

Chapter 2

Chemical Equilibrium



Revision Paper



مكتبة الفكر

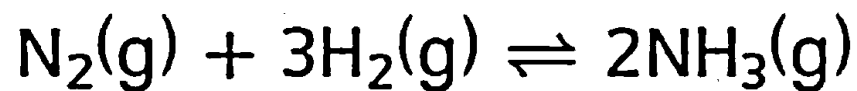
A State of Dynamic Balance

Chapter 2
Lesson 1 – Revision Paper

Example 1

01

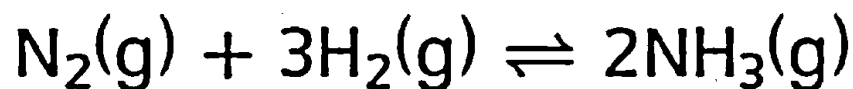
Write the equilibrium constant expression for the following reaction.



Example 1

01

Write the equilibrium constant expression for the following reaction.



Form a ratio of product concentration to reactant concentrations.

$$K_{\text{eq}} = \frac{[\text{C}]^c}{[\text{A}]^a [\text{B}]^b}$$

State the general form of the equilibrium constant expression.

$$K_{\text{eq}} = \frac{[\text{NH}_3]^c}{[\text{N}_2]^a [\text{H}_2]^b}$$

Substitute $\text{A} = \text{N}_2$, $\text{B} = \text{H}_2$, and $\text{C} = \text{NH}_3$.

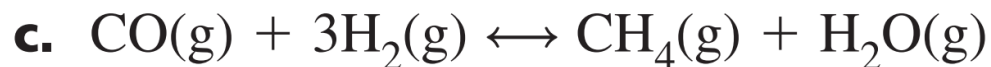
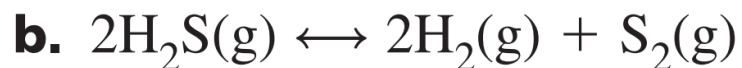
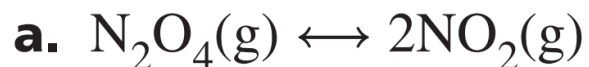
$$K_{\text{eq}} = \frac{[\text{NH}_3]^2}{[\text{N}_2] [\text{H}_2]^3}$$

Substitute $a = 1$, $b = 3$, and $c = 2$.

APPLICATIONS 1

02

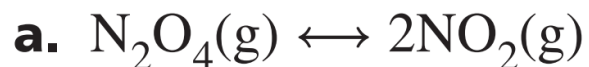
Write equilibrium constant expressions for these equilibria.



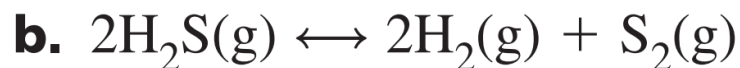
APPLICATIONS 1

02

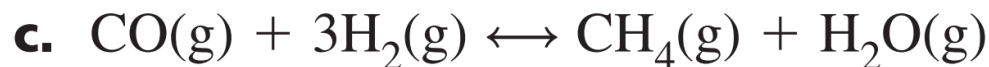
Write equilibrium constant expressions for these equilibria.



$$K_{\text{eq}} = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]}$$



$$K_{\text{eq}} = \frac{[\text{H}_2]^2[\text{S}_2]}{[\text{H}_2\text{S}]^2}$$

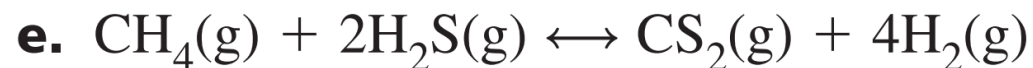
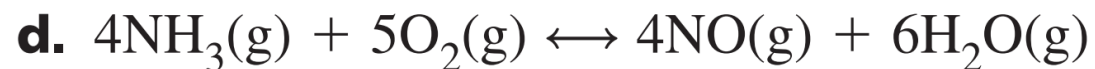


$$K_{\text{eq}} = \frac{[\text{CH}_4][\text{H}_2\text{O}]}{[\text{CO}][\text{H}_2]^3}$$

APPLICATIONS 1

03

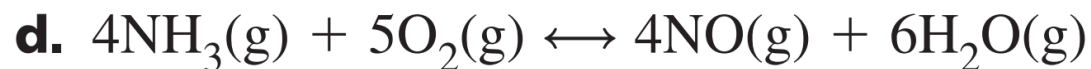
Write equilibrium constant expressions for these equilibria.



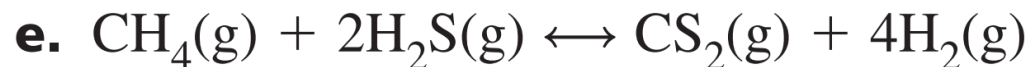
APPLICATIONS 1

03

Write equilibrium constant expressions for these equilibria.



$$K_{\text{eq}} = \frac{[\text{NO}]^4[\text{H}_2\text{O}]^6}{[\text{NH}_3]^4[\text{O}_2]^5}$$



$$K_{\text{eq}} = \frac{[\text{CS}_2][\text{H}_2]^4}{[\text{CH}_4][\text{H}_2\text{S}]^2}$$

APPLICATIONS 2

04

Write the chemical equation that has the equilibrium constant expression

$$K_{\text{eq}} = \frac{[\text{CO}]^2[\text{O}_2]}{[\text{CO}_2]^2}$$

APPLICATIONS 2

04

Write the chemical equation that has the equilibrium constant expression

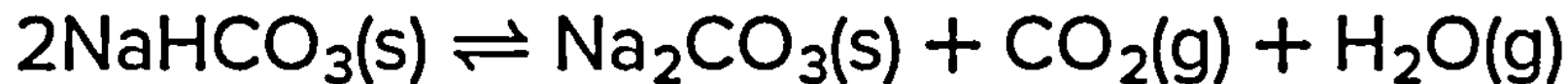
$$K_{\text{eq}} = \frac{[\text{CO}]^2[\text{O}_2]}{[\text{CO}_2]^2}$$



Example 2

05

Write the equilibrium constant expression for the decomposition of baking soda (sodium hydrogen carbonate).



