Unit 3: AP Free Response Practice #1 [2010B #3, 10 points]

A sample of ore containing the mineral tellurite, TeO_2, was dissolved in acid. The resulting solution was then reacted with a solution of $K_2Cr_2O_7$ to form telluric acid, H_2TeO_4. The unbalanced chemical equation for the reaction is given below.

$$3\ TeO_2(s) + \ Cr_2O_7^{2-}(aq) + \ 8\ H^+(aq) \rightarrow 3\ H_2TeO_4(aq) + \ 2\ Cr^{3+}(aq) + \ H_2O(l)$$

a. Identify the molecule or ion that is being oxidized in the reaction.

b. Give the oxidation number of Cr in the $Cr_2O_7^{2-}$(aq) ion.

In the procedure described above, 46.00 mL of 0.03109 M $K_2Cr_2O_7$ was added to the ore sample after it was dissolved in acid. When the chemical reaction had progressed as completely as possible, the amount of unreacted (excess) $Cr_2O_7^{2-}$(aq) was determined by titrating the solution with 0.110 M $Fe(NO_3)_2$. The reaction that occurred during the titration is represented by the following balanced equation.

$$6\ Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14\ H^+(aq) \rightarrow 2\ Cr^{3+}(aq) + 6\ Fe^{3+}(aq) + 7\ H_2O(l)$$

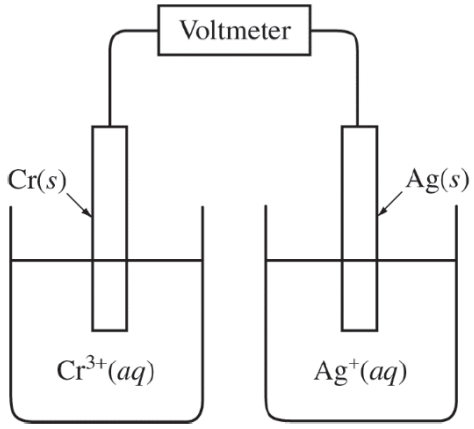
A volume of 9.85 mL of 0.110 M $Fe(NO_3)_2$ was required to reach the equivalence point.

c. Calculate the number of moles of excess $Cr_2O_7^{2-}$(aq) that was titrated.

d. Calculate the number of moles of $Cr_2O_7^{2-}$(aq) that reacted with the tellurite.

e. Calculate the mass, in grams, of tellurite that was in the ore sample.

AP Free Response Practice #2 (2018 #6, 4 points)



Half-Reaction	$E°$ (V)
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+ 0.80
$Cr^{3+}(aq) + 3\ e^- \rightarrow Cr(s)$	?

A student sets up a galvanic cell at 298 K that has an electrode of Ag(s) immersed in a 1.0 M solution of Ag^+(aq) and an electrode of Cr(s) immersed in a 1.0 M solution of Cr^{3+}(aq), as shown in the diagram above.

a. The student measures the voltage of the cell shown above and discovers that it is zero. Identify the missing component of the cell, and explain its importance for obtaining a nonzero voltage.

b. The student adds the missing component to the cell and measures $E°_{cell}$ to be +1.54 V. As the cell operates, Ag^+ ions are reduced. Use this information and the information in the table above to do the following.

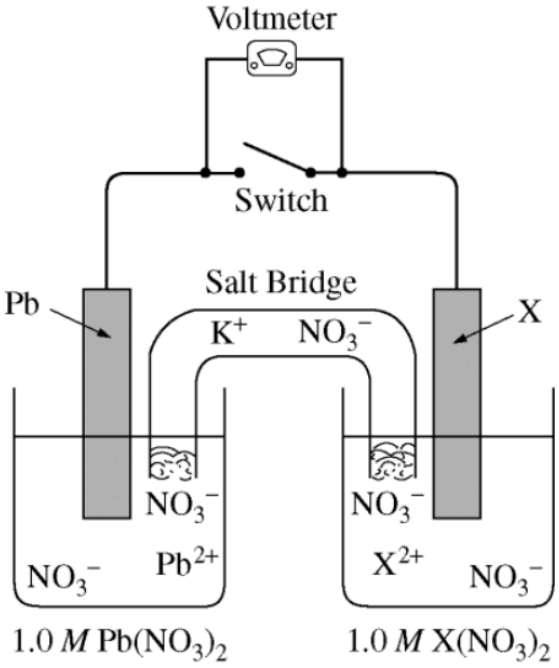
   i. Calculate the value of $E°$ for the half-reaction $Cr^{3+} + 3\ e^- \rightarrow Cr(s)$.

   ii. Write the balanced net-ionic equation for the overall reaction that occurs as the cell operates.

   iii. Calculate the value of $\Delta G°$ for the overall cell reaction in J/mol_{rxn}.

