Marks 5

- A galvanic cell is made of a $Zn^{2+}/Zn$ half cell with $[Zn^{2+}]$ = 2.0 M and an $Ag^{+}/Ag$ half cell with $[Ag^{+}]$ = 0.050 M. Calculate the electromotive force of the cell at 25 °C.

**The standard reduction reactions and potentials for the two half cells are:**

$$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s) \qquad E° = -0.76 \text{ V}$$
$$Ag^{+}(aq) + e^- \rightarrow Ag(s) \qquad E° = +0.80 \text{ V}$$

**The least positive ($Zn^{2+}/Zn$) couple is reversed giving the overall reaction:**

$$Zn(s) + 2Ag^{+}(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s) \qquad E° = (+0.76 \text{ V}) + (0.80) = 1.56 \text{ V}$$

**As non-standard concentrations are used, the cell potential is calculated using the Nernst equation. The reaction involves the transfer of $2e^-$ so with $n$ = 2 this becomes:**

$$E = E° - \frac{RT}{nF}\ln Q = E° - \frac{RT}{nF}\ln\left(\frac{[Zn^{2+}(aq)]}{[Ag^{+}(aq)]^2}\right)$$

$$= (+1.56 \text{ V}) - -\frac{(8.314 \text{ J K}^{-1}\text{ mol}^{-1})(298 \text{ K})}{(2 \times 96485 \text{ C mol}^{-1})}\ln\left(\frac{2.0}{0.050^2}\right) = +1.47 \text{ V}$$

Answer: **+1.47 V**

Calculate the equilibrium constant of the reaction at 25 °C.

**The equilibrium constant is related to the standard cell potential:**

$$E° = \frac{RT}{nF}\ln K$$

**Hence,**

$$\ln K = E° \times \frac{nF}{RT} = (1.56 \text{ V}) \times \frac{(2 \times 96485 \text{ C mol}^{-1})}{(8.314 \text{ J K}^{-1}\text{ mol}^{-1})(298 \text{ K})} = 121.5$$

$$K = 5.9 \times 10^{52}$$

Answer: $K = 5.9 \times 10^{52}$

Calculate the standard Gibbs free energy of the reaction at 25 °C.

**Using $\Delta G° = nFE°$:**

$$\Delta G° = -(2 \times 96485 \text{ C mol}^{-1}) \times (+1.56 \text{ V}) = -301 \text{ kJ mol}^{-1}$$

Answer: **–301 kJ mol$^{-1}$**

ANSWER CONTINUES ON THE NEXT PAGE

Indicate whether the reaction is spontaneous or not. Give a reason for your answer.

**As $E > 0$, $\Delta G° < 0$ and $K$ is very large: the reaction is spontaneous.**

Express the overall reaction in the shorthand voltaic cell notation.

**$Zn(s) \,|\, Zn^{2+}(aq)$ (2.0 M) $||$ $Ag^{+}(aq)$ (0.050 M) $|$ $Ag(s)$**