Slides on the Nernst equation and concentration cells

CH102 Spring 2016, A1 and A2 lecture 25

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The Nernst equation

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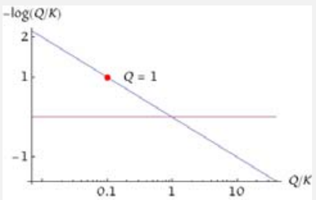
Voltage E versus Q/K



We have discovered that $-\log(Q/K)$ behaves as we expect voltage E to behave versus Q/K.

We will learn that at 25 °C, the constant of proportionality is $-(0.06/n_e)$, so that

$$E = -(0.06/n_e)\ \text{V}\ \log(Q/K)$$

in terms of the moles n_e of electrons transferred per reaction unit.

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$E = -(0.06/n_e)\ \text{V}\ \log(Q/K)$

Calculate the voltage at 25 °C for $n_e = 1$ when $Q = (1/100)\ K$

$E = 0.12$ V

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$E = -(0.06/n_e)$ V $\log(Q/K)$

Calculate the voltage at 25 °C for $n_e = 1$ when $Q = (1/10)\ K$

$E = 0.06$ V

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$E = -(0.06/n_e)$ V $\log(Q/K)$

Calculate the voltage at 25 °C for $n_e = 1$ when $Q = (10)\ K$

$E = -0.06$ V

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$E = -(0.06/n_e)$ V $\log(Q/K)$

At 25 °C for $n_e = 1$, ...
each order of magnitude change in Q/K ...
changes voltage by 0.06 V.

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$E = -(0.06/n_e)$ V $\log(Q/K)$

Write an expression for E when $Q = 1$.

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$E = -(0.06/n_e)$ V $\log(Q/K)$

The value of E when $Q = 1$ is called the standard voltage and at 25 °C is written as

$$E(Q = 1) = E^\circ = +(0.06/n_e)\ \text{V}\ \log(K)$$

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[TP] The value of E when $Q = 1$ at 25 °C is

$$E(Q = 1) = E^\circ = +(0.06/n_e)\ \text{V}\ \log(K)$$

For $n_e = 1$, if K is different by a factor of ten (say, 17 instead of 1.7), the magnitude of standard voltage will change by …

20% 1. 10 V
20% 2. 1 V
20% 3. 0.1 V
20% 4. 0.06 V
20% 5. Some other amount

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[TP] The value of E when $Q = 1$ at 25 °C is

$$E(Q = 1) = E^\circ = +(0.06/n_e)\ \text{V}\ \log(K)$$

For $n_e = 3$, if K is different by a factor of ten (say, 17 instead of 1.7), the magnitude of standard voltage will change by …

25% 1. 0.18 V
25% 2. 0.06 V
25% 3. 0.02 V
25% 4. Some other amount

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[TP] The value of E when $Q = 1$ at 25 °C is

$$E(Q = 1) = E^\circ = +(0.06/n_e)\ \text{V}\ \log(K)$$

A typical physiological value of E° is 0.18 V.
For $n_e = 1$ this corresponds to the value of K equal to …

17% 1. 0.1
17% 2. 1
17% 3. 10
17% 4. 100
17% 5. 1000
17% 6. Some other value

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$E = -(0.06/n_e)$ V $\log(Q/K)$

The value of E when $Q = 1$ at 25 °C is

$E(Q = 1) = E° = +(0.06/n_e)$ V $\log(K)$

Calculate K corresponding to $E° = 1.8$ V for $n_e = 1$.

$K = 10^{30}$. Very large!

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$E = -(0.06/n_e)$ V $\log(Q/K)$

The value of E when $Q = 1$ at 25 °C is

$E(Q = 1) = E° = +(0.06/n_e)$ V $\log(K)$

Express the cell voltage for any value of Q in terms of $E°$, that is, in term of the cell voltage when $Q = 1$.

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$E = -(0.06/n_e)$ V $\log(Q/K)$

The value of E when $Q = 1$ at 25 °C is

$E(Q = 1) = E° = +(0.06/n_e)$ V $\log(K)$

The cell voltage at 25 °C for any value of Q in terms of the cell voltage when $Q = 1$ is

$E(\text{any } Q) = E° - (0.06/n_e)$ V $\log(Q)$

This is called the Nernst equation

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Exploring the Nernst equation

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[TP] At 25 °C

$E = E^o - (0.06/n_e) \log(Q)$

What is the value of E when everything is in standard states?

