

Recitation Worksheet 13: Electrochemistry

Name:

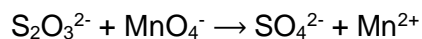
MyID:

Instructions:

1. Please enter your first and last name as it appears on the eLC classlist (do not use a nickname).
2. Your UGA myID is a combination of letters and numbers (example: Dr. Abdelrahman MyID is ema88805).
Do not use your 81x number.
 - A. If you do not have access to a printer, type your answers in the worksheet PDF and then upload it to **Gradescope** by Friday, April 28th at 11:59 pm. Write your work on separate sheets of paper, convert to a PDF and upload to the "Recitation Worksheet 13 Dropbox" on eLC.
 - B. If you are using an app to annotate the worksheet, make sure the pages are in the correct order and have the same layout as the original or Gradescope will not be able to read it.
 - C. If you have access to a printer, print out the worksheet, write your answer in the answer boxes, and show your work on it when appropriate. Then convert it to a PDF and upload to **Gradescope** by Friday, April 28th at 11:59 pm. You do not need to upload anything to eLC. The pages must be in the correct order and have the same layout as the original, or Gradescope will not be able to read it.
 - D. There is a **Gradescope App** available for both iOS and Android devices that allows you to scan and submit your printed work or you can submit your fillable PDF directly. Detailed instructions on how to access and use the app can be found on your CHEM 1212 class eLC page under content → Welcome module → Gradescope → Gradescope new mobile app.
3. Answers must be written in the corresponding answer box, or no credit will be awarded.
4. The instructions for uploading worksheets to Gradescope can be found in the Content area of eLC in the Welcome Module.
1. Which assignment of oxidation number is **INCORRECT** for the underlined element? Select all that apply. Insert letters without spaces in the answer box, example **ABCD**.

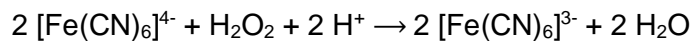
- A. $\text{K}_2\text{Cr}_2\text{O}_7$; +6
- B. NH_3 ; +3
- C. H_2PO_2^- ; +1
- D. SeO_3^{2-} ; +4
- E. $\text{Cu}(\text{NO}_3)_2$; +2

2. What is the coefficient of **Mn²⁺** if the reaction below occurs in **acidic solution**?



- A. 5
- B. 7
- C. 8
- D. 10
- E. 14

3. What is the **reducing agent** in the following reaction between hexacyanoferrate(II) complex and hydrogen peroxide in acidic solution?



- A. $[\text{Fe}(\text{CN})_6]^{4-}$
- B. H_2O_2
- C. H^+
- D. $[\text{Fe}(\text{CN})_6]^{3-}$
- E. H_2O

4. Which statement is true about redox reactions?

- A. A half-reaction can occur by itself.
- B. A redox reaction in base can include excess H^+ after it has been balanced.
- C. Two oxidations can occur instead of one oxidation and one reduction.
- D. At least 2 atoms must have their oxidation states change during a redox reaction.
- E. None of these statements are true.

5. Which of the following equations are an oxidation-reduction reaction? Select all that apply. Insert letters without spaces in the answer box, example **ABCD**.

- A. $\text{H}_2\text{CO}_3(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
 B. $2 \text{Li}(\text{s}) + 2 \text{H}_2\text{O}(\text{l}) \rightarrow 2 \text{LiOH}(\text{aq}) + \text{H}_2(\text{g})$
 C. $\text{C}_3\text{H}_8(\text{g}) + 5 \text{O}_2(\text{g}) \rightarrow 3 \text{CO}_2(\text{g}) + 5 \text{H}_2\text{O}(\text{g})$
 D. $4 \text{Ag}(\text{s}) + \text{PtCl}_4(\text{aq}) \rightarrow 4 \text{AgCl}(\text{s}) + \text{Pt}(\text{s})$
 E. $2 \text{HClO}_4(\text{aq}) + \text{Ca}(\text{OH})_2(\text{aq}) \rightarrow 2 \text{H}_2\text{O}(\text{l}) + \text{Ca}(\text{ClO}_4)_2(\text{aq})$
 F. $3 \text{Cu}(\text{NO}_3)_2(\text{aq}) + 2 \text{Na}_3\text{PO}_4(\text{aq}) \rightarrow 6 \text{NaNO}_3 + \text{Cu}_3(\text{PO}_4)_2$

6. For the reaction:



What is E° for the reduction half-cell reaction of $[\text{PtCl}_4]^{2-}$ to Pt in acidic solution? Please refer to the table below for additional information. Keep your answers to two significant figures.

