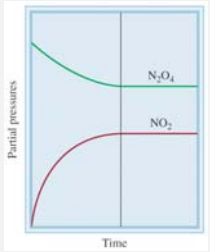


[TP] The figure shows how the partial pressures of the N_2O_4 and NO_2 change with time due to the chemical reaction

$$N_2O_4 \rightarrow 2\ NO_2$$

for certain initial conditions. At these initial conditions (far left), the following is known about the chemical reaction.

25% 1. It is spontaneous
25% 2. It is at equilibrium
25% 3. It is non-spontaneous
25% 4. Its spontaneity is not known without further information



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Lecture 13 CH102 A1 (MWF 9:05 am)

Tuesday, February 20, 2018

- Complete: Review of colligative properties

Begin ch13: Equilibrium

- Reaction quotient, Q, spontaneity, and equilibrium
- Predicting direction of change
- Q depends on how a reaction is written

Next: Complete ch13: Knowing K does not fix individual concentrations. Disturbing equilibrium (Le Chatelier)

Colligative properties summary

Non-volatile solute (negligible vapor pressure) ...

- lowers vapor pressure of solvent
- raises boiling point of solvent
- lowers freezing point of solvent

If solute cannot pass through a membrane ...

- the solvent will create an osmotic pressure

Details and practice in lab and in discussion

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Practice question

What height column of benzene ($D = 0.876$ g/mL) generates a pressure of 248 Pa? Express your answer in cm, to the correct number of significant figures. Recall that $\Pi = Dgh$, Pa = kg/(m s^2), and $g = 9.80665$ m/s^2.

Answer: 2.89 cm

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Begin ch 13

Dynamic chemical equilibrium

Spontaneity of "reactants" → "products"

If products (right side) increase with time, we say …
the reaction is spontaneous.

If reactants (left side) increase with time, we say …
the reaction is nonspontaneous.

If the amount of reactants and products do not change with time, we say …
the reaction is at equilibrium.

Reaction quotient Q measures progress

$A \rightarrow B + C$

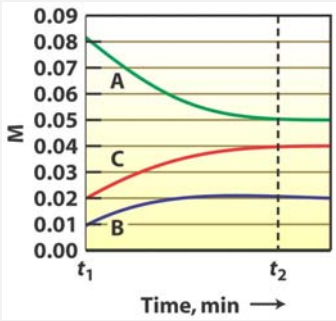
$Q = \frac{\text{products}}{\text{reactants}} = \frac{[B][C]}{[A]}$

Q at t_1 is smaller (less products)

Q at t_2 is larger (more products)

Q for $t > t_2$ no longer changes

For $t > t_2$, $Q = K$, equilibrium constant



Reaction quotient Q measures progress

For $A \rightarrow B + C$, the reaction quotient is …

$$Q = \frac{[B][C]}{[A]}$$

The numerical value of the reaction quotient when the concentrations have their equilibrium values $[A]_e$, $[B]_e$ and $[C]_e$ …

and so no longer change with time, is called the equilibrium constant …

$$Q = K = \frac{[B]_e[C]_e}{[A]_e}$$

Q versus *K* is the key to assessing spontaneity

If $Q < K$, product must form to get to equilibrium,
so spontaneous

If $Q > K$, reactants must form to get to equilibrium,
so nonspontaneous

If $Q = K$, no change in amounts of reactants and products,
so equilibrium

So, Q/K is the key quantity to monitor.

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$N_2O_4 \rightarrow 2\ NO_2$

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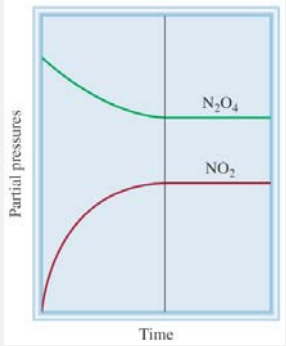

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$N_2O_4 \rightarrow 2\ NO_2$

The reaction quotient is

$$Q = [NO_2]^2/[N_2O_4]$$

The numerical value of the reaction quotient when the concentrations have their equilibrium values

$[N_2O_4]_e$ and $[NO_2]_e$

and so no longer change with time, is called the equilibrium constant

$$K = [NO_2]_e^2/[N_2O_4]_e$$

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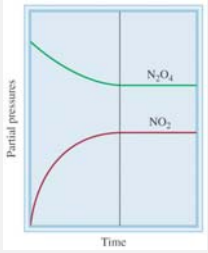

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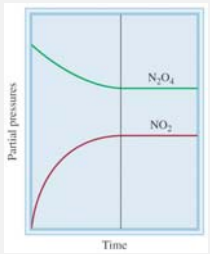
[TP] At the initial conditions (far left) for the reaction
$N_2O_4 \rightarrow 2\ NO_2$
the following is known about the ratio Q/K.

25% 1. It is greater than 1
25% 2. It is equal to 1
25% 3. It is less than 1
25% 4. The ratio is not known without further information



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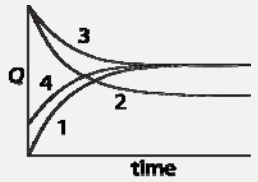
[TP] For the reaction
$N_2O_4 \rightarrow 2\ NO_2$
which curve on the right shows the corresponding change of Q with time?

20% 1. 1
20% 2. 2
20% 3. 3
20% 4. 4
20% 5. None



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[Group Quiz] The figure shows how the partial pressures of the N_2O_4 and NO_2 change with time due to the chemical reaction
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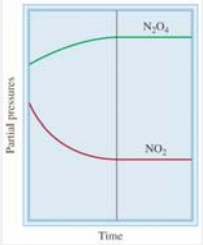

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Q versus K is the key to assessing spontaneity

If $Q < K$, product must form to get to equilibrium,
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If $Q > K$, reactants must form to get to equilibrium,
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If $Q = K$, no change in amounts of reactants and products,
so equilibrium

So, Q/K is the key quantity to monitor.