Example 2

05

Write the equilibrium constant expression for the decomposition of baking soda (sodium hydrogen carbonate).



Form a ratio of product concentrations to reactant concentrations.

$$K_{\text{eq}} = \frac{[\text{C}]^c [\text{D}]^d [\text{E}]^e}{[\text{A}]^a [\text{B}]^b}$$

State the general form of the equilibrium constant expression.

$$K_{\text{eq}} = \frac{[\text{Na}_2\text{CO}_3]^c [\text{CO}_2]^d [\text{H}_2\text{O}]^e}{[\text{NaHCO}_3]^a}$$

Substitute $\text{A} = \text{NaHCO}_3$, $\text{C} = \text{Na}_2\text{CO}_3$, $\text{D} = \text{CO}_2$, and $\text{E} = \text{H}_2\text{O}$.

$$K_{\text{eq}} = \frac{[\text{Na}_2\text{CO}_3]^1 [\text{CO}_2]^1 [\text{H}_2\text{O}]^1}{[\text{NaHCO}_3]^2}$$

Substitute $a = 2$, $c = 1$, $d = 1$, and $e = 1$.

$$K_{\text{eq}} = [\text{CO}_2][\text{H}_2\text{O}]$$

Omit terms involving solid substances.

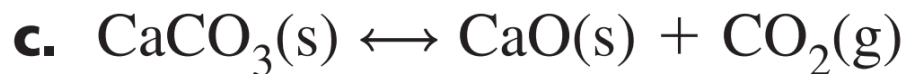
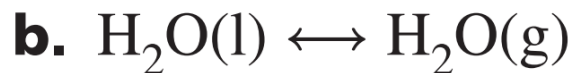
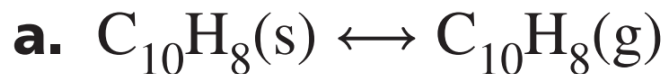
Example 2 – Page 57

2.1 A State of Dynamic Balance

APPLICATIONS 3

o6

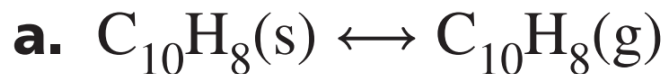
Write equilibrium constant expressions for these heterogeneous equilibria.



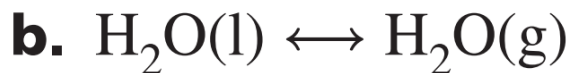
APPLICATIONS 3

o6

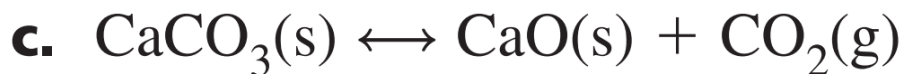
Write equilibrium constant expressions for these heterogeneous equilibria.



$$K_{\text{eq}} = [\text{C}_{10}\text{H}_8(\text{g})]$$



$$K_{\text{eq}} = [\text{H}_2\text{O}(\text{g})]$$

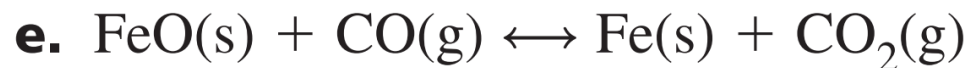
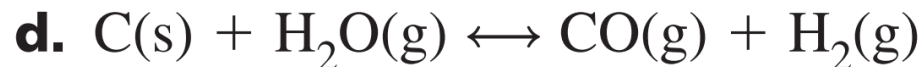


$$K_{\text{eq}} = [\text{CO}_2(\text{g})]$$

APPLICATIONS 3

07

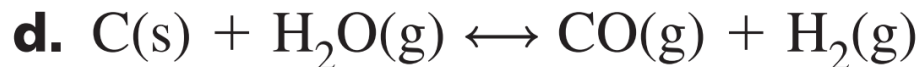
Write equilibrium constant expressions for these heterogeneous equilibria.



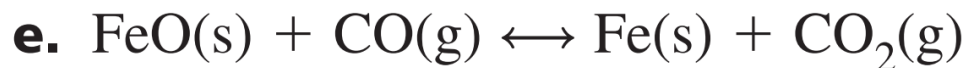
APPLICATIONS 3

07

Write equilibrium constant expressions for these heterogeneous equilibria.



$$K_{\text{eq}} = \frac{[\text{CO(g)}][\text{H}_2\text{(g)}]}{[\text{H}_2\text{O(g)}]}$$



$$K_{\text{eq}} = \frac{[\text{CO}_2\text{(g)}]}{[\text{CO(g)}]}$$

APPLICATIONS 4

o8

Solid iron reacts with chlorine gas to form solid **iron(III) chloride**. Write the balanced equation and the equilibrium constant expression for the reaction.

APPLICATIONS 4

o8

Solid iron reacts with chlorine gas to form solid **iron(III) chloride**. Write the balanced equation and the equilibrium constant expression for the reaction.



$$K_{\text{eq}} = \frac{1}{[\text{Cl}_2]^3}$$

Example 3

Calculate the value of K_{eq} for the equilibrium expression $K_{eq} = \frac{[NH_3]^2}{[N_2][H_2]^3}$ given concentration data at one equilibrium position:

$[NH_3] = 0.933 \text{ mol/L}$, $[N_2] = 0.533 \text{ mol/L}$, $[H_2] = 1.600 \text{ mol/L}$.

