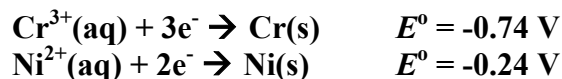


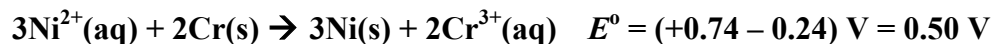
**Marks**  
**6**

- A galvanic cell consists of a  $\text{Cr}^{3+}/\text{Cr}$  half-cell with unknown  $[\text{Cr}^{3+}]$  and a  $\text{Ni}^{2+}/\text{Ni}$  half-cell with  $[\text{Ni}^{2+}] = 1.20 \text{ M}$ . The electromotive force of the cell at  $25^\circ\text{C}$  was measured to be  $0.55 \text{ V}$ . What is the concentration of  $\text{Cr}^{3+}$  in the  $\text{Cr}^{3+}/\text{Cr}$  half-cell?

From the standard reduction potentials,



The most negative is reversed to give an overall reaction and cell potential of



From the Nernst equation for this 6 electron reaction,

$$\begin{aligned} E &= E^\circ - \frac{RT}{nF} \ln Q = E^\circ - \frac{RT}{nF} \ln \frac{[\text{Cr}^{3+}(\text{aq})]^2}{[\text{Ni}^{2+}(\text{aq})]^3} \\ &= (0.50 \text{ V}) - \frac{(8.314 \text{ J K}^{-1} \text{ mol}^{-1})(298 \text{ K})}{6 \times 96485 \text{ mol}^{-1}} \ln \frac{[\text{Cr}^{3+}(\text{aq})]^2}{(1.20)^3} \end{aligned}$$

Solving this gives,

$$[\text{Cr}^{3+}(\text{aq})] = 3.8 \times 10^{-3} \text{ M}$$

Answer:  $3.8 \times 10^{-3} \text{ M}$

Calculate the equilibrium constant of the reaction at  $25^\circ\text{C}$ .

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

$$E^\circ = \frac{RT}{nF} \ln K$$

Using  $E^\circ = +0.50 \text{ V}$ ,

$$0.50 \text{ V} = \frac{(8.314 \text{ J K}^{-1} \text{ mol}^{-1})(298 \text{ K})}{6 \times 96485 \text{ mol}^{-1}} \ln K$$

Solving this gives:

$$K = 5.5 \times 10^{50}$$

Answer:  $5.5 \times 10^{50}$

ANSWER CONTINUES ON THE NEXT PAGE

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

**The Gibbs free energy change is related to the standard cell potential through:**

$$\begin{aligned}\Delta G^{\circ} &= -nFE^{\circ} \\ &= -6 \times (96485 \text{ mol}^{-1}) \times (0.50 \text{ V}) = -290 \text{ kJ mol}^{-1}\end{aligned}$$

Answer: **-290 kJ mol<sup>-1</sup>**

Express the overall reaction in the shorthand voltaic cell notation.

