~~40~~ 52

Unit 3: AP Free Response Practice ~~#2~~ #4 [2012 #6, 9 points (modified)]

2. In a laboratory experiment, Pb and an unknown metal Q were immersed in solutions containing aqueous ions of unknown metals Q and X. The following reactions summarize the observations.

Observation 1: $Pb(s) + X^{2+}(aq) \rightarrow Pb^{2+}(aq) + X(s)$

Observation 1: $Q(s) + X^{2+}(aq) \rightarrow$ no reaction

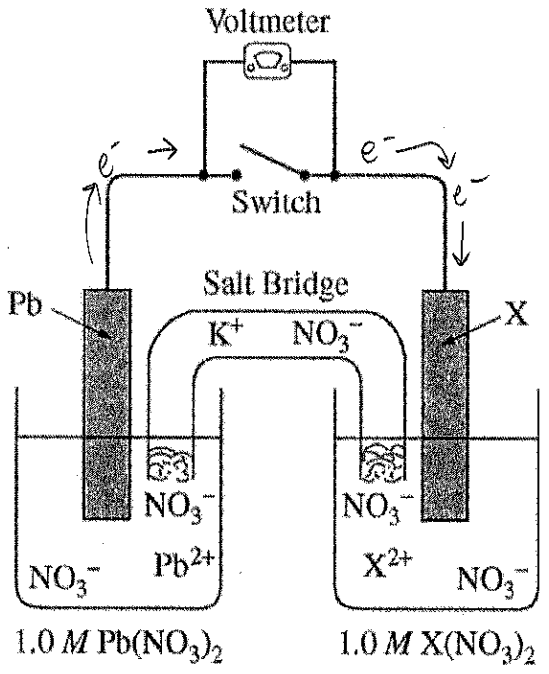
Observation 1: $Pb(s) + Q^{2+}(aq) \rightarrow Pb^{2+}(aq) + Q(s)$

a) On the basis of the reactions indicated above, arrange the three metals, Pb, Q, and X, in order from least reactive to most reactive on the lines provided below. [*2 points*]

Q , X , Pb

least reactive metal most reactive metal

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.



Anode

Cathode

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

b) Write the equation for the half-reaction that occurs at the anode. [*1 point*]

c) The value of the standard potential for the cell, E°, 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. [*1 point*]

ii. Determine the identity of metal X.

d) Describe what happens to the mass of each electrode as the cell operates. [*1 point*]

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 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. [*1 point*]

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. [*1 point*]

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. [*1 point*]

b.) $Pb_{(s)} \rightarrow Pb^{2+}_{(aq)} + 2e^-$

c.)(i) $E^\circ_{cell} = E^\circ_{ox} + E^\circ_{red}$

$0.47 = +0.13 + E^\circ_{red} \Rightarrow E^\circ_{red} = 0.47 - 0.13 = \boxed{+0.34\,V}$

(ii) $X = Cu_{(s)}$

d.) The mass of the Pb electrode decreases and the mass of the Cu electrode increases.

e)(i) $V = \emptyset$, b/c without ions from the salt bridge, a charge imbalance between the half-cells will prevent e^- from flowing through the wire.

(ii) $V > 0.47\,V$, b/c SO_4^{2-} reacts with Pb^{2+} to form a precipate, decreasing $[Pb^{2+}]$, a product. This change causes $Q < 1$, so the cell voltage will be higher than the standard cell voltage.

(iii) $V < 0.47\,V$, b/c over time (as the cell runs), $[Pb^{2+}] \uparrow$ (a product) and $[Cu^{2+}] \downarrow$ (a reactant). Both changes increase Q, so the cell voltage will be less than the standard cell voltage.