Example 3

Calculate the value of K_{eq} for the equilibrium expression $K_{eq} = \frac{[NH_3]^2}{[N_2][H_2]^3}$ given concentration data at one equilibrium position:

$$[NH_3] = 0.933 \text{ mol/L}, [N_2] = 0.533 \text{ mol/L}, [H_2] = 1.600 \text{ mol/L}.$$

$$K_{eq} = \frac{[0.933]^2}{[0.533][1.600]^3} = 0.399$$

Substitute $[NH_3] = 0.933 \text{ mol/L}$,
 $[N_2] = 0.533 \text{ mol/L}$, and $[H_2] = 1.600 \text{ mol/L}$.

APPLICATIONS 5

10

Calculate K_{eq} for the equilibrium $N_2O_4(g) \leftrightarrow 2NO_2(g)$ using the data $[N_2O_4] = 0.0185 \text{ mol/L}$ and $[NO_2] = 0.0627 \text{ mol/L}$.

APPLICATIONS 5

10

Calculate K_{eq} for the equilibrium $N_2O_4(g) \leftrightarrow 2NO_2(g)$ using the data $[N_2O_4] = 0.0185 \text{ mol/L}$ and $[NO_2] = 0.0627 \text{ mol/L}$.

$$K_{eq} = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(0.0627)^2}{(0.0185)} = 0.213$$

APPLICATIONS 6

11

Calculate K_{eq} for the equilibrium $\text{CO(g)} + 3\text{H}_2\text{(g)} \leftrightarrow \text{CH}_4\text{(g)} + \text{H}_2\text{O(g)}$ using the data $[\text{CO}] = 0.0613 \text{ mol/L}$, $[\text{H}_2] = 0.1839 \text{ mol/L}$, $[\text{CH}_4] = 0.0387 \text{ mol/L}$, and $[\text{H}_2\text{O}] = 0.0387 \text{ mol/L}$.

APPLICATIONS 6

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Calculate K_{eq} for the equilibrium $\text{CO(g)} + 3\text{H}_2\text{(g)} \leftrightarrow \text{CH}_4\text{(g)} + \text{H}_2\text{O(g)}$ using the data $[\text{CO}] = 0.0613 \text{ mol/L}$, $[\text{H}_2] = 0.1839 \text{ mol/L}$, $[\text{CH}_4] = 0.0387 \text{ mol/L}$, and $[\text{H}_2\text{O}] = 0.0387 \text{ mol/L}$.

$$K_{eq} = \frac{[\text{CH}_4][\text{H}_2\text{O}]}{[\text{CO}][\text{H}_2]^3} = \frac{(0.0387)(0.0387)}{(0.0613)(0.1839)^3} = 3.93$$

APPLICATIONS 7

12

The reaction $\text{COCl}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{Cl}_2(\text{g})$ reaches equilibrium at 900 K. K_{eq} is 8.2×10^{-2} . If the equilibrium concentrations of CO and Cl_2 are 0.150M , what is the equilibrium concentration of COCl_2 ?

APPLICATIONS 7

12

The reaction $\text{COCl}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{Cl}_2(\text{g})$ reaches equilibrium at 900 K. K_{eq} is 8.2×10^{-2} . If the equilibrium concentrations of CO and Cl_2 are 0.150M , what is the equilibrium concentration of COCl_2 ?

$$\frac{[\text{CO}][\text{Cl}_2]}{[\text{COCl}_2]} = 8.2 \times 10^{-2}$$

$$\frac{(0.150)(0.150)}{[\text{COCl}_2]} = 8.2 \times 10^{-2}$$

$$[\text{COCl}_2] = \frac{(0.150)(0.150)}{(8.2 \times 10^{-2})} = 0.27\text{M}$$

Review 8

13

How the size of the equilibrium constant relates to the amount of product formed at equilibrium?

- a) Products are favored when **K_{eq}** is less than 1
- b) Products are favored when **K_{eq}** is more than 1
- c) Products are less when **K_{eq}** is more than 1
- d) **K_{eq}** does not relate to the amount of products formed

Review 8

13

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Review 9

14

Compare **homogeneous** and **heterogeneous** equilibria.

Review 9

14

Compare **homogeneous** and **heterogeneous** equilibria.

In a **homogenous** equilibrium all the reactants and products are in the **same** physical state.

In a **heterogeneous** equilibrium reactants and products are in **different** physical states.

Review 10

15

Which is not a characteristic for a reaction mixture that is in a state of chemical equilibrium?

- a) no reactant or product can enter or leave the system.
- b) temperature remain constant.
- c) equilibrium is dynamic.
- d) it has limited number of equilibrium positions.

Review 10

15

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Review 11

16

Determine the value of **K_{eq}** at **400 K** for this equation:



if $[\text{PCl}_5] = 0.135 \text{ mol/L}$, $[\text{PCl}_3] = 0.550 \text{ mol/L}$, and $[\text{Cl}_2] = 0.550 \text{ mol/L}$

Review 11

16

Determine the value of **K_{eq}** at **400 K** for this equation:



if $[\text{PCl}_5] = 0.135 \text{ mol/L}$, $[\text{PCl}_3] = 0.550 \text{ mol/L}$, and $[\text{Cl}_2] = 0.550 \text{ mol/L}$

$$K_{\text{eq}} = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]}$$

$$K_{\text{eq}} = \frac{(0.550)(0.550)}{(0.135)} = 2.24$$

Review 12

17

K_{eq} and Temperature		
263 K	273 K	373 K
0.0250	0.500	4.500

The table shows the value of the equilibrium constant for a reaction at three different temperatures. At which temperature is the concentration of the products the greatest?

