

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

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

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

BOSTON UNIVERSITY

Lecture 27 CH102 A1 (MWF 9:05 am)

Friday, April 5, 2019

- Complete: Cell voltage versus Q/K: The Nernst equation
- Exploring the Nernst equation

Next lecture: Concentration cells: Mixing → electric current

Begin ch 17: Spontaneous change: How far?

Notes: Spontaneity: Second law of thermodynamics
http://quantum.bu.edu/courses/ch102-spring-2018/handouts.html

BOSTON UNIVERSITY

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

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

BOSTON UNIVERSITY

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

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

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

BOSTON UNIVERSITY

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

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

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

BOSTON UNIVERSITY 9

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

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

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 ...

0% 1. 0.18 V
0% 2. 0.06 V
0% 3. 0.02 V
0% 4. Some other amount

BOSTON UNIVERSITY 10

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

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

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

0% 1. 0.1
0% 2. 1
0% 3. 10
0% 4. 100
0% 5. 1000
0% 6. Some other value

BOSTON UNIVERSITY 11

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

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

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

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

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

BOSTON UNIVERSITY 12

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

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

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

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

BOSTON UNIVERSITY 13

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

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

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

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

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

This is called the Nernst equation

BOSTON UNIVERSITY 14

Exploring the Nernst equation

At 25 °C $E(\text{any } Q) = E° - (0.06/n_e)\ \mathrm{V}\ \log(Q)$

$$E° = +(\ 0.06/n_e\ )\ \mathrm{V}\ \log(K)$$

BOSTON UNIVERSITY 15

[TP] At 25 °C

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

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

25% 1. $E = \infty$
25% 2. $E = 0$
25% 3. $E = E°$
25% 4. None of the above

BOSTON UNIVERSITY 16

[TP] At 25 °C

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

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

0% 1. $E = \infty$
0% 2. $E = 0$
0% 3. $E = E°$
0% 4. None of the above

[TP] At 25 °C

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

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

25% 1. $E = \infty$
25% 2. $E = 0$
25% 3. $E = E°$
25% 4. None of the above

[Quiz] At 25 °C

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

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

25% 1. $E = \infty$
25% 2. $E = 0$
25% 3. $E = E°$
25% 4. None of the above

[TP] For A + B ⇄ 2 C + D at 25 °C

$$E° = (0.06/n_e)\ \mathrm{V}\log(K)$$

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. $\sqrt{K}$
17% 6. None of the above

[TP] For A + B ⇄ 2 C + D at 25 °C

$E° = (0.06/n_e)\ \text{V} \log(K)$

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. $\sqrt{n_e}$
17% 6. None of the above

BOSTON UNIVERSITY 21

[Quiz] For A + B ⇄ 2 C + D at 25 °C

$E° = (0.06/n_e)\ \text{V} \log(K)$

What is the value of $E°$ for

2 A + 2 B ⇄ 4 C + 2 D?

17% 1. $E°$
17% 2. $2\ E°$
17% 3. $(E°)^2$
17% 4. $E°/2$
17% 5. $\sqrt{E°}$
17% 6. None of the above

BOSTON UNIVERSITY 22

[TP] For A + B ⇄ 2 C + D at 25 °C

$E° = (0.06/n_e)\ \text{V} \log(K)$

What is the value of $E°$ when all concentrations are doubled?

17% 1. $E°$
17% 2. $2\ E°$
17% 3. $(E°)^2$
17% 4. $E°/2$
17% 5. $\sqrt{E°}$
17% 6. None of the above

BOSTON UNIVERSITY 23

[Quiz] For A + B ⇄ 2 C + D at 25 °C, if $E = 3.7$ V, $E° = 2.0$ V, and $n_e = 1$, what is the value of E when all concentrations are doubled?

20% 1. $E < 3.7$ V
20% 2. $E > 3.7$ V
20% 3. $(E°)^2$
20% 4. $E°/2$
20% 5. $\sqrt{E°}$

BOSTON UNIVERSITY 24

Concentration cells: Mixing → electric current

BOSTON UNIVERSITY

25

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!

BOSTON UNIVERSITY

26

[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

BOSTON UNIVERSITY

Response Counter

27

[TP] What do you expect to be true about the process

$Cl^-(1\ M) \rightarrow Cl^-(0.0001\ M)$?

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

BOSTON UNIVERSITY

28

[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

BOSTON UNIVERSITY

Response Counter

10

29

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

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

BOSTON UNIVERSITY

Response Counter

30

[TP] The process
$Cl^-(1\ M) \rightleftarrows Cl^-(0.0001\ M)$
is spontaneous. The correct cell line notation is …

1. Pt(s) | Cl^-(0.0001 M) | Cl_2 (1 bar) || Cl^-(1 M) | Cl_2 (1 bar) | Pt(s)
2. Pt(s) | Cl^-(0.0001 M) | Cl_2 (1 bar) || Cl_2 (1 bar) | Cl^-(1 M) | Pt(s)
3. Pt(s) | Cl^-(1 M) | Cl_2 (1 bar) || Cl^-(0.0001 M) | Cl_2 (1 bar) | Pt(s)
4. Pt(s) | Cl^-(1 M) | Cl_2 (1 bar) || Cl_2 (1 bar) | Cl^-(0.0001 M) | Pt(s)
5. None of the above

BOSTON UNIVERSITY

31

[TP] The voltage of a chloride concentration cell is x V. If the pressure of the chlorine gas in the anode is doubled, the new voltage will …

25% 1. be larger than x V.
25% 2. remain x V.
25% 3. be smaller than x V.
25% 4. Further information needed.

BOSTON UNIVERSITY

33

[Group Quiz] 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 0.10 mg/L. The voltage of this cell is …

20% 1. $E = +0.67$ V
20% 2. $E = +0.50$ V
20% 3. $E = +0.33$ V
20% 4. $E = +0.17$ V
20% 5. Something else

BOSTON UNIVERSITY

Recipe for concentration cell reaction and Q

1. Write skeleton reaction, for example
   $A^+(\text{conc}, aq) \rightarrow A^+(\text{dil}, aq)$ or
   $B^-(\text{conc}, aq) \rightarrow B^-(\text{dil}, aq)$
2. Write half reaction for reactant and for product, labelling each component as being in anode or cathode.

BOSTON UNIVERSITY

Recipe for concentration cell reaction and Q

1. Write skeleton reaction, for example
   $A^+(\text{conc}, aq) \rightarrow A^+(\text{dil}, aq)$ or
   $B^-(\text{conc}, aq) \rightarrow B^-(\text{dil}, aq)$
2. Write half reaction for reactant and for product, labelling each component as being in anode or cathode.
3. Combine half reactions, noting the value of n_e.
4. Write expression for Q
5. Use $E = -\frac{0.06}{n_e}\text{V}\log(Q)$

BOSTON UNIVERSITY