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Predicting direction of change

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[TP] For the reaction

$$2\,A + B \rightarrow 2\,C$$

at a certain time the value of its reaction quotient is $Q = 7$. This means the value of the equilibrium constant for the reaction is ...

25% 1. < 7
25% 2. 7
25% 3. > 7
25% 4. Further information needed

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[TP] The value of the equilibrium constant for the gas-phase reaction

$$2\,A + B \rightarrow C$$ is $K = 10$.

At a certain time the partial pressures are A, B and C are, respectively, 1 bar, 1 bar and 2 bar.
The value of the reaction quotient is $Q =$ ...

33% 1. 2
33% 2. 10
33% 3. Further information needed

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[Quiz] The value of the equilibrium constant for the gas-phase reaction

$$2\,A + B \rightarrow C$$ is $K = 10$.

At a certain time the partial pressures are A, B and C are, respectively, 1 bar, 1 bar and 2 bar.
Under these conditions, the value of the equilibrium constant is $K =$ ...

33% 1. 2
33% 2. 10
33% 3. Further information needed

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[TP] The value of the equilibrium constant for the gas-phase reaction
$2\ A + B \rightarrow C$ is $K = 10$.
At a certain time the partial pressures are A, B and C are, respectively, 0.2 bar, 1 bar and 4 bar.
The value of the reaction quotient is $Q =$ ...

20% 1. 0.04
20% 2. 4
20% 3. 10
20% 4. 100
20% 5. None of the these

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[TP] The value of the equilibrium constant for the gas-phase reaction
$2\ A + B \rightarrow C$ is $K = 10$.
At a certain time the partial pressures are A, B and C are such that the value of the reaction quotient is $Q = 100$.
As time passes, the value of Q will ...

33% 1. increase
33% 2. stay the same
33% 3. decrease

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[TP] The value of the equilibrium constant for the gas-phase reaction
$2\ A + B \rightarrow C$ is $K = 10$.
At a certain time the value of the reaction quotient is $Q = 6$.
As time passes, the value of Q will ...

33% 1. increase
33% 2. stay the same
33% 3. decrease

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Q depends on how a reaction is written

At a certain time, the value of the reaction quotient for the reaction

$2\ A + B \rightleftharpoons 2\ C$

is $Q_1 = 4.0$.

At the same time, what would be the value of Q be for the reaction

$4\ A + 2\ B \rightleftharpoons 4\ C$?

$$Q_4 = \frac{(C)^4}{(A)^4(B)^2} = Q_1^2 = 16$$

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Q depends on how a reaction is written

At a certain time, the value of the reaction quotient for the reaction

$2\ \mathrm{A} + \mathrm{B} \rightleftharpoons 2\ \mathrm{C}$

is $Q_1 = 4.0$.

At the same time, what would be the value of Q be for the reaction

$2\ \mathrm{C} \rightleftharpoons 2\ \mathrm{A} + \mathrm{B}$?

$$Q_2 = \frac{(\mathrm{A})^2(\mathrm{B})}{(\mathrm{C})^2} = \frac{1}{Q_1} = 0.25$$

Q depends on how a reaction is written

At a certain time, here are the values of the reaction quotients for two different reactions,

$2\ \mathrm{A} \rightleftharpoons \mathrm{B}$, $Q_5 = \frac{(\mathrm{B})}{(\mathrm{A})^2} = 2$

$\mathrm{C} \rightleftharpoons 3\ \mathrm{D}$, $Q_6 = \frac{(\mathrm{D})^3}{(\mathrm{C})} = 5$

At the same time, what would be the value of Q be for the reaction

$2\ \mathrm{A} + \mathrm{C} \rightleftharpoons \mathrm{B} + 3\mathrm{D}$?

$$Q_7 = \frac{(\mathrm{B})(\mathrm{D})^3}{(\mathrm{A})^2(\mathrm{C})} = Q_5 \times Q_6 = 10$$

[TP] The value of the equilibrium constant for the reaction

$2\ \mathrm{A} + \mathrm{B} \rightleftharpoons \mathrm{C}$

is $K = 10$. The value of the equilibrium constant for the reaction

$6\ \mathrm{A} + 3\ \mathrm{B} \rightleftharpoons 3\ \mathrm{C}$

is ...

0% 1. 10
0% 2. 30
0% 3. 100
0% 4. 1000
0% 5. None of the above

[TP] The value of the equilibrium constant for the reaction

$2\ \mathrm{A} + \mathrm{B} \rightleftharpoons \mathrm{C}$

is $K = 10$. The value of the equilibrium constant for the reaction

$2\ \mathrm{C} \rightleftharpoons 4\ \mathrm{A} + 2\ \mathrm{B}$

is ...

20% 1. −10
20% 2. 0.1
20% 3. 0.01
20% 4. −0.001
20% 5. None of the above

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[Group Quiz] The value of the equilibrium constant for the reaction

$2\ A \rightleftharpoons C$ is $K_1 = 4$

and that for the reaction

$D \rightleftharpoons C$ is $K_2 = 0.5$.

The value of the equilibrium constant for the reaction

$2\ A \rightleftharpoons D$ is $K_3 =$ ...

20% 1. 2
20% 2. 4
20% 3. 6
20% 4. 8
20% 5. None of the above

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10

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