- a) at 273 K
- b) at 263 K
- c) at 373 K
- d) concentration is not affected by temperature

Review 12

17

K_{eq} and Temperature		
263 K	273 K	373 K
0.0250	0.500	4.500

The table shows the value of the equilibrium constant for a reaction at three different temperatures. At which temperature is the concentration of the products the greatest?

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Mastering Concepts 34

18

Given the fact that the concentrations of reactants and products are not changing, why is the word dynamic used to describe chemical equilibrium?

Mastering Concepts 34

18

Given the fact that the concentrations of reactants and products are not changing, why is the word dynamic used to describe chemical equilibrium?

Reactants are continuing to form products and products are continuing to form reactants.

Mastering Concepts 36

19

Does the following equation represent a **homogeneous** equilibrium or a **heterogeneous** equilibrium? Explain your answer. $\text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{H}_2\text{O}(\text{l})$

Mastering Concepts 36

19

Does the following equation represent a **homogeneous** equilibrium or a **heterogeneous** equilibrium? Explain your answer. $\text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{H}_2\text{O}(\text{l})$

The equation represents a **heterogeneous** equilibrium because the reactants and products are present in more than one physical state.

Mastering Concepts 37

20

_____ is a particular set of equilibrium concentrations.

- a) chemical equilibrium
- b) equilibrium position
- c) equilibrium constant
- d) reversible reaction

Mastering Concepts 37

20

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- c) equilibrium constant
- d) reversible reaction

Mastering Concepts 38

21

_____ is the ratio of product concentrations to reactant concentrations, with each concentration raised to the power corresponding to its coefficient in the balanced equation.

- a) law of chemical equilibrium
- b) chemical equilibrium
- c) equilibrium constant
- d) reversible reaction

Mastering Concepts 38

21

_____ is the ratio of product concentrations to reactant concentrations, with each concentration raised to the power corresponding to its coefficient in the balanced equation.

- a) law of chemical equilibrium
- b) chemical equilibrium
- c) **equilibrium constant**
- d) reversible reaction

Mastering Concepts 39

22

The concentrations of _____ and _____ are omitted from the equilibrium constant expression.

- a) pure liquids – gases
- b) pure gases – pure liquids
- c) pure solids – pure gases
- d) pure solids – pure liquids

Mastering Concepts 39

22

The concentrations of _____ and _____ are omitted from the equilibrium constant expression.

- a) pure liquids – gases
- b) pure gases – pure liquids
- c) pure solids – pure gases
- d) **pure solids – pure liquids**

Mastering Concepts 41

23

What happens to **K_{eq}** for an equilibrium system if the equation for the reaction is rewritten in reverse?

- a) The new value of K_{eq} is the square root of the original value.
- b) The new value of K_{eq} is the negative of the original value.
- c) The new value of K_{eq} is the reciprocal of the original value.
- d) The new value of K_{eq} is the same as the original value.

Mastering Concepts 41

23

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- d) The new value of K_{eq} is the same as the original value.

Mastering Concepts 42

24

An equilibrium system contain small and unchanging amounts of products and large amounts of reactants? What can you say about the relative size of **K_{eq}** for this equilibrium?

- a) K_{eq} must have a large numerical value.
- b) K_{eq} must have a small numerical value.
- c) K_{eq} can be a small or large numerical value.
- d) K_{eq} have numerical value greater than 1.

Mastering Concepts 42

24

An equilibrium system contain small and unchanging amounts of products and large amounts of reactants? What can you say about the relative size of **K_{eq}** for this equilibrium?

- a) K_{eq} must have a large numerical value.
- b) K_{eq} must have a small numerical value.**
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- d) K_{eq} have numerical value greater than 1.

Mastering Problems 44

25

Write equilibrium constant expressions for these homogeneous equilibria.



Mastering Problems 44

25

Write equilibrium constant expressions for these homogeneous equilibria.



$$K_{\text{eq}} = \frac{[\text{N}_2]^3[\text{H}_2\text{O}]^4}{[\text{N}_2\text{H}_4]^2[\text{NO}_2]^2}$$

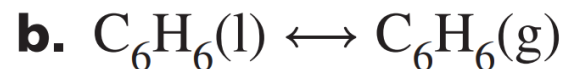
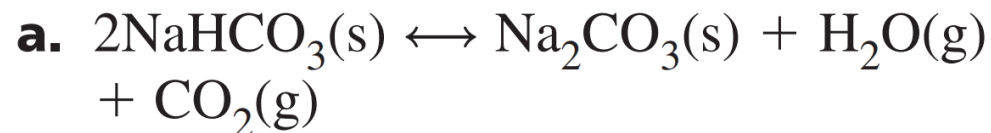


$$K_{\text{eq}} = \frac{[\text{NbCl}_3][\text{NbCl}_5]}{[\text{NbCl}_4]^2}$$

Mastering Problems 45

26

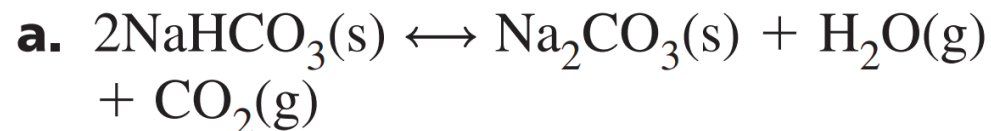
Write equilibrium constant expressions for these heterogeneous equilibria.