25% 1. $E = \infty$

25% 2. $E = 0$

25% 3. $E = E^o$

25% 4. None of the above

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[TP] At 25 °C

$E = E^o - (0.06/n_e) \log(Q)$

What is the value of E when everything is at equilibrium?

25% 1. $E = \infty$

25% 2. $E = 0$

25% 3. $E = E^o$

25% 4. None of the above

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[TP] At 25 °C

$E = E^o - (0.06/n_e) \log(Q)$

What is the value of E when there are no products present?

25% 1. $E = \infty$

25% 2. $E = 0$

25% 3. $E = E^o$

25% 4. None of the above

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[TP] At 25 °C

$E = E^o - (0.06/n_e) \log(Q)$

What is the value of E when there are only products present?

25% 1. $E = \infty$

25% 2. $E = 0$

25% 3. $E = E^o$

25% 4. None of the above

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[TP] For A + B ⇋ 2 C + D at 25 °C

$E^o = (0.06/n_e) \log(K)$

What is the value of the equilibrium constant for

2 A + 2 B ⇋ 4 C + 2 D?

17% 1. K
17% 2. $2\ K$
17% 3. K^2
17% 4. $K/2$
17% 5. $K^{½}$
17% 6. None of the above

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[TP] For A + B ⇋ 2 C + D at 25 °C

$E^o = (0.06/n_e) \log(K)$

What is the value of n_e for

2 A + 2 B ⇋ 4 C + 2 D?

17% 1. n_e
17% 2. $2\ n_e$
17% 3. $n_e^{\,2}$
17% 4. $n_e/2$
17% 5. $n_e^{\,½}$
17% 6. None of the above

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[TP] For A + B ⇋ 2 C + D at 25 °C

$E^o = (0.06/n_e) \log(K)$

What is the value of E^o for

2 A + 2 B ⇋ 4 C + 2 D?

17% 1. E^o
17% 2. $2\ E^o$
17% 3. E^{o2}
17% 4. $E^o/2$
17% 5. $E^{o½}$
17% 6. None of the above

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[TP] For A + B ⇋ 2 C + D at 25 °C

$E^o = (0.06/n_e) \log(K)$

What is the value of E^o when all concentrations are doubled?

17% 1. E^o
17% 2. $2\ E^o$
17% 3. E^{o2}
17% 4. $E^o/2$
17% 5. $E^{o½}$
17% 6. None of the above

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Concentration cells: Mixing → electric current

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Concentration cells: Mixing → electric current

What happens when ink is dropped into water?

It disperses spontaneously

What happens when salt water is dropped into fresh water?

It disperses spontaneously

Let's see how to harness such spontaneity of mixing …

to generate electricity!

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[TP] What do you expect to be true about the process
$Cl^-(0.0001\ M) \rightarrow Cl^-(1\ M)$?

25% 1. $E > 0$
25% 2. $E = 0$
25% 3. $E < 0$
25% 4. More information needed

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[TP] What do you expect to be true about the process
$Cl^-(1\ M) \rightarrow Cl^-(0.0001\ M)$?

25% 1. $E > 0$
25% 2. $E = 0$
25% 3. $E < 0$
25% 4. More information needed

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[TP] What is true about the process
$Cl^-(1\ M) \rightarrow Cl^-(0.0001\ M)$?

25% 1. $K > 1$
25% 2. $K = 1$
25% 3. $K < 1$
25% 4. More information needed

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[TP] What is true about the process
$Cl^-(1\ M) \rightarrow Cl^-(0.0001\ M)$?

25% 1. $E^o > 0$
25% 2. $E^o = 0$
25% 3. $E^o < 0$
25% 4. More information needed

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[TP] A concentration cell is constructed with Q corresponding to the Cl^- concentration difference between sea water and river water at 25 °C. Assume that the Cl^- concentration (due to dissolved NaCl) of sea water is 35 g/L and than that of river water is 1.0 mg/L. The voltage of this cell is …

20% 1. $E = +0.13$ V
20% 2. $E = +0.27$ V
20% 3. $E = +0.54$ V
20% 4. $E = +1.08$ V
20% 5. Something else

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