

Lecture 14 CH102 A2 (MWF 11:15 am) Spring 2019 Copyright © 2019 Dan Dill dan@bu.edu

[TP] The reaction $3 A(aq) \rightleftharpoons 2 B(aq)$ is at equilibrium, with $[A]_e = 0.10 \text{ M}$ and $[B]_e = 2.0 \text{ M}$ and so $K = 4000$. Then 0.05 M of A is added.

At the moment of this change, the value of $[A]$ will be ...

33% 1. 0.05 M
33% 2. 0.10 M
33% 3. 0.15 M

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Lecture 14 CH102 A2 (MWF 11:15 am)

Friday, February 22, 2019

- Review: Knowing K **does not** fix individual concentrations.
- Disturbing equilibrium (Le Chatelier)

Being ch14: Acid-base equilibria in aqueous solutions

- The pH of water

Next: Composition of water. Weak acids and strong acids. Getting weak acid K_a values; $pK_a = -\log(K_a)$; Using K_a to get $[H_3O^+]$. Titration: What happens when some OH^- is added to an acid

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Knowing K does not fix individual concentrations

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Practice question

At 25°C the equilibrium constant for the reaction $3 A + B \rightleftharpoons 2 C$ is 0.145. In one experiment, a student measured **at equilibrium** that the concentrations of A and B are each 2.45 M. In a second experiment, the student measured **at equilibrium** that $[A]_e = 2.45 \text{ M}$ but $[B]_e = 1.94 \text{ M}$. Must there be errors in one or both of the measurements?

If errors, show why.

If no errors, show why.

BOSTON UNIVERSITY 7

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Disturbing equilibrium

Essential idea: A system at equilibrium responds to a disturbance by ...

partially offsetting the disturbance.



9

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[TP] The reaction $3 A(aq) \rightleftharpoons 2 B(aq)$ is at equilibrium, with $[A]_e = 0.10 \text{ M}$ and $[B]_e = 2.0 \text{ M}$ and so $K = 4000$. Then 0.05 M of A is added.

At the moment of this change, the value of $[A]$ will be ...

33% 1. 0.05 M

33% 2. 0.10 M

33% 3. 0.15 M

Response
Counter

10

10

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[TP] The reaction $3 A(aq) \rightleftharpoons 2 B(aq)$ is at equilibrium, with $[A]_e = 0.10 \text{ M}$ and $[B]_e = 2.0 \text{ M}$ and so $K = 4000$. Then 0.05 M of A is added.

At the moment of this change, the value of Q will be ...

33% 1. > 4000

33% 2. $= 4000$

33% 3. < 4000

Response
Counter

10

11

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[TP] The reaction $3 A(aq) \rightleftharpoons 2 B(aq)$ is at equilibrium, with $[A]_e = 0.10 \text{ M}$ and $[B]_e = 2.0 \text{ M}$ and so $K = 4000$. Then 0.05 M of A is added.

At the moment of this change, the system will ...

33% 1. have too much reactant

33% 2. still be at equilibrium

33% 3. have too much product

Response
Counter

10

12

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[TP] The reaction $3 A(aq) \rightleftharpoons 2 B(aq)$ is at equilibrium, with $[A]_e = 0.10 \text{ M}$ and $[B]_e = 2.0 \text{ M}$ and so $K = 4000$. Then 0.05 M of A is added. After the system is once again at equilibrium, $[A]_e$ **must** be ...

- 33% 1. $< 0.10 \text{ M}$
33% 2. $= 0.10 \text{ M}$
33% 3. $> 0.10 \text{ M}$

Response
Counter

13

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[Quiz] The reaction $3 A(aq) \rightleftharpoons 2 B(aq)$ is at equilibrium, with $[A]_e = 0.10 \text{ M}$ and $[B]_e = 2.0 \text{ M}$ and so $K = 4000$. Then 0.05 M of A is added. After the system is once again at equilibrium, $[B]_e$ **must** be ...

- 33% 1. $< 2.0 \text{ M}$
33% 2. $= 2.0 \text{ M}$
33% 3. $> 2.0 \text{ M}$

Response
Counter

14

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Disturbing equilibrium

Essential idea: A system at equilibrium responds to a disturbance by **partially offsetting** the disturbance.

This behavior is called **Le Chatelier's principle**.



15

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Begin ch14:
Acid-base equilibria in aqueous solutions



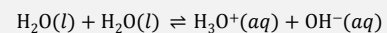
16

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The pH of water

Write down the **chemical equilibrium** that accounts for the pH of water.



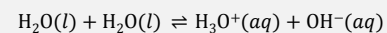
17

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The pH of water

Write down the **reaction quotient** for the water autoionization equilibrium,



$$Q_w = [\text{H}_3\text{O}^+][\text{OH}^-]$$

$$K_w = [\text{H}_3\text{O}^+]_e [\text{OH}^-]_e$$



19

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The pH of water

Pure water at 50 °C is measured to have a **pH of 6.63**.

Write down the value of **$[\text{H}_3\text{O}^+]_e$ at 50 °C**.

$$[\text{H}_3\text{O}^+]_e = 10^{-6.63} = 2.34 \times 10^{-7}$$



20

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The pH of water

Pure water at 50 °C is measured to have a **pH of 6.63**.

Write down the value of **$[\text{OH}^-]_e$ at 50 °C**.

$$[\text{OH}^-]_e = [\text{H}_3\text{O}^+]_e = 10^{-6.63} = 2.34 \times 10^{-7}$$



21

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The pH of water

Pure water at 50 °C is measured to have a pH of 6.63.

Write down the value of the reaction quotient of the water autoionization at equilibrium at 50 °C.

$$Q_{w,e} = K_w = [\text{H}_3\text{O}^+]_e [\text{OH}^-]_e = (10^{-6.63})^2 = 5.48 \times 10^{-14}$$



22

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[TP] Pure water at 50 °C is measured to have a pH of 6.63.
This means that pure water at 50 °C is ...

- 0% 1. acidic
- 0% 2. neutral
- 0% 3. basic



23

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[TP] Pure water at 10 °C has $[\text{H}_3\text{O}^+] = 5.39 \times 10^{-8}$.
This means that pure water at 10 °C is ...

- 0% 1. acidic
- 0% 2. neutral
- 0% 3. basic



24

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[Quiz] The pH of pure water is different at different temperatures.
This means that as temperature changes ...

- 0% 1. the proportions of $\text{H}_3\text{O}^+(aq)$ and $\text{OH}^-(aq)$ to one another in pure water change
- 0% 2. the acidity of pure water changes
- 0% 3. the value of the equilibrium constant changes
- 0% 4. All of the above
- 0% 5. None of the above



26

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Equilibrium constants change with temperature

The pH of pure water at 50 °C is 6.63.

The pH of pure water at 25 °C is 7.00.

The pH of pure water at 10 °C is 7.27.

Sketch K_w versus temperature for $\text{H}_2\text{O}(l) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{OH}^-(aq)$.



27

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Equilibrium constants change with temperature

If $A \rightleftharpoons B$ is **endothermic** (gains energy from its surroundings),
its K **increases with temperature**.

If $A \rightleftharpoons B$ is **exothermic** (loses energy to its surroundings),
its K **decreases with temperature**.

Later, we'll learn **why** K is related to $\Delta_r H$ in this way.



28

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[TP] The pH of pure water at 50 °C is 6.63.

The pH of pure water at 25 °C is 7.00.

This means the autoionization of water,

$\text{H}_2\text{O}(l) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{OH}^-(aq)$
is ...

- 0% 1. Exothermic
- 0% 2. Endothermic
- 0% 3. More information needed to know



29