutralized to produce a salt solution of Na^+ and A^-. Since HA is a weak acid, we know A^- is a weak base that will make the solution basic.

$A^-(aq) + H_2O(l) \leftrightarrows HA(aq) + OH^-(aq)$ – 2 marks (The expected equation)

Also accepted as an equation: $HA(aq) + NaOH(aq) \rightarrow NaA(aq) + H_2O(l)$ (or equivalent)

c) pKa = 4.82

d) Small rise after initial pH

Flattened buffer region around pKa

Large inflections at calculated equivalence point (S like curve)

pH at equivalence above 7.0

high and flat pH after equivalence.