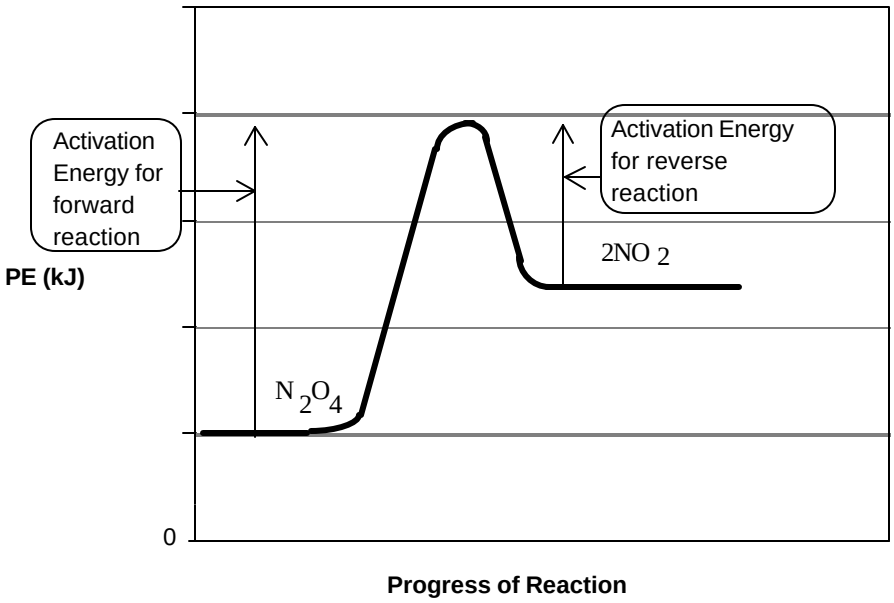
Tutorial 3 - Solutions
Factors Affecting Equilibrium

Answer to question 1 on page 2 of Tutorial 3.



$$N_2O_{4(g)} + heat \rightleftarrows 2\ NO_{2(g)}$$

1. Now, consider the forward reaction and the reverse reaction. Which reaction do you think would be most affected by an increase in temperature? **___the forward reaction___**

Explanation:

In an endothermic reaction like this, the <u>forward reaction</u> has the higher activation energy (see the graph above).

If the activation energy is high, it means only a few molecules have enough energy for a successful reaction. When the temperature is increased, the number of molecules with sufficient energy will increase and the rate of reaction will increase.

For a reaction with a low activation energy (like the reverse reaction here), most molecules already have sufficient energy to react and increasing the temperature will not have as much affect.

So, to summarize:

> ***Temperature* will always have *more effect* on the reaction with the *higher activation energy*.**

Answer to question 2 on page 7 of Tutorial 3

2. Given the equilibrium: $CO_{2(g)} + NO_{(g)} \rightleftarrows CO_{(g)} + NO_{2(g)}$

Some NO_2 is added to the system.

The _____**reverse**_____ reaction will speed up.

$$CO_{2(g)} + NO_{(g)} \rightleftarrows CO_{(g)} + NO_{2(g)}$$

This will cause the [CO_2] and the [NO] to _____**increase**_____

$$CO_{2(g)} + NO_{(g)} \rightleftarrows CO_{(g)} + NO_{2(g)}$$

Therefore, after awhile, the rate of the _____**forward**_____ reaction will speed up, and there will be a new equilibrium.

Because the rate of the _____**reverse**_____ reaction was higher for

awhile, in the ***new*** equilibrium mixture, the [CO_2] and the [NO] will be ____**higher**__

than they were before and the [CO] and the [NO_2] will be ___**lower**_____ than after we added the NO_2.

We can say that adding the NO_2 ***shifted*** the equilibrium to the _____**left**_____

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Answers to question 3 on page 10 of Tutorial 3

3. Given the equilibrium: $\mathbf{2}C_2H_{6(g)} + \mathbf{7}O_{2(g)} \rightleftarrows \mathbf{4}CO_{2(g)} + \mathbf{6}H_2O_{(g)}$

2 + 7 = 9 moles of gas 4 + 6 = 10 moles of gas

a) *Increasing* the *total pressure* on this system, will cause a shift to the side with **_less_**

moles of gas, which in this case is the ____**left**_____ side.

b) *Decreasing* the *total pressure* on this system, will cause a shift to the side with **more** moles of gas, which in this case is the ____**right**_____ side.

c) *Increasing the total volume* on this system (the same as _____**decreasing**__ the total pressure) will cause a shift to the side with _____**more**____ moles of gas, which in this case is the _____**right**___ side.

d) *Decreasing the total volume* on this system (the same as _____**increasing**___ the total pressure) will cause a shift to the side with _____**less**_____ moles of gas, which in this case is the ____**left**_____ side.

Answers to Self-Test starting on page 12 of Tutorial 3

1. When a chemical system is at equilibrium, when the temperature is increased, the _____**end**othermic reaction speeds up the most.

2. In the reaction: A + B $\rightleftharpoons$ C + 43.3 kJ

a) When the temperature is increased the (forward/reverse) _____**reverse**_____ reaction speeds up more.

b) During this time, the [A] and [B] will _____crease and the [C] will _____**de**crease.

c) Because [A] and [B] are _____**in**creasing, the rate of the _____**forward**____ reaction will increase.

d) Sooner or later, the forward rate and the reverse rate will again become ___**equal**__. At this point a new _____**equilibrium**_____ is established.

e) In the new equilibrium, [A] and [B] will be _____**high**er than they were before the temperature is increased.

