Chemistry 10123, **Exam 4** **Answer Key**
April 22, 2020

1. (7 points) Use the ion-electron method to balance the following redox reaction that occurs in ***basic*** solution. Write ***complete, balanced equations*** for the individual half-reactions and for the overall net ionic equation. Also, ***circle the oxidizing agent***.

$$Al_{(s)} + NO_2^-{}_{(aq)} \longrightarrow AlO_2^-{}_{(aq)} + N_2H_{4(aq)}$$

Reduction Half Reaction:

$$10\ e^- + 8\ H_2O + 2\ NO_2^- \longrightarrow N_2H_4 + 12\ OH^- \quad \times 3$$

Oxidation Half Reaction:

$$4\ OH^- + Al \longrightarrow AlO_2^- + 2\ H_2O + 3\ e^- \quad \times 10$$

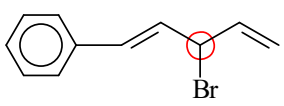
Net Ionic Equation:

$$4\ H_2O + 4\ OH^- + 10\ Al + 6\ NO_2^- \longrightarrow 3\ N_2H_4 + 10\ AlO_2^-$$

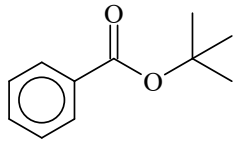
2. (4 points) A compound sometimes called "magnesium cerium sulfate" has the formula $MgCe(SO_4)_3$. Give the oxidation states of all four elements in this compound.

Mg = + 2 O = - 2 Ce = + 4 S = + 6

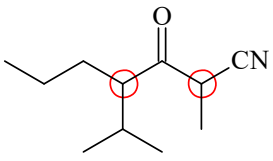
3. (9 points) Write the systematic name of each compound below its structure. Also, circle any carbon atoms which are ***asymmetric (chiral) centers*** in these structures.



3-bromo-1-phenyl-1,4-pentadiene



tert-butyl benzoate



2-cyano-4-*iso*propyl-3-heptanone

4. (6 points) Write ***balanced ionic equations*** for the half-reactions.

   (a) The ***anode*** reaction in the electrolysis of *aqueous* K_2SO_4.

   $$2\ H_2O \longrightarrow O_2 + 4\ H^+ + 4\ e^-$$

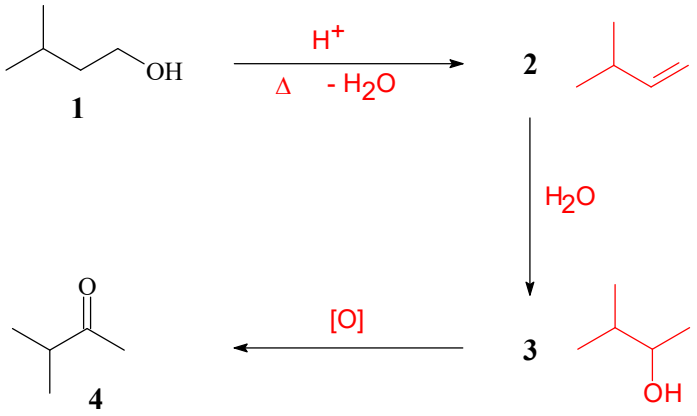
   (b) The ***anode*** reaction in the electrolysis of *molten* $CaBr_2$.

   $$2\ Br^- \longrightarrow Br_2 + 2\ e^-$$

   (c) The ***cathode*** reaction in the electrolysis of *aqueous* $NiCl_2$.

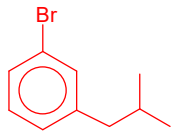
   $$Ni^{2+} + 2\ e^- \longrightarrow Ni$$

5. (8 points) Using some of the organic reactions that we have studied, alcohol **1** can be converted into ketone **4** in a 3-step sequence which involves the intermediate formation of compounds **2** and **3**. Draw ***complete structural formulas*** for compounds **2** and **3** (*with all carbons, hydrogens, etc., clearly shown*). On the reaction arrows, indicate the necessary reagents and/or reaction conditions that are required for these transformations.

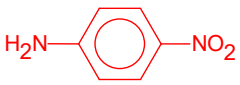


6. (8 points) Draw ***complete structural formulas*** for each of the following organic compounds.

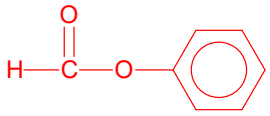
   (a) 1-bromo-3-*iso*butylbenzene



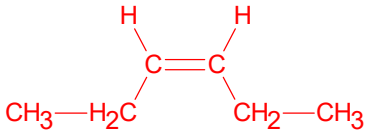
   (b) *p*-nitroaniline



   (c) phenyl formate



   (d) *cis*-3-hexene



7. A ***battery*** is constructed based on the following electrochemical cell in which the volume of solution in each half-cell is 200 mL.

$$Fe_{(s)} \mid Fe^{2+}\ (1.00\ M) \parallel Au^{3+}\ (1.00\ M) \mid Au_{(s)}$$

(a) (6 points) Write balanced chemical equations for the anode, cathode, and overall cell reactions.

Anode: $Fe_{(s)} \longrightarrow Fe^{2+}_{(aq)} + 2\ e^-$ $\quad E° = -(-0.44\ v)$

Cathode: $Au^{3+}_{(aq)} + 3\ e^- \longrightarrow Au_{(s)}$ $\quad E° = 1.50\ v$

Cell: $3\ Fe_{(s)} + 2\ Au^{3+}_{(aq)} \longrightarrow 3\ Fe^{2+}_{(aq)} + 2\ Au_{(s)}$

(b) (3 points) Determine the ***initial voltage*** of this battery.