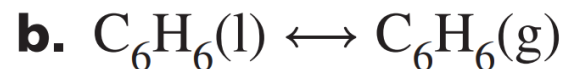
Mastering Problems 45

26

Write equilibrium constant expressions for these heterogeneous equilibria.



$$K_{\text{eq}} = [\text{H}_2\text{O}][\text{CO}_2]$$



$$K_{\text{eq}} = [\text{C}_6\text{H}_6(\text{g})]$$

Mastering Problems 46

27

Heating limestone ($\text{CaCO}_3(\text{s})$) forms quicklime ($\text{CaO}(\text{s})$) and **carbon dioxide gas**. Write the equilibrium constant expression for this reversible reaction.

Mastering Problems 46

27

Heating limestone ($\text{CaCO}_3(\text{s})$) forms quicklime ($\text{CaO}(\text{s})$) and **carbon dioxide gas**. Write the equilibrium constant expression for this reversible reaction.

$$K_{\text{eq}} = [\text{CO}_2]$$

Mastering Problems 47

28

Suppose you have a cube of pure manganese metal measuring **5.25 cm** on each side. You find that the mass of the cube is **1076.6 g**. What is the **molar concentration** of manganese in the cube?

(Mg molar mass = 54.94 g/mol)

Mastering Problems 47

28

Suppose you have a cube of pure manganese metal measuring **5.25 cm** on each side. You find that the mass of the cube is **1076.6 g**. What is the **molar concentration** of manganese in the cube?

(Mg molar mass = 54.94 g/mol)

$$\text{Volume of the cube} = (5.25 \text{ cm})^3 = 145 \text{ cm}^3$$

$$145 \text{ cm}^3 \times \frac{1 \text{ L}}{1000 \text{ cm}^3} = 0.145 \text{ L}$$

$$\text{Molar mass of manganese} = 54.94 \text{ g/mol}$$

$$1076.6 \text{ g Mn} \times \frac{1 \text{ mol Mn}}{54.94 \text{ g Mn}} = 19.596 \text{ mol Mn}$$

$$\frac{19.596 \text{ mol}}{0.145 \text{ L}} = 135 \text{ mol/L Mn}$$

Mastering Problems 48

29

Concentrations of A, B, and C		
A (mol/L)	B (mol/L)	C (mol/L)
0.500	0.621	0.700
0.250	0.525	0.250

K_{eq} is **3.63** for the reaction $A + 2B \rightleftharpoons C$. The table shows the concentrations of the reactants and product in two different reaction mixtures at the same temperature. Determine whether both reactions are at equilibrium.

Mastering Problems 48

29

Concentrations of A, B, and C		
A (mol/L)	B (mol/L)	C (mol/L)
0.500	0.621	0.700
0.250	0.525	0.250

K_{eq} is **3.63** for the reaction **A + 2B ⇌ C**. The table shows the concentrations of the reactants and product in two different reaction mixtures at the same temperature. Determine whether both reactions are at equilibrium.

Calculate **K_{eq}** using the two sets of data.

$$K_{eq} = \frac{[C]}{[A][B]^2} = 3.63$$

$$\frac{(0.700)}{(0.500)(0.621)^2} = 3.63$$

$$\frac{(0.250)}{(0.250)(0.525)^2} = 3.63$$

Both reactions are at equilibrium.

Mastering Problems 49

30

When steam is passed over iron filings, **solid iron(III) oxide** and gaseous **hydrogen** are produced in a reversible reaction . Write the balanced chemical equation and the equilibrium constant expression for the reaction, which yields iron(III) oxide and hydrogen gas.

Mastering Problems 49

30

When steam is passed over iron filings, **solid iron(III) oxide** and gaseous **hydrogen** are produced in a reversible reaction . Write the balanced chemical equation and the equilibrium constant expression for the reaction, which yields iron(III) oxide and hydrogen gas.



$$K_{\text{eq}} = \frac{[\text{H}_2]^3}{[\text{H}_2\text{O}]^3}$$

Multiple Choice Question 1

31

Which describes a system that has reached chemical equilibrium?

- a) No new product is formed by the forward reaction.
- b) The reverse reaction no longer occurs in the system.
- c) The concentration of reactants in the system is equal to the concentration of products.
- d) The rate at which the forward reaction occurs equals the rate of the reverse reaction.

Multiple Choice Question 1

31

Which describes a system that has reached chemical equilibrium?

- a) No new product is formed by the forward reaction.
- b) The reverse reaction no longer occurs in the system.
- c) The concentration of reactants in the system is equal to the concentration of products.
- d) The rate at which the forward reaction occurs equals the rate of the reverse reaction.**

Factors Affecting Chemical Equilibrium

Chapter 2
Lesson 2 – Revision Paper



Reading Check

01

How an equilibrium shifts if a reactant is **removed**?

- a) equilibrium shifts to left
- b) equilibrium shifts to right
- c) equilibrium does not change

Reading Check

01

How an equilibrium shifts if a reactant is **removed**?

- a) **equilibrium shifts to left**
- b) equilibrium shifts to right
- c) equilibrium does not change

Review 13

02

Explain how a system at equilibrium respond to a stress and list factors that can be stresses on an equilibrium system.

Review 13

02

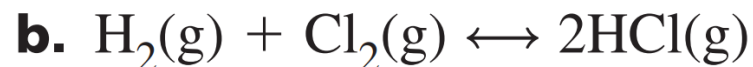
Explain how a system at equilibrium respond to a stress and list factors that can be stresses on an equilibrium system.

If possible, the equilibrium shifts in the direction that relieves the stress. Factors that can be stresses on an equilibrium system are changes in concentration, changes in pressure (volume), and changes in temperature.

Review 14

03

Explain how decreasing the volume of the reaction vessel affects each equilibrium.