 V

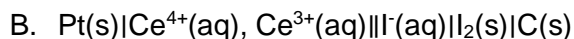
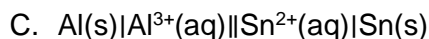
Half-reaction	E° (V)	Half-reaction	E° (V)
$\text{F}_2 + 2\text{e}^- \rightarrow 2\text{F}^-$	2.87	$\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$	0.40
$\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$	1.99	$\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$	0.34
$\text{Co}^{3+} + \text{e}^- \rightarrow \text{Co}^{2+}$	1.82	$\text{Hg}_2\text{Cl}_2 + 2\text{e}^- \rightarrow 2\text{Hg} + 2\text{Cl}^-$	0.27
$\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow 2\text{H}_2\text{O}$	1.78	$\text{AgCl} + \text{e}^- \rightarrow \text{Ag} + \text{Cl}^-$	0.22
$\text{Ce}^{4+} + \text{e}^- \rightarrow \text{Ce}^{3+}$	1.70	$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2\text{SO}_3 + \text{H}_2\text{O}$	0.20
$\text{PbO}_2 + 4\text{H}^+ + \text{SO}_4^{2-} + 2\text{e}^- \rightarrow \text{PbSO}_4 + 2\text{H}_2\text{O}$	1.69	$\text{Cu}^{2+} + \text{e}^- \rightarrow \text{Cu}^+$	0.16
$\text{MnO}_4^- + 4\text{H}^+ + 3\text{e}^- \rightarrow \text{MnO}_2 + 2\text{H}_2\text{O}$	1.68	$2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$	0.00
$\text{IO}_4^- + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{IO}_3^- + \text{H}_2\text{O}$	1.60	$\text{Fe}^{3+} + 3\text{e}^- \rightarrow \text{Fe}$	-0.036
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$	1.51	$\text{Pb}^{2+} + 2\text{e}^- \rightarrow \text{Pb}$	-0.13
$\text{Au}^{3+} + 3\text{e}^- \rightarrow \text{Au}$	1.50	$\text{Sn}^{2+} + 2\text{e}^- \rightarrow \text{Sn}$	-0.14
$\text{PbO}_2 + 4\text{H}^+ + 2\text{e}^- \rightarrow \text{Pb}^{2+} + 2\text{H}_2\text{O}$	1.46	$\text{Ni}^{2+} + 2\text{e}^- \rightarrow \text{Ni}$	-0.23
$\text{Cl}_2 + 2\text{e}^- \rightarrow 2\text{Cl}^-$	1.36	$\text{PbSO}_4 + 2\text{e}^- \rightarrow \text{Pb} + \text{SO}_4^{2-}$	-0.35
$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$	1.33	$\text{Cd}^{2+} + 2\text{e}^- \rightarrow \text{Cd}$	-0.40
$\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$	1.23	$\text{Fe}^{2+} + 2\text{e}^- \rightarrow \text{Fe}$	-0.44
$\text{MnO}_2 + 4\text{H}^+ + 2\text{e}^- \rightarrow \text{Mn}^{2+} + 2\text{H}_2\text{O}$	1.21	$\text{Cr}^{3+} + \text{e}^- \rightarrow \text{Cr}^{2+}$	-0.50
$\text{IO}_3^- + 6\text{H}^+ + 5\text{e}^- \rightarrow \frac{1}{2}\text{I}_2 + 3\text{H}_2\text{O}$	1.20	$\text{Cr}^{3+} + 3\text{e}^- \rightarrow \text{Cr}$	-0.73
$\text{Br}_2 + 2\text{e}^- \rightarrow 2\text{Br}^-$	1.09	$\text{Zn}^{2+} + 2\text{e}^- \rightarrow \text{Zn}$	-0.76
$\text{VO}_2^+ + 2\text{H}^+ + \text{e}^- \rightarrow \text{VO}^{2+} + \text{H}_2\text{O}$	1.00	$2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^-$	-0.83
$\text{AuCl}_4^- + 3\text{e}^- \rightarrow \text{Au} + 4\text{Cl}^-$	0.99	$\text{Mn}^{2+} + 2\text{e}^- \rightarrow \text{Mn}$	-1.18
$\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^- \rightarrow \text{NO} + 2\text{H}_2\text{O}$	0.96	$\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$	-1.66
$\text{ClO}_2 + \text{e}^- \rightarrow \text{ClO}_2^-$	0.954	$\text{H}_2 + 2\text{e}^- \rightarrow 2\text{H}^-$	-2.23
$2\text{Hg}^{2+} + 2\text{e}^- \rightarrow \text{Hg}_2^{2+}$	0.91	$\text{Mg}^{2+} + 2\text{e}^- \rightarrow \text{Mg}$	-2.37
$\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$	0.80	$\text{La}^{3+} + 3\text{e}^- \rightarrow \text{La}$	-2.37
$\text{Hg}_2^{2+} + 2\text{e}^- \rightarrow 2\text{Hg}$	0.80	$\text{Na}^+ + \text{e}^- \rightarrow \text{Na}$	-2.71
$\text{Fe}^{3+} + \text{e}^- \rightarrow \text{Fe}^{2+}$	0.77	$\text{Ca}^{2+} + 2\text{e}^- \rightarrow \text{Ca}$	-2.76
$\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2\text{O}_2$	0.68	$\text{Ba}^{2+} + 2\text{e}^- \rightarrow \text{Ba}$	-2.90
$\text{MnO}_4^- + \text{e}^- \rightarrow \text{MnO}_4^{2-}$	0.56	$\text{K}^+ + \text{e}^- \rightarrow \text{K}$	-2.92
$\text{I}_2 + 2\text{e}^- \rightarrow 2\text{I}^-$	0.54	$\text{Li}^+ + \text{e}^- \rightarrow \text{Li}$	-3.05
$\text{Cu}^+ + \text{e}^- \rightarrow \text{Cu}$	0.52		