$E°_{cell} = E°_{red} + E°_{oxid} = 1.50 + 0.44 = 1.94\ v$

(c) (7 points) **SHOW ALL WORK.** Determine the free energy change for the cell reaction of this battery under standard conditions.

$\Delta G° = -nFE° = -(6\ mole\ e^-)(96485\ coul/mole\ e^-)(1.94\ joul=/coul)$

$\Delta G° = -1.123 \times 10^6\ J = -1123\ kJ$

(d) (10 points) **SHOW ALL WORK.** Determine the voltage of this battery after it has delivered a current of 0.30 amp for 48 hours.

$E = E° - (0.0592/n) \log Q$ where $n = 6$ and $Q = [Fe^{2+}]^3 / [Au^{3+}]^2$

$(0.30\ amp)(48\ hr)(3600\ sec/hr) = 51{,}840\ amp{\cdot}sec = 51{,}840\ coul$

$(51{,}840\ coul)(1\ mole\ e^- / 96{,}485\ coul) = 0.5373\ mole\ e^-$

initially, moles $Fe^{2+} = 0.200$ moles and moles $Au^{3+} = 0.200$ moles

moles of Au^{3+} consumed $= (0.5373\ mole\ e^-)(1\ mole\ Au^{3+} / 3\ mole\ e^-)$

$= 0.1791$ moles

moles of Au^{3+} after 48 hr $= 0.200 - 0.1791 = 0.02094$ moles

$[Au^{3+}] = (0.02094\ moles) / (0.200\ L) = 0.1047\ M$

moles of Fe^{2+} formed $= (0.5373\ mole\ e^-)(1\ mole\ Fe^{2+} / 2\ mole\ e^-)$

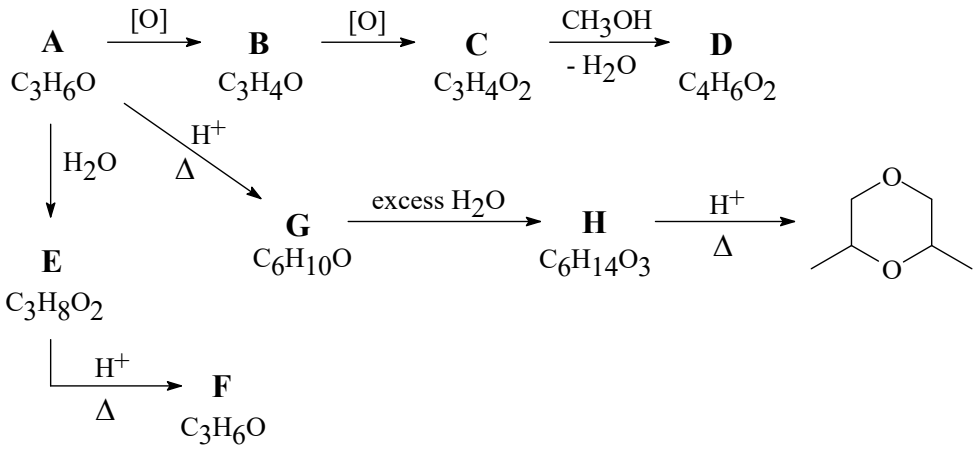
$= 0.2687$ moles

moles of Fe^{2+} after 48 hr $= 0.200 + 0.2686 = 0.4687$ moles

$[Fe^{2+}] = (0.4687\ moles) / (0.200\ L) = 2.343\ M$

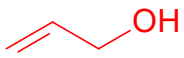
$E = 1.94 - (0.0592 / 6) \log [\ (2.343)^3 / (0.1047)^2\ ] = 1.91\ v$

8. (24 points) An unknown organic compound (**A**) has the simple molecular formula C_3H_6O and contains an alcohol group. Compound **A** is found to undergo the reaction sequences summarized below. (Notice that compounds **A** and **F** have the same molecular formula.)



Draw ***complete structural formulas*** for compounds **A** – **H**. You may write either fully or partially condensed formulas as long as the molecular structure, including the positions of any functional group(s), is clearly shown.

A:



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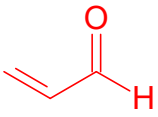

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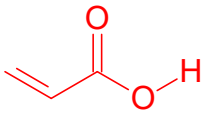
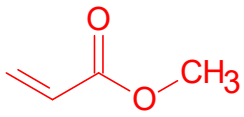
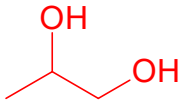


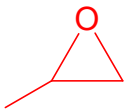
D:



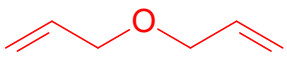
E:



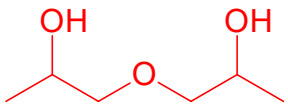
F:



G:



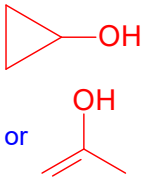
H:



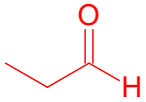
9. (8 points) In addition to compounds **A** and **F** in question 8 above, there are several **other** ***structural isomers*** of molecular formula C_3H_6O. Write clear ***structural formulas*** for C_3H_6O isomers that are good examples of each of the following functional group classes.

ketone

alcohol



aldehyde



ether