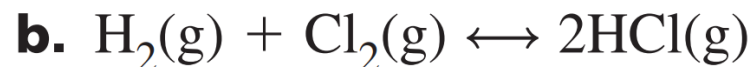
Review 14

03

Explain how decreasing the volume of the reaction vessel affects each equilibrium.



The equilibrium shifts to the right.



The stress has no effect on the equilibrium.

Review 15

04

Decide whether **higher** or **lower** temperatures will produce more **CH₃CHO** in the following equilibrium:



Review 15

04

Decide whether **higher** or **lower** temperatures will produce more **CH₃CHO** in the following equilibrium:



ΔH° is negative, so the reaction is exothermic, and heat is released as a product. Decreasing a product (lowering the temperature) causes the reaction to shift to the right and produce more products. Thus, more CH₃CHO will be produced at lower temperatures.

Review 16

05

Concentration Data in mol/L		
Reaction	[A]	[B]
1	0.0100	0.0200
2	0.0500	0.500

The table shows the concentrations of substances **A** and **B** in two reaction mixtures. **A** and **B** react according to the equation $2A \rightleftharpoons B$; $K_{eq} = 200$. Are the two mixtures at different equilibrium positions?

Review 16

05

Concentration Data in mol/L		
Reaction	[A]	[B]
1	0.0100	0.0200
2	0.0500	0.500

The table shows the concentrations of substances **A** and **B** in two reaction mixtures. **A** and **B** react according to the equation $2A \rightleftharpoons B$; $K_{eq} = 200$. Are the two mixtures at different equilibrium positions?

$$\text{Reaction 1: } \frac{[B]}{[A]^2} = \frac{(0.0200)}{(0.0100)^2} = 200$$

$$\text{Reaction 2: } \frac{[B]}{[A]^2} = \frac{(0.500)}{(0.0500)^2} = 200$$

The two mixtures are at the same equilibrium position.

Mastering Concepts 50

o6

A _____ on a reaction at equilibrium is any change in concentration, volume (pressure), or temperature which causes the equilibrium to shift.

- a) shift
- b) reverse
- c) catalyst
- d) stress

Mastering Concepts 50

o6

A _____ on a reaction at equilibrium is any change in concentration, volume (pressure), or temperature which causes the equilibrium to shift.

- a) shift
- b) reverse
- c) catalyst
- d) **stress**

_____ states that an equilibrium will shift in the direction that relieves a stress.

- a) law of chemical equilibrium
- b) Le Chatelier's principle
- c) Boyle's law
- d) Henri-Louis Le Chatelier

_____ states that an equilibrium will shift in the direction that relieves a stress.

- a) law of chemical equilibrium
- b) Le Chatelier's principle**
- c) Boyle's law
- d) Henri-Louis Le Chatelier

Mastering Concepts 52

o8

Why does removing a reactant cause an equilibrium shift to the left?

Mastering Concepts 52

o8

Why does removing a reactant cause an equilibrium shift to the left?

In order to restore the equilibrium ratio of reactants and products, the equilibrium shifts in the direction of the reactants.

Mastering Concepts 53

09

When an equilibrium shifts to the right, what happens to the concentrations of the reactants and the products?

- a) reactants decrease, products increase
- b) reactants increase, products increase
- c) reactants decrease, products decrease
- d) reactants increase, products decrease

Mastering Concepts 53

09

When an equilibrium shifts to the right, what happens to the concentrations of the reactants and the products?

- a) **reactants decrease, products increase**
- b) reactants increase, products increase
- c) reactants decrease, products decrease
- d) reactants increase, products decrease

Mastering Concepts 54

10

Use Le Châtelier's principle to explain how a shift in the equilibrium $\text{H}_2\text{CO}_3(\text{aq}) \rightleftharpoons \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$ causes a soft drink to go flat when its container is left open.

Mastering Concepts 54

10

Use Le Châtelier's principle to explain how a shift in the equilibrium $\text{H}_2\text{CO}_3(\text{aq}) \rightleftharpoons \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$ causes a soft drink to go flat when its container is left open.

Because $\text{CO}_2(\text{g})$ continually escapes from the open container, the equilibrium shifts to the right until $\text{H}_2\text{CO}_3(\text{aq})$ is depleted.

Mastering Concepts 55

11

How would each of the following changes affect the equilibrium position of the system used to produce **methanol** from carbon monoxide and hydrogen?



- a. adding CO to the system
- b. cooling the system
- c. adding a catalyst to the system
- d. removing CH₃OH from the system
- e. decreasing the volume of the system

Mastering Concepts 55

11

How would each of the following changes affect the equilibrium position of the system used to produce **methanol** from carbon monoxide and hydrogen?



a. adding CO to the system

The equilibrium shifts to the right.

b. cooling the system

The equilibrium shifts to the right.

c. adding a catalyst to the system

The equilibrium does not shift.

d. removing CH₃OH from the system

The equilibrium shifts to the right.

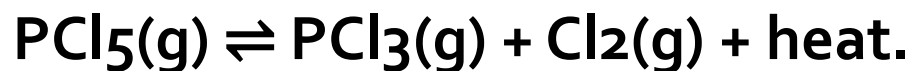
e. decreasing the volume of the system

The equilibrium shifts to the right.

Mastering Concepts 56

12

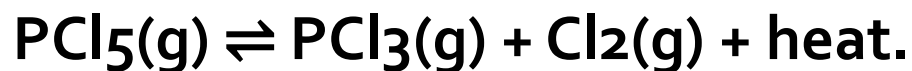
Explain how a temperature increase would affect the equilibrium represented by the following equation.



Mastering Concepts 56

12

Explain how a temperature increase would affect the equilibrium represented by the following equation.

