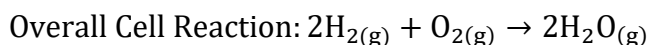


Sample Questions for the Chemistry of Industry Topic Test

1. Fuel Cells

Many car developers are trying to find more efficient methods of powering automobiles while also being environmentally friendly. A more recent option being implemented into modern cars has been to use Hydrogen Fuel Cells as an alternative to gasoline and diesel.

- a.** The following is the overall reaction for a hydrogen fuel cell occurring at 25 °C, under basic conditions. From this reaction, write out the half-cell reactions that take place for a hydrogen fuel cell. Then, state which half reaction is the cathode and which is the anode.



- b.** Calculate the E° (Standard EMF) of the Cell at 25 °C, using the using the standard reduction potentials chart found at the end of these sample questions. Show all work to support answer and box or circle the final answer.

(This question continues on the next page.)

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- c.** While the E° found in part (b) is accurate under standard conditions, the environment of your automobile might not always be standard. Using the Nernst equation, calculate the cell potential of the hydrogen fuel cell when the temperature is 38°C . Assume your fuel cell has 100 mL of H_2 gas at 0.5 atm and 100 mL of O_2 gas at 1.0 atm.
- d.** If your car has a reader indicating that 0.058 moles of O_2 was consumed in one hour, calculate the charge (in Coulombs) that has been given to your car.

2. Magnetic Resonance Imaging

Magnetic Resonance Imaging, otherwise known as MRI, is a safe, non-invasive technique for physicians to see inside the body. For some procedures, a gadolinium contrast solution is injected into the patient via intravenous injection, better known as IV. The contrast solution improves the visibility of inflammation, tumors, blood vessels and, for some organs, blood supply.

- a.** At 8:00 am, a 15 mL dose of a gadolinium contrast dye is injected into a patient. Assume the gadolinium immediately mixes uniformly with the blood in circulation. The average body contains 5.1 liters of blood. What is the initial concentration of gadolinium (Gd) in circulation after injection? Assume the dye contains 1.825 mmol/mL of gadolinium, and *ignore the increase in blood volume from the injection of the 15 mL dose*. Give answer in mg/dL. (Note: 1 dL = 100 mL, 1 mol = 1000 mmol). Show work for full credit.
- b.** A patient is about to undergo a procedure that requires a blood gadolinium level below 20 mg/dL. The elimination half-life of a gadolinium contrast agent is 1.5 hours. For the part described in part a, can doctors proceed with this procedure at 11:00 am? If not, what time will it be when it is safe for them to proceed? Show work for full credit.

3. Cadmium Toxicity

According to the EPA, the highest tolerable concentration of Cd^{2+} in drinking water is 0.005 mg/L. Super Batteries Inc. uses cadmium in its battery production but has found high levels of cadmium ions in the wastewater. It is your job to determine the best method of cadmium removal.

- a. Express the high tolerable concentration of Cd^{2+} in drinking water in molar units (mol/L). Show your work and circle your final answer.
- b. Given the table of solubility constants at 25°C for some of the species below, only based on the pK_{sp} , what would be the best anion to add in order to precipitate the most Cd^{2+} ion? Explain how you came to your conclusion. Hint: if you do not know what pK_{sp} is, consider how to calculate pH from hydronium concentration.

Species	pK_{sp}
$\text{Cd}_3(\text{AsO}_4)_2$	32.66
CdC_2O_4	7.8
CdS	27.92
$\text{Cd}(\text{OH})_2$	13.64
CdCO_3	11.3

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- c.** Super Batteries Inc. wants to treat its wastewater before releasing it back into the local river, so the wastewater is currently in a tank for treatment.
- i.** After adding a reactant containing your chosen anion, the Cd^{2+} in the tank is now at the highest tolerable concentration level by EPA standards. If you did not find an answer to part (a), use a concentration of 10^{-7} M for cadmium. What is the concentration of the remaining anion?
- ii.** From the table in part (b), choose the anion that would precipitate the second-most cadmium (II) ion. Repeat the calculation from part c (i) for this anion.
- iii.** Assuming that the best anion has the least concentration of cadmium (II) ion remaining, do you still agree with your answer for part b? Explain, referencing your answers to part c (i) and c (ii).

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- d. What would happen if one of the other waste products also had the ability to precipitate with the added anion from part b? Explain your answer.
- e. Emily likes keeping the waste treatment room at high temperatures while Alex prefers colder temperatures. Assuming that the temperature change is significant, which condition is better for this precipitation reaction to occur? Explain.

Standard Potential (V)	Reduction Half-Reaction
2.87	$\text{F}_2(\text{g}) + 2\text{e}^- \longrightarrow 2\text{F}^-(\text{aq})$
1.51	$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \longrightarrow \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$
1.36	$\text{Cl}_2(\text{g}) + 2\text{e}^- \longrightarrow 2\text{Cl}^-(\text{aq})$
1.33	$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \longrightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$
1.23	$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \longrightarrow 2\text{H}_2\text{O}(\text{l})$
1.06	$\text{Br}_2(\text{l}) + 2\text{e}^- \longrightarrow 2\text{Br}^-(\text{aq})$
0.96	$\text{NO}_3^-(\text{aq}) + 4\text{H}^+(\text{aq}) + 3\text{e}^- \longrightarrow \text{NO}(\text{g}) + \text{H}_2\text{O}(\text{l})$
0.80	$\text{Ag}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Ag}(\text{s})$
0.77	$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Fe}^{2+}(\text{aq})$
0.68	$\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{H}_2\text{O}_2(\text{aq})$
0.59	$\text{MnO}_4^-(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) + 3\text{e}^- \longrightarrow \text{MnO}_2(\text{s}) + 4\text{OH}^-(\text{aq})$
0.54	$\text{I}_2(\text{s}) + 2\text{e}^- \longrightarrow 2\text{I}^-(\text{aq})$
0.40	$\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \longrightarrow 4\text{OH}^-(\text{aq})$
0.34	$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Cu}(\text{s})$
0	$2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{H}_2(\text{g})$
-0.28	$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Ni}(\text{s})$
-0.44	$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Fe}(\text{s})$
-0.76	$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Zn}(\text{s})$
-0.83	$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \longrightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$
-1.66	$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \longrightarrow \text{Al}(\text{s})$
-2.71	$\text{Na}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Na}(\text{s})$
-3.05	$\text{Li}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Li}(\text{s})$

Credit for this table goes to the Department of Chemistry at Georgetown University. It can be found at the following url: <http://bouman.chem.georgetown.edu/S02/lect25/e6a.gif>