

SI Chemistry - Full Discipline Demo

Equilibrium and Le Châtelier's Principle

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Chemistry - Full Discipline Demo
Course	SI Chemistry - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term with the best description.

Chemical equilibrium	State that occurs when the concentrations of all reactants and products are constant.	1
Chemical system	Is used to determine if the reactions favor the products or the reactants	2
Equilibrium constant	States that when a change is imposed on chemical system will shift in the direction that reduces the total effect of change.	3
Le Châtelier's principle	The reactants, products, and energy associated with a chemical reaction.	4

Correct answers:

- 1 Chemical equilibrium 2 Equilibrium constant 3 Le Châtelier's principle
4 Chemical system

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Identify the variables that must remain constant to maintain an equilibrium constant and equilibrium position.

	Variables that Must Remain Constant	Variables that Do Not Need to Remain Constant
⌘ Color ⌘ Concentration ⌘ Pressure ⌘ Size ⌘ Temperature	1	2

Correct answers:

1 Concentration Pressure Temperature 2 Size Color

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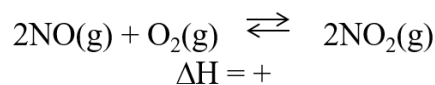
Review the chemical equation below and identify the result that a change imposed on the system would have.

⚡ Favors endothermic forward reaction, shifts right

⚡ Favors forward reaction (fewer mols of gas), shifts right

⚡ Favors forward reaction, shifts right

⚡ Favors reverse reaction, shifts left



Change Imposed	Result
Adding nitrogen dioxide	1
Adding nitrogen monoxide	2
Decreasing the volume	3
Increasing the temperature	4

Correct answers:

- 1 Favors reverse reaction, shifts left 2 Favors forward reaction, shifts right
- 3 Favors forward reaction (fewer mols of gas), shifts right
- 4 Favors endothermic forward reaction, shifts right

Exploration

The state of chemical equilibrium occurs when the concentrations of ____.

- ☒ all reactants and all products remain constant ✓
- ☐ products is less than the concentration of reactants
- ☐ reactants is greater than the concentrations of products

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Chemical equilibrium occurs when free energy exists in the ____.

☐ highest possible value

☒ lowest possible value

✓

Generally, if the value of K is greater than 1, we say that the reaction favors the ____ and if the value of K is less than 1, the reaction favors the ____.

☐ products; reactants

☐ reactants; products

☐ Neither reactants nor products are favored.

✓

The equilibrium position of a reaction requires the variables of ____, ____, and ____ to remain constant.

☐ color, pressure, concentration

☐ concentration, time, temperature

☒ pressure, temperature, concentration

☐ time, color, temperature

✓

Le Châtelier's principle includes the idea that a change imposed on a chemical system will cause the system to find a new chemical equilibrium where free energy exists at the highest possible value.

☐ True

☒ False

✓

If the ratio of products over reactants has increased, the chemical system will shift to the left, meaning that ____.

☐ Q is equal to K

☒ Q is greater than K

☐ Q is less than K

✓

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The reaction quotient is calculated using initial concentrations.

☐ True



☐ False

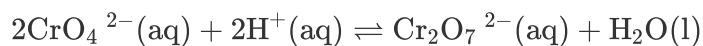
Exercise 1

Use your results to determine if the forward reaction in the potassium chromate/HCl reaction is endothermic or exothermic. Explain your answer, using the table below to help construct your thoughts.

Type of Change	Chemical System Shift (Right shifts toward product. Left Shifts toward reactant.)
Increase concentration of reactant OR Decrease concentration of product	Right
Decrease concentration of reactant OR Increase concentration of product	Left
Increase temperature of an exothermic reaction	Left
Increase temperature of an endothermic reaction	Right
Decrease temperature of an exothermic reaction	Right
Decrease temperature of an endothermic reaction	Left
Decrease pressure (gases only)	Toward the side with more gas molecules
Increase pressure (gases only)	Toward the side with less gas molecules

The data collected and observations made in Data Table 2 suggest that the chromate/HCl reaction is endothermic. As heat is added to the reaction the chemical system shifts to the right (orange) and as heat is removed from the reaction (placing it in cold water bath) the chemical system shifts to the left (forming yellow chromate).