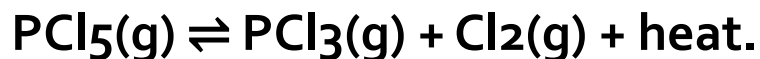


Heating would favor the reverse (endothermic) reaction by shifting the equilibrium the left.

Mastering Concepts 57

13

A liquid solvent for chlorine is poured into a flask in which the following reaction is at equilibrium:

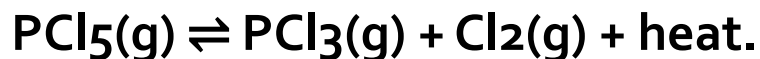


How is the equilibrium affected when some of the chlorine gas dissolves in the liquid?

Mastering Concepts 57

13

A liquid solvent for chlorine is poured into a flask in which the following reaction is at equilibrium:



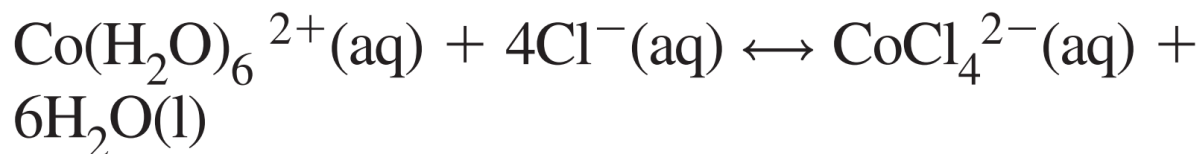
How is the equilibrium affected when some of the chlorine gas dissolves in the liquid?

The equilibrium shifts to the right to produce more chlorine.

Mastering Concepts 58

14

The figure shows the following **endothermic** reaction at equilibrium at room temperature.



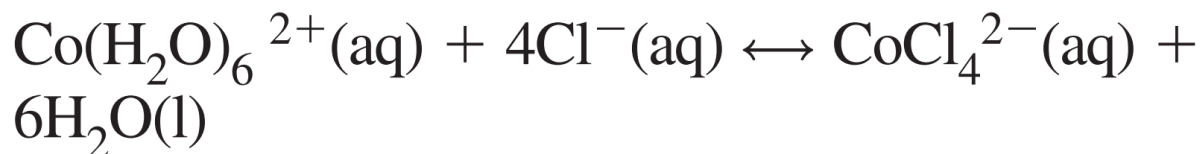
Given that $\text{Co}(\text{H}_2\text{O})_6^{2+}(\text{aq})$ is **pink** and $\text{CoCl}_4^{2-}(\text{aq})$ is **blue**, what visual change would you expect to see if the flask were placed in an ice bath? Explain.



Mastering Concepts 58

14

The figure shows the following **endothermic** reaction at equilibrium at room temperature.



Given that $\text{Co}(\text{H}_2\text{O})_6^{2+}(\text{aq})$ is **pink** and $\text{CoCl}_4^{2-}(\text{aq})$ is **blue**, what visual change would you expect to see if the flask were placed in an ice bath? Explain.



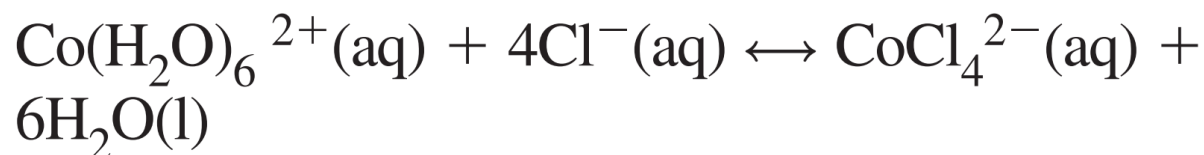
The solution would become more pink as the equilibrium shifted to the left, releasing heat.



Mastering Concepts 59

15

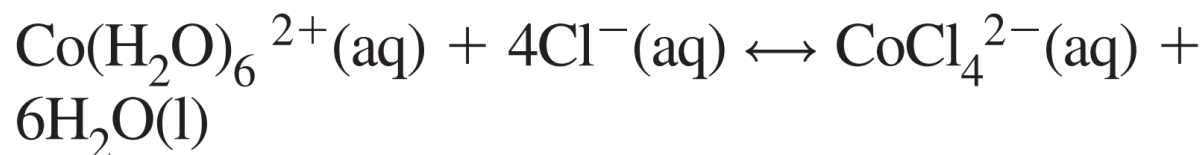
For the equilibrium described in Question 58, what visual change would you expect to see if **10 g** of solid **potassium chloride** were added and dissolved? Explain.



Mastering Concepts 59

15

For the equilibrium described in Question 58, what visual change would you expect to see if **10 g** of solid **potassium chloride** were added and dissolved? Explain.



The solution would become bluer. Dissolving potassium chloride would increase the concentration of chloride ions, causing the equilibrium to shift to the right.

Mastering Concepts 6o

16

Given two reaction at equilibrium:



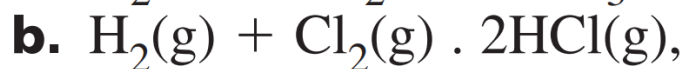
What happens to systems when the volume changes?

- a) equilibrium position changes for both reactions
- b) equilibrium position changes for (a), but not (b)
- c) equilibrium position changes for (b), but not (a)
- d) equilibrium position doesn't change for both reactions

Mastering Concepts 6o

16

Given two reaction at equilibrium:



What happens to systems when the volume changes?

- a) equilibrium position changes for both reactions
- b) equilibrium position changes for (a), but not (b)**
- c) equilibrium position changes for (b), but not (a)
- d) equilibrium position doesn't change for both reactions

Mastering Concepts 61

17

Would you expect the numerical value of **K_{eq}** for the following equilibrium to increase or decrease with increasing temperature? Explain your answer.