Unit 3: AP Free Response Practice #3 (2012 #6, modified) [8 points]

The diagram below shows an electrochemical cell that is constructed with a Pb electrode immersed in 100. mL of 1.0 M $Pb(NO_3)_2(aq)$ and an electrode made of metal X immersed in 100. mL of 1.0 M $X(NO_3)_2(aq)$. A salt bride containing saturated aqueous KNO_3 connects the anode compartment to the cathode compartment. The electrodes are connected to an external circuit containing a switch, which is open. When a voltmeter is connected to the circuit as shown, the reading on the voltmeter is 0.47 V. When the switch is closed, electrons flow through the switch from the Pb electrode toward the X electrode.



Half-reaction	Standard Reduction Potential
$Cu^+ + e^- \rightarrow Cu(s)$	+ 0.52 V
$Cu^{2+} + 2\,e^- \rightarrow Cu(s)$	+ 0.34 V
$Pb^{2+} + 2\,e^- \rightarrow Pb(s)$	− 0.13 V
$Ni^{2+} + 2\,e^- \rightarrow Ni(s)$	− 0.25 V

a) Write the equation for the half-reaction that occurs at the anode.

b) The value of the standard potential for the cell, E^o, is 0.47 V. Use the table of reduction potentials provided to answer the following.

i. Determine the standard reduction potential for the half reaction that occurs at the cathode.

ii. Determine the identity of metal X.

c) Describe what happens to the mass of each electrode as the cell operates.

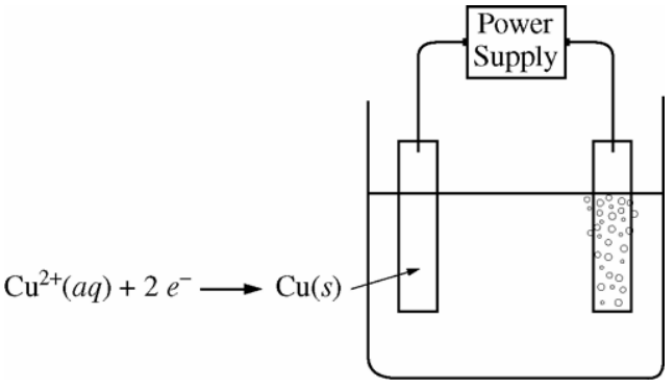
d) During a laboratory session, students set up the electrochemical cell shown above. For each of the following three scenarios, choose the correct value of the cell voltage and justify your answer.

i. A student bumps the cell setup, resulting in the salt bridge losing contact with the solution in the cathode compartment. Is V equal to 0.47 or is V equal to 0? Justify your choice.

ii. A student spills a small amount of 0.5 M $Na_2SO_4(aq)$ into the compartment with the Pb electrode, resulting in the formation of a precipitate. Is V greater than 0.47, equal to 0.47, or less than 0.47? Justify your choice.

iii. After the laboratory session is over, a student leaves the switch closed. The next day, the student opens the switch and reads the voltmeter. Is V greater than 0.47, equal to 0.47, or less than 0.47? Justify your choice.

Unit 3: AP Free Response Practice #4 (2007 FR #3, modified) [10 points]



3. An external direct-current power supply is connected to two platinum electrodes immersed in a beaker containing 1.0 M $CuSO_4$(aq) at 25°C, as shown in the diagram above. As the cell operates, copper metal is deposited onto one electrode and O_2(g) is produced at the other electrode. The two reduction half-reactions for the overall reaction that occurs in the cell are shown in the table below.

Half-Reaction	$E°$(V)
$O_2(g) + 4\ H^+(aq) + 4\ e^- \rightarrow 2\ H_2O(l)$	+1.23
$Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$	+0.34

a. On the diagram, indicate the direction of electron flow in the wire.

b. Write the balanced net ionic equation for the electrolysis reaction that occurs in the cell.

c. Predict the algebraic sign of $\Delta G°$ for the reaction. Justify your prediction.

d. Calculate the value of $\Delta G°$ for the reaction.

An electric current of 1.50 amps passes through the cell for 40.0 minutes.

e. Calculate the mass, in grams, of the Cu(s) that is deposited on the electrode.

f. Calculate the dry volume, in liters measured at 25°C and 1.16 atm, of the $O_2(g)$ that is produced.