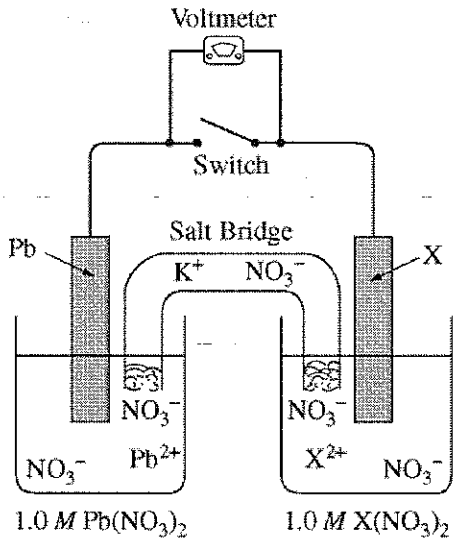
AP® CHEMISTRY
2012 SCORING GUIDELINES

Question 6 (continued)

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 bridge 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.



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

$Pb(s) \rightarrow Pb^{2+}(aq) + 2\,e^-$	1 point is earned for the correct equation.

(c) The value of the standard potential for the cell, $E°$, is 0.47 V.

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

$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$ $E^\circ_{cathode} = E^\circ_{cell} + E^\circ_{anode}$ $E^\circ_{cathode} = 0.47 + (-0.13) = 0.34$ V	1 point is earned for the calculated reduction potential with mathematical justification.

Question 6 (continued)

(ii) Determine the identity of metal X.

The metal is copper.	1 point is earned for identification of the metal.

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

The mass of the Pb electrode decreases and the mass of the Cu electrode increases.	1 point is earned for <u>both</u> descriptions.

(e) 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 choice.

(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.

V = 0 V. The transfer of ions through the salt bridge will stop. A charge imbalance between the half-cells will prevent electrons from flowing through the wire.	1 point is earned for the correct choice with an appropriate explanation.

(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 less than 0.47 or is V greater than 0.47 ? Justify your choice.

V > 0.47 V. The sulfate ion will react with the Pb^{2+} ion to form a precipitate. This results in a thermodynamically favored anode half-cell reaction and hence a larger potential difference. The choice may also be justified using the Nernst equation. $E_{cell} = E^{\circ}_{cell} - \left(\frac{RT}{nF}\right)\ln\frac{[Pb^{2+}]}{[Cu^{2+}]}$ Decreasing the $[Pb^{2+}]$ will increase the cell voltage.	1 point is earned for the correct choice with an appropriate explanation.

(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 less than 0.47 or is V equal to 0.47? Justify your choice.

V < 0.47 V. Over time, $[Pb^{2+}]$ increases and $[Cu^{2+}]$ decreases, making both half-cell reactions less thermodynamically favorable. The choice may also be justified using the Nernst equation. Increasing $[Pb^{2+}]$ and decreasing $[Cu^{2+}]$ decreases the cell voltage. The choice may also be justified by stating that the voltage is zero as a result of the establishment of equilibrium.	1 point is earned for the correct choice with an appropriate explanation.