In the new equilibrium, [C] will be _____**low**er than it was before.

f) In this example, we say that the equilibrium has shifted to the _____**left**_____

3. Given the reaction: A + B $\rightleftarrows$ C + 43.3 kJ

a) When the temperature is decreased the (forward/reverse) _____**forward**___ reaction will be the faster one.. (**the endothermic reverse reaction slows down**)

b) During this time, the [A] and [B] will ____**de**crease and the [C] will ____**in**crease.

c) Because [C] is _____**in**creasing, the rate of the _____**reverse**_____ reaction will increase.

d) Sooner or later, the forward rate and the reverse rate will again become __**equal**___.

At this point a new _____**equilibrium**_____ is established.

e) In the new equilibrium, [A] and [B] will be _____**low**er than they were before the temperature is increased.

In the new equilibrium, [C] will be _____**high**er than it was before.

f) In this example, we say that the equilibrium has shifted to the _____**right**_____

4. In the reaction: A + B + 324 kJ $\rightleftarrows$ C

a) When the temperature is increased the (forward/reverse) _____**forward**_____ reaction speeds up more.

b) During this time, the [A] and [B] will ____**de**crease and the [C] will _____**in**crease.

c) Because [C] is _**in**creasing, the rate of the _____**reverse**_____ reaction will increase.

d) Sooner or later, the forward rate and the reverse rate will again become __**equal**__.

At this point a new _____**equilibrium**_____ is established.

e) In the new equilibrium, [A] and [B] will be _____**low**er than they were before the temperature is increased.

In the new equilibrium, [C] will be _____**high**er than it was before.

f) In this example, we say that the equilibrium has shifted to the _____**right**_____

5. Given the equilibrium: $B_{(g)} + C_{(g)} \rightleftarrows D_{(g)} + E_{(g)} + \text{heat}$

   a) Some B is added to the mixture at equilibrium. The rate of the _____**forward**_____ reaction will increase due to the increase in the [B].

   b) While this is happening, the [D] and [E] will gradually _____**in**crease.

   c) The ____**in**crease in the [D] and [E] will cause the rate of the_____**reverse**_____ reaction to increase.

   d) When the rates of the forward and reverse reactions are equal, we have a new

   _____**equilibrium**_____

   e) Due to the addition of B, the equilibrium will shift to the _____**right**____

   [B] and [C] will _____**de**crease and [D] and [E] will _____**in**crease

6. Given the equilibrium: $B_{(g)} + C_{(g)} \rightleftarrows D_{(g)} + E_{(g)} + \text{heat}$

   a) Some D is added to the mixture at equilibrium. The rate of the _____**reverse**_____ reaction will increase due to the increase in the [D].

   b) While this is happening, the [B] and [C] will gradually _____**in**crease.

   c) The _**in**crease in the [B] and [C] will cause the rate of the ____**forward**__ reaction to increase.

   d) When the rates of the forward and reverse reactions are equal, we have a new

   _____**equilibrium**_____

   e) Due to the addition of D, the equilibrium will shift to the _____**left**_____

   [B] and [C] will ____**in**crease and [D] and [E] will _____**de**crease.

7. Given the equilibrium: $2A_{(g)} + B_{(g)} \rightleftarrows 2C_{(g)}$

   a) If the total pressure on the system is increased, the _____**forward**_____ reaction will speed up the most. **to compensate for the increased pressure.**

   b) While this is happening, the [C] will _____**in**crease.

c) This _____**in**crease in [C] will cause the _____**reverse**_____ reaction to speed up.

d) When the new equilibrium is reached, the [A] and [B] will be _____**low**er than before and the [C] will be _____**higher**_____ than before.

e) We say that the increase in total pressure has caused the equilibrium to shift to the **_right (the side with the least moles of gas.)_____**.

8. Given the equilibrium: $2A_{(g)} + B_{(g)} \rightleftarrows 2C_{(g)}$

a) If the total pressure on the system is decreased, the _____**reverse**_____ reaction will be the faster one.

b) While this is happening, the [A] and the [B] will _____**in**crease.

c) This _____**in**crease in [A] and the [B] will cause the _____**forward**____reaction to speed up.

d) When the new equilibrium is reached, the [A] and [B] will be _____**high**er than before and the [C] will be _____**lower**_____ than before.

e) We say that the decrease in total pressure has caused the equilibrium to shift to the _____**left**_____.

9. Given the equilibrium : $NO_{(g)} + CO_{2(g)} \rightleftarrows NO_{2(g)} + CO_{(g)}$

a) Will an increase in total pressure have an affect on the equilibrium? _____**no**_____

b) Explain your answer to question (a) **__the same number of moles on both sides. It could <u>not</u> compensate for the increased pressure by shifting either way.__**

10. Given the equilibrium: $2A_{(g)} + B_{(g)} \rightleftarrows 2C_{(g)}$

a) If the total ***volume*** of the system is decreased, the _____**pressure**_____ will increase, and the _____**forward**_____ reaction will be the faster one.

b) While this is happening, the [C] will _____**in**crease.

c) This ___**in**crease in [C] will cause the ____**reverse**__ reaction to speed up.

d) When the new equilibrium is reached, the [A] and [B] will be _____**low**er than before and the [C] will be _____**higher**_____ than before.

e) We say that the decrease in total ***volume*** has caused the equilibrium to shift to the _____**right**_____.

11. Given the equilibrium: $2A_{(g)} + B_{(g)} \rightleftarrows 2C_{(g)}$ + heat

a) How will this equilibrium be affected if a ***catalyst*** is added to the mixture? **it won't**

b) Explain your answer to "a" in terms of forward and reverse reaction rates

a catalyst speeds up the forward rate and the reverse rate by the same amount, so the rates are still equal and the equilibrium is not affected.

A catalyst will cause a reaction which is not at equilibrium to reach equilibriumfaster.

You have now finished Tutorial 3. If you have any questions, check with the teacher before going on.