[TP] For the redox process

$$Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$$

when the ions each are 1 M, Zn(s) is consumed. This means ...

20% 1. $K > 1$
20% 2. $K < 1$
20% 3. $Q > 1$
20% 4. $Q < 1$
20% 5. More information needed

Response Counter

5

Lecture 26 CH102 A1 (MWF 9:05 am)

Friday, March 31, 2017

- Review: What determines cell voltage, E_{cell}?
- Calculating standard cell voltage, $E°_{\text{cell}}$.
- Cell voltage versus spontaneity.

Next lecture: Complete: Cell voltage versus spontaneity. The Nernst equation. Exploring the Nernst equation. Concentration cells: Mixing → electric current

For oxidation numbers and balancing redox equations, please work through http://goo.gl/MMEUCs.

What determines cell voltage, E_{cell}?

We know spontaneity is determined by Q relative to K.

For now we can simplify things by arranging for $Q = 1$, typically by making reactants and products be in their standard state.

This arrangement defines what we call the standard free energy change,

$$\Delta G°_{\text{cell}} = -n_e F E°_{\text{cell}}$$

Calculating standard cell voltage, $E°_{\text{cell}}$

Since $E°_{\text{cell}}$ is proportional to the $\Delta G°_{\text{cell}}$,

$$\Delta G°_{\text{cell}} = -n_e F E°_{\text{cell}}$$

and because we know how to express a redox process as the sum of its half reactions, we can use Hess's law to express $\Delta G°_{\text{cell}}$ as

$$\Delta G°_{\text{cell}} = \Delta G°_{\text{cathode}} + \Delta G°_{\text{anode}}$$

Calculating standard cell voltage, E^o_{cell}

By convention, reduction half reactions have a standard reduction potential E°, whose value is the cell potential relative to the standard hydrogen electrode, SHE,

$2\ H^+(1\ M) + 2\ e^- \rightarrow H_2(1\ atm),\ E^o = 0\ V$

All other reductions defined relative to SHE

$Zn^{2+}(1\ M) + 2\ e^- \rightarrow Zn(s),\ E^o = -0.763\ V$

$Cu^{2+}(1\ M) + 2\ e^- \rightarrow Cu(s),\ E^o = +0.340\ V$

etc.

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Calculating standard cell voltage, E^o_{cell}

This means we can write

$\Delta G^o_{cathode} = -n_e\, F E^o_{cathode}$ and $\Delta G^o_{anode} = +n_e\, F E^o_{anode}$

The reason for the '+' in the anode expression is because oxidation takes place there — the reverse of reduction — and so the sign of its contribution to free energy change must be reversed.

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Calculating standard cell voltage, E^o_{cell}

Combining the three expressions

$\Delta G^o_{cathode} = -n_e\, F E^o_{cathode}$ and $\Delta G^o_{anode} = +n_e\, F E^o_{anode}$

$\Delta G^o_{cell} = \Delta G^o_{cathode} + \Delta G^o_{anode}$

$\Delta G^o_{cell} = -n_e\, F E^o_{cell}$

we get the fundamental expression for E^o_{cell} in terms of reduction potentials,

$E^o_{cell} = E^o_{cathode} - E^o_{anode}$

Note that both $E^o_{cathode}$ and E^o_{anode} are standard reduction potentials.

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Calculating standard cell voltage, E^o_{cell}

Here is an example: Does Cu^{2+} oxidize Zn?

$Cu^{2+}(1\ M) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(1\ M),\ E^o > 0?$

The standard reduction potentials are

$Zn^{2+}(1\ M) + 2\ e^- \rightarrow Zn(s),\ E^o = -0.763\ V$

$Cu^{2+}(1\ M) + 2\ e^- \rightarrow Cu(s),\ E^o = +0.340\ V$

The standard cell potential is

$E^o_{cell} = E^o_{cathode} - E^o_{anode}$

$= +0.340\ V - (-0.763\ V) = +1.103\ V > 0$

So, Zn is oxidized by Cu^{2+}

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Cell voltage versus spontaneity

Spontaneity is proportional to voltage

Spontaneity is proportional to how far away from equilibrium

Voltage versus Q/K?

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[TP] For the redox process

$$Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$$

when the ions each are 1 M, $Zn(s)$ is consumed. This means ...

20% 1. $K > 1$
20% 2. $K < 1$
20% 3. $Q > 1$
20% 4. $Q < 1$
20% 5. More information needed

Response Counter 5

17

[Quiz] For the redox process

$$Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$$

when $Q = x$, $Zn(s)$ is consumed. This means ...

20% 1. $K > 1$
20% 2. $K < 1$
20% 3. $Q > K$
20% 4. $Q < K$
20% 5. More information needed

Response Counter 5

18

[TP] For the redox process

$$Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$$

when $Q = 10$, $Zn(s)$ is consumed.
This means over time the cell voltage will ...

25% 1. become smaller
25% 2. stay the same
25% 3. become larger
25% 4. More information needed

Response Counter 5

19

[TP] For the redox process

$$Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$$

when $Q = 10$, $Zn(s)$ is consumed.
Compared to the voltage when $Q = 1$, the voltage when $Q = 10$ is ...

25% 1. smaller
25% 2. the same
25% 3. larger
25% 4. More information needed

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[Group Quiz] For the redox process

$$M^{+}(aq) + X(s) \rightarrow M(s) + X^{+}(aq)$$

when $Q = 0.1$, $M(s)$ is formed.
Compared to the voltage when $Q = 1$, the magnitude of the voltage when $Q = 0.1$ is ...

25% 1. smaller
25% 2. the same
25% 3. larger
25% 4. More information needed

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[TP] For the redox process

$$Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$$

when $[Cu^{2+}] = 0$ and $[Zn^{2+}] = 4$, the voltage is ...

33% 1. < 0
33% 2. 0
33% 3. > 0

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[TP] A redox reaction has $K = 10$. If there are only products present, $-\log(Q/K)$ is ...

17% 1. $+\infty$
17% 2. 2
17% 3. 1
17% 4. 0
17% 5. -1
17% 6. $-\infty$

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