

[TP] The reaction 3 A(*aq*) ⇌ 2 B(*aq*) is at equilibrium, with
$[A]_e$ = 0.10 M and $[B]_e$ = 2.0 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 A1 (MWF 9:05 am)

Wednesday, February 22, 2017

- Clicker ID 62142A ?
- Knowing K does not fix individual concentrations
- Disturbing equilibrium (Le Chatelier)

Next lecture: Begin ch14: The pH of water; Composition of liquid water; weak acids and strong acids.

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Knowing K does not fix individual concentrations

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Chapter 13 equilibrium calculations

Pages 505—507 illustrate how to calculate equilibrium concentrations by solving polynomial (quadratic, etc.) equations for the change in concentration.

This is doable but can be time consuming.

We will not need to use this method.

Rather, in chapter 14, we will learn to use an approximate method that is broadly applicable to aqueous acid-base equilibria.

Here, in chapter 13, we will illustrate equilibration by providing the equilibrium values.

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Equilibration examples

Essential lesson:
Knowing K does not fix individual equilibrium concentrations.

Let's see how this works for

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

for three different sets of initial concentrations

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Worked Example 13.5, p 505

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0.00600	0	
Change				
Equilibrium				
Equilibrium				

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Worked Example 13.5, p 505

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

Since $Q < K$, "too little product" and so …

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0.00600	0	0
Change				
Equilibrium				
Equilibrium				

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Worked Example 13.5, p 505

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

… we form some product by consuming some reactant.

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0.00600	0	0
Change	$-x$	$-x$	$+2x$	
Equilibrium				
Equilibrium				

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Worked Example 13.5, p 505

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g),\ K = 33$

The unknown x is found by adjusting its value so that the equilibrium concentrations give the numerical value of Q to be K.

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0.00600	0	0
Change	$-x$	$-x$	$+2x$	
Equilibrium	$0.00600 - x$	$0.00600 - x$	$2x$	K
Equilibrium				

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Worked Example 13.5, p 505

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g),\ K = 33$

Remember, solving for x can be the "hard part". In ch14 we'll learn approximate methods that make doing so easy. Here we'll give the exact results.

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0.00600	0	0
Change	$-x$	$-x$	$+2x$	
Equilibrium	$0.00600 - x$	$0.00600 - x$	$2x$	K
Equilibrium				

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Worked Example 13.5, p 505

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g),\ K = 33$

$x = 0.00445$

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0.00600	0	0
Change	$-x$	$-x$	$+2x$	
Equilibrium	$0.00600 - x$	$0.00600 - x$	$2x$	K
Equilibrium	0.00155	0.00155	0.00890	33

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Worked Example 13.5, p 505, again

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g),\ K = 33$

Different starting conditions ...

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0	0.00200	
Change				
Equilibrium				
Equilibrium				

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Worked Example 13.5, p 505, again

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

Since $Q = \infty > K$, "too much product" and so ...

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0	0.00200	∞
Change				
Equilibrium				
Equilibrium				

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Worked Example 13.5, p 505, again

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

... we form some reactants by consuming some product.

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0	0.00200	∞
Change	$+ x$	$+ x$	$- 2x$	
Equilibrium				
Equilibrium				

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Worked Example 13.5, p 505, again

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

The unknown x is found by adjusting its value so that the equilibrium concentrations give the numerical value of Q to be K.

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0	0.00200	∞
Change	$+ x$	$+ x$	$- 2x$	
Equilibrium	$0.00600 + x$	x	$0.00200 - 2x$	K
Equilibrium				

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Worked Example 13.5, p 505, again

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

$x = 0.0000194$

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0	0.00200	∞
Change	$+ x$	$+ x$	$- 2x$	
Equilibrium	$0.00600 + x$	x	$0.00200 - 2x$	K
Equilibrium	0.00602	0.0000194	0.00196	33

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Worked Example 13.5, p 505, once again

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

Still different starting conditions …

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0.0000100	0.00200	
Change				
Equilibrium				
Equilibrium				

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Worked Example 13.5, p 505, once again

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

Since $Q = 66.7 > K$, "too much product" and so …

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0.0000100	0.00200	66.7
Change				
Equilibrium				
Equilibrium				

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Worked Example 13.5, p 505, once again

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

… we form some reactants by consuming some product.

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0.0000100	0.00200	66.7
Change	$+ x$	$+ x$	$- 2x$	
Equilibrium				
Equilibrium				

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Worked Example 13.5, p 505, once again

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

The unknown x is found by adjusting its value so that the equilibrium concentrations give the numerical value of Q to be K.

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0.0000100	0.00200	66.7
Change	$+ x$	$+ x$	$- 2x$	
Equilibrium	$0.00600 + x$	$0.0000100 + x$	$0.00200 - 2x$	K
Equilibrium				

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Worked Example 13.5, p 505, once again

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

$x = 9.78 \times 10^{-6}$

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0.0000100	0.00200	66.7
Change	$+ x$	$+ x$	$- 2x$	
Equilibrium	$0.00600 + x$	$0.0000100 + x$	$0.00200 - 2x$	K
Equilibrium	0.00601	0.0000198	0.00198	33

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Worked Example 13.5, p 505

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

Different starting points ...

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Initial	0.00600	0.00600	0	0
Initial	0.00600	0	0.00200	∞
Initial	0.00600	0.0000100	0.00200	66.7

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Worked Example 13.5, p 505

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, $K = 33$

Different starting points ...
different equilibrium concentrations

	$H_2(g)$	$I_2(g)$	$HI(g)$	Q
Equilibrium	0.00155	0.00155	0.00890	33
Equilibrium	0.00602	0.0000194	0.00196	33
Equilibrium	0.00601	0.0000198	0.00198	33

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Disturbing equilibrium

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

partially offsetting the disturbance.

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[TP] The reaction 3 A(aq) ⇌ 2 B(aq) is at equilibrium, with $[A]_e = 0.10$ M and $[B]_e = 2.0$ 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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[TP] The reaction 3 A(aq) ⇌ 2 B(aq) is at equilibrium, with $[A]_e = 0.10$ M and $[B]_e = 2.0$ 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

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[TP] The reaction 3 A(aq) ⇌ 2 B(aq) is at equilibrium, with $[A]_e = 0.10$ M and $[B]_e = 2.0$ 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

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[TP] The reaction 3 A(aq) ⇌ 2 B(aq) is at equilibrium, with $[A]_e = 0.10$ M and $[B]_e = 2.0$ 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 M
33% 2. = 0.10 M
33% 3. > 0.10 M

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[Group Quiz] The reaction 3 A(*aq*) ⇌ 2 B(*aq*) is at equilibrium, with
$[A]_e$ = 0.10 M and $[B]_e$ = 2.0 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 M
33% 2. = 2.0 M
33% 3. > 2.0 M

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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.

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