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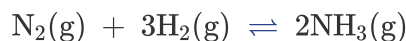
Write the equation for the equilibrium constant (K) of the reaction studied in this exercise.

$$K = ([\text{Cr}_2\text{O}_7^{2-}]) / [\text{CrO}_4^{2-}]^2 [\text{H}^+]^2$$

Consider the chemical reaction: $\text{N}_2 + 3\text{H}_2$ yields 2NH_3 . If the concentration of the reactant H_2 was increased from $1.0 \times 10^{-2} \text{ M}$ to $2.5 \times 10^{-1} \text{ M}$, calculate the reaction quotient (Q) and determine which way the chemical system would shift by comparing the value of Q to K.

Use this information to answer Questions 3, 4, and 5:

The equilibrium constant (K) of the reaction below is $K = 6.0 \times 10^{-2}$, with initial concentrations as follows:
 $[\text{H}_2] = 1.0 \times 10^{-2} \text{ M}$, $[\text{N}_2] = 4.0 \text{ M}$, and $[\text{NH}_3] = 1.0 \times 10^{-4} \text{ M}$.



$$Q = ([1.0 \times 10^{-4} \text{ mol/L}]_0^2) / ([4.0 \text{ mol/L}]_0 [2.5 \times 10^{-1} \text{ mol/L}]_0^3)$$

$$Q = 1.6 \times 10^{-7}$$

As Q is much smaller than K, the ratio of products over reactants has decreased and the chemical system will shift to the right.

If the concentration of the reactant H_2 was decreased from $1.0 \times 10^{-2} \text{ M}$ to $2.7 \times 10^{-4} \text{ M}$, calculate the reaction quotient (Q) and determine which way the chemical system would shift by comparing the value of Q to K.

$$Q = ([1.0 \times 10^{-4} \text{ mol/L}]_0^2) / ([4.0 \text{ mol/L}]_0 [2.7 \times 10^{-4} \text{ mol/L}]_0^3)$$

$$Q = 1.27 \times 10^2$$

As Q is much larger than K, the ratio of products over reactants has increased and the chemical system will shift to the left.

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If the concentration of the product NH_3 was increased from $1.0 \times 10^{-4} \text{ M}$ to $5.6 \times 10^{-3} \text{ M}$, calculate the reaction quotient (Q) and determine which way the chemical system would shift by comparing the value of Q to K.

$$Q = ([5.6 \times 10^{-3} \text{ mol/L}]_0^2) / ([4.0 \text{ mol/L}]_0 [1.0 \times 10^{-2} \text{ mol/L}]_0^3)$$

$$Q = 7.84$$

As Q is much larger than K, the ratio of products over reactants has increased and the chemical system will shift to the left.

Data Table 1: Chromate and Dichromate
(SAMPLE ANSWER BELOW)

Color of Chromate	Color of Dichromate	Number of Drops of NaOH to Shift Equilibrium Position
Yellow	Orange	10

Data Table 2: Endothermic & Exothermic Equilibrium Position
(SAMPLE ANSWER BELOW)

	Reaction at Room Temperature	Reaction in Cold Water Bath	Reaction in Hot Water Bath
Color	Orange	Orange and Yellow with white precipitate	Orange
Chemical System Shift (Left or Right)		Left	Right
Explanation of why chemical system is shifted to the left or to the right		As the color includes yellow, it suggests that there is chromate present in the reaction and the chemical system has shifted to the left.	The color is orange, indicative of dichromate, suggesting that the addition of heat has shifted the chemical system to the right.

Exercise 2

From your observations and data collected in Data Table 3, describe the direction of the equilibrium position shift upon addition of NaOH.