7. Which of the reactions do you predict to be **non-spontaneous** in the forward direction? Assume all the reactants and products in their standard states. Please refer to the table in question 6 for additional information.

☐

- A. $\text{Cu}^{2+}(\text{aq}) + 2\text{I}^{-}(\text{aq}) \rightarrow \text{Cu}(\text{s}) + \text{I}_2(\text{s})$
B. $4\text{NO}_3^{-}(\text{aq}) + 4\text{H}^{+}(\text{aq}) \rightarrow 3\text{O}_2(\text{g}) + 4\text{NO}(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
C. $2\text{Br}^{-}(\text{aq}) + \text{I}_2(\text{s}) \rightarrow \text{Br}_2(\text{aq}) + 2\text{I}^{-}(\text{aq})$
D. $\text{Au}(\text{s}) + \text{NO}_3^{-}(\text{aq}) \rightarrow \text{Au}^{3+}(\text{aq}) + \text{NO}(\text{g})$ (in acidic solution)
E. All of the above reactions are non-spontaneous in the forward direction.

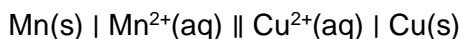
8. Calculate the E°_{cell} for the following reactions. Please refer to the table in question 6 for additional information. Keep your answers to two decimal places.

 V V V

9. Which statements below is **FALSE** regarding standard cell potentials? Select all that apply. Insert letters without spaces in the answer box, example **ABCD**.

- A. E°_{cell} is positive for spontaneous reactions.
B. Electrons will flow from the positive electrode to the negative electrode in a galvanic cell.
C. E°_{cell} is the difference in voltage between the anode and the cathode, $E^\circ_{\text{cell}} = E^\circ_{\text{cell}}(\text{anode}) - E^\circ_{\text{cell}}(\text{cathode})$.
D. The electrode potential of the standard hydrogen electrode is exactly zero.
E. The electrode in any half-cell with a greater tendency to undergo reduction is negatively charged relative to the standard hydrogen electrode and therefore has a negative E° .

10. What is the redox reaction represented by the following cell notation?

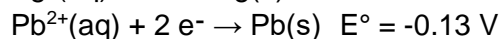
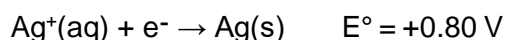


- A. $\text{Cu(s)} + \text{Mn}^{2+}(\text{aq}) \rightarrow \text{Mn(s)} + \text{Cu}^{2+}(\text{aq})$
B. $\text{Mn(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Cu(s)} + \text{Mn}^{2+}(\text{aq})$
C. $2 \text{Mn(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Cu(s)} + 2 \text{Mn}^{2+}(\text{aq})$
D. $2 \text{Cu(s)} + \text{Mn}^{2+}(\text{aq}) \rightarrow \text{Mn(s)} + 2 \text{Cu}^{2+}(\text{aq})$
E. $3 \text{Mn(s)} + 2 \text{Cu}^{2+}(\text{aq}) \rightarrow 2 \text{Cu(s)} + 3 \text{Mn}^{2+}(\text{aq})$

11. Which of the choices represents the correct cell notation for $\text{Sn(s)} + 2 \text{H}^+(\text{aq}) \rightarrow \text{Sn}^{2+}(\text{aq}) + \text{H}_2(\text{g})$?