From the observations and data collected in Data Table 3, it appears that the addition of NaOH of product (dark blue, ferric ferrocyanide). Thus the addition of the NaOH

shifts the chemical system to the left.

Data Table 3: Ferric Ferrocyanide
(SAMPLE ANSWER BELOW)

Color of Potassium Ferrocyanide	Color of Ferric Ferrocyanide	Number of Drops of NaOH to Shift Equilibrium Position	Observations when Equilibrium is Shifted
Pale Yellow	Dark Blue	25	The dark blue ferric ferrocyanide is gone and dark orange flecks appear. the overall color is pale yellow.

Competency Review

A chemical system is in equilibrium when free energy exists at ____.

- ☐ the highest possible value
- ☒ the lowest possible value ✓
- ☐ equal proportions

During a chemical reaction, if the concentration of reactants and products doesn't change, the reaction has likely stopped.

- ☐ True
- ☒ False ✓

To predict which direction a reaction will move to reach equilibrium, investigate the ____.

- ☐ equilibrium constant
- ☐ equilibrium position
- ☒ reaction quotient ✓

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If Q is less than K , the ratio of products over reactants has ____, and the chemical system will shift to the ____.

- ☐ increased; right
- ☐ increased; left
- ☐ decreased; left
- ☒ decreased; right

✓

The equilibrium position of a reaction requires certain environmental variables to remain constant. These variables are ____.

- ☒ pressure, temperature, and concentration
- ☐ temperature and concentration
- ☐ pressure, temperature, and time
- ☐ None of the above.

✓

According to Le Châtelier's Principle, an increase in the concentration of product will shift the chemical system to ____.

- ☐ the right
- ☒ the left
- ☐ neither the right nor left

✓

Le Châtelier's Principle states that ____.

- ☒ when a change (pressure, temperature, concentration) is imposed on a chemical system (chemical reaction), the chemical system will shift in the direction that reduces the total effect of change, finding a new chemical equilibrium where free energy exists at the lowest possible value
- ☐ when a change (pressure, temperature, time) is imposed on a chemical system (chemical reaction), the chemical system will shift in the direction that reduces the total effect of change, finding a new chemical equilibrium where free energy exists at the highest possible value
- ☐ when a change (pressure, temperature, concentration) is imposed on a chemical system (chemical reaction), the chemical system will shift in the direction that increases the total effect of change, finding a new chemical equilibrium where free energy exists at the lowest possible value

✓

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The chemical reaction of chromate and dichromate is indicated by a ____.

- ☐ change in the state of matter
- ☒ color change
- ☐ temperature change

✓

Generally, if the value of K is greater than 1, we say that the reaction favors the products. This makes sense mathematically because the ____ go in the numerator of the equation.

- ☒ products
- ☐ reactants
- ☐ concentrations

✓

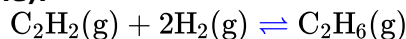
Consider the reaction $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$. If the concentration of the product NH_3 decreased, which way would the chemical system shift?

- ☐ Left
- ☒ Right
- ☐ It would not shift.

✓

Extension Questions

Assume that you are in charge of a designing a process to produce acetylene (C_2H_2) from ethane (C_2H_6), which is the reverse of the reaction shown above. Use your knowledge of equilibrium to suggest a set of conditions that would maximize the concentration of acetylene (C_2H_2) at equilibrium. Assume that it is possible to add or remove any of the three components of this system and to change the general conditions of the reaction (pressure, temperature, volume).



$$\Delta H = -$$

Use your knowledge of equilibrium to suggest a set of conditions that would maximize the concentration of acetylene (C_2H_2) at equilibrium.

(SAMPLE ANSWER BELOW)

- Add ethane during the reaction to keep its concentration high
- Remove hydrogen during the reaction to keep its concentration low
- Run the reaction at a high temperature
- Run the reaction at low pressure

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Typesetting math: 100%