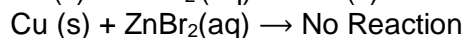
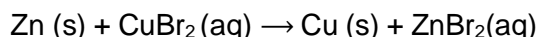
- A. $\text{H}^+(\text{aq}) \mid \text{H}_2(\text{g}) \mid \text{Pt} \parallel \text{Sn(s)} \mid \text{Sn}^{2+}(\text{aq})$
- B. $\text{H}_2(\text{g}) \mid \text{H}^+(\text{aq}) \mid \text{Pt} \parallel \text{Sn}^{2+}(\text{aq}) \mid \text{Sn(s)}$
- C. $\text{Sn}^{2+}(\text{aq}) \mid \text{Sn(s)} \parallel \text{H}_2(\text{g}) \mid \text{H}^+(\text{aq}) \mid \text{Pt}$
- D. $\text{Sn(s)} \mid \text{Sn}^{2+}(\text{aq}) \parallel \text{H}^+(\text{aq}) \mid \text{H}_2(\text{g}) \mid \text{Pt}$
- E. $\text{Sn(s)} \mid \text{H}_2(\text{g}) \parallel \text{Sn}^{2+}(\text{aq}) \mid \text{H}^+(\text{aq}) \mid \text{Pt}$

12. A galvanic cell consists of one half-cell that contains Ag(s) and $\text{Ag}^+(\text{aq})$, and one half-cell that contains Pb(s) and $\text{Pb}^{2+}(\text{aq})$. What species are produced at the electrodes under standard conditions?



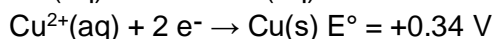
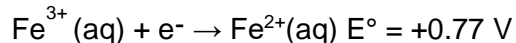
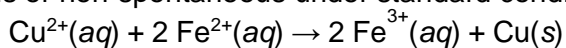
- A. Ag(aq) is formed at the cathode and, Pb(s) is formed at the anode.
- B. Ag(s) is formed at the cathode, and $\text{Pb}^{2+}(\text{aq})$ is formed at the anode.
- C. Pb(s) is formed at the cathode, and $\text{Ag}^+(\text{aq})$ is formed at the anode.
- D. $\text{Pb}^{2+}(\text{aq})$ is formed at the cathode, and Cu(s) is formed at the anode.

13. Given the following laboratory observation, which of the following statements is **FALSE**?

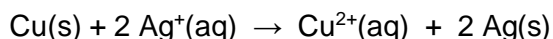


- A. Zn is a stronger reducing agent than Cu.
- B. Cu^{2+} is a stronger oxidizing agent than Zn^{2+} .
- C. Cu is a stronger reducing agent than Zn.
- D. The fact that Cu doesn't react with ZnBr_2 proves that copper attracts electrons more than does Zn.
- E. None of the above.

14. Calculate the standard cell potential for the galvanic cell reaction given below and determine whether this reaction is spontaneous or non-spontaneous under standard conditions.

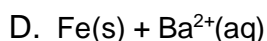
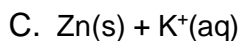
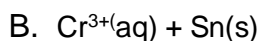


- A. $E^{\circ} = -0.43 \text{ V}$, nonspontaneous.
B. $E^{\circ} = -0.43 \text{ V}$, spontaneous.
C. $E^{\circ} = +0.43 \text{ V}$, nonspontaneous.
D. $E^{\circ} = +0.43 \text{ V}$, spontaneous.
15. A galvanic cell consists of a silver electrode in 1.0 mol/L solution of silver nitrate, a copper electrode in 1.0 mol/L solution of copper(II) nitrate, and a salt bridge. The spontaneous cell reaction is:



When the two electrodes are connected by a wire, which of the following **does not** take place? Select all that apply. Insert letters without spaces in the answer box, example **ABCD**.

- a. Electrons flow in the wire from the copper electrode to the silver electrode.
b. The silver electrode increases in mass as the cell operates.
c. There is a net movement of silver ions through the salt bridge from the silver half-cell to the copper half-cell.
d. There is a net movement of copper ions through the salt bridge from the copper half-cell to the silver half-cell.
e. The copper electrode decreases in mass as the cell operates.
16. Determine which of the following pairs of reactants will result in a spontaneous reaction at 25°C. Please refer to the table in question 6 for additional information.



E. None of the above pairs will react.