Mastering Concepts 61

17

Would you expect the numerical value of **K_{eq}** for the following equilibrium to increase or decrease with increasing temperature? Explain your answer.



The numerical value of **K_{eq}** would decrease as the equilibrium shifted to the left, absorbing heat.

Mastering Concepts 62

18

Explain how you would regulate the pressure to favor the products in the following equilibrium system.



Mastering Concepts 62

18

Explain how you would regulate the pressure to favor the products in the following equilibrium system.

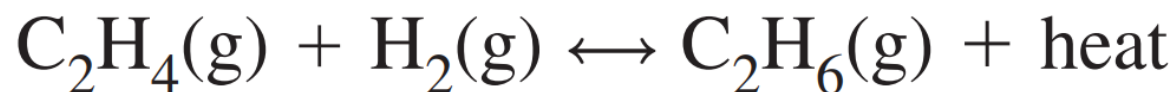


Decreasing the pressure would favor the formation of MgO and CO₂ because a gaseous product tends to restore the pressure.

Mastering Concepts 63

19

Ethylene (C_2H_4) reacts with hydrogen to form ethane (C_2H_6).



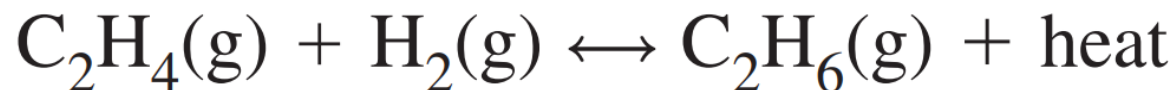
How would you regulate the temperature of this equilibrium in order to accomplish each of the following?

- a.** increase the yield of ethane
- b.** decrease the concentration of ethylene
- c.** increase the amount of hydrogen in the system

Mastering Concepts 63

19

Ethylene (C_2H_4) reacts with hydrogen to form ethane (C_2H_6).



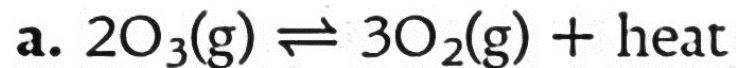
How would you regulate the temperature of this equilibrium in order to accomplish each of the following?

- a.** increase the yield of ethane
 lower the temperature
- b.** decrease the concentration of ethylene
 lower the temperature
- c.** increase the amount of hydrogen in the system
 raise the temperature

Mixed Review 76

20

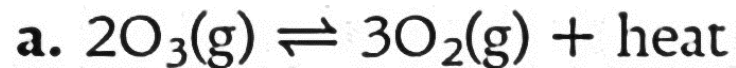
How would these equilibria be affected by decreasing the temperature?



Mixed Review 76

20

How would these equilibria be affected by decreasing the temperature?



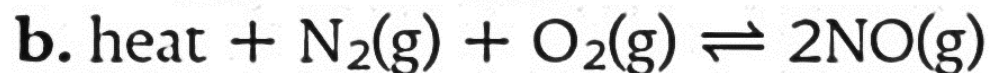
a. Reaction will shift right

b. Reaction will shift left

Mixed Review 77

21

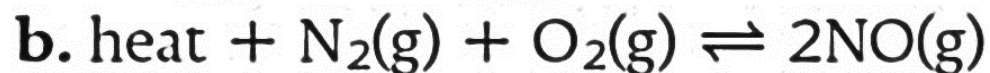
How would simultaneously increasing the temperature and volume of the system affect these equilibria?



Mixed Review 77

21

How would simultaneously increasing the temperature and volume of the system affect these equilibria?



- a. An increase in temperature will shift the reaction to left, and an increase of volume will shift the reaction to right
- b. An increase in temperature will shift the reaction to right, and an increase of volume will not affect the equilibrium.

Mixed Review 81

22

In the equilibrium system $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$, N_2O_4 is colorless and NO_2 is reddish-brown. Explain the different colors of the equilibrium system as shown in the image

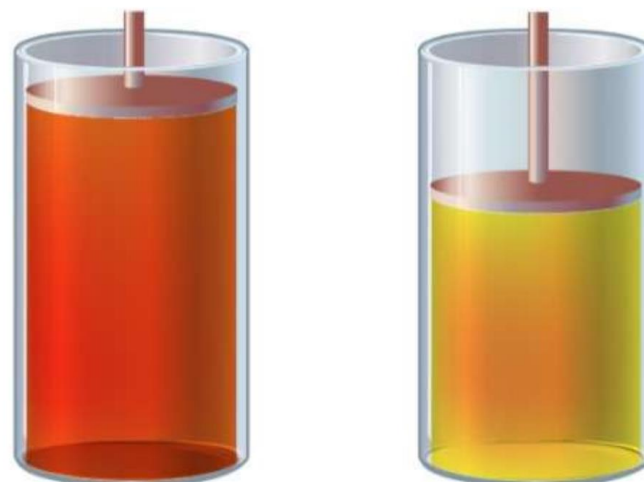


Mixed Review 81

22

In the equilibrium system $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$, N_2O_4 is colorless and NO_2 is reddish-brown. Explain the different colors of the equilibrium system as shown in the image

عند وجود ضغط عالٍ (حجم أقل) يتجه الاتزان نحو الطرف الذي يقلل من قيمة الضغط، ويتم ذلك بالاتجاه نحو اليسار مستهلكاً المزيد من NO_2 ذي اللون البني المحمر اللون، ومنتجاً المزيد من N_2O_4 العديم اللون.



Using Equilibrium Constants

Chapter 2
Lesson 3 – Revision Paper

Table 3 - Solubility Product Constants at 298 K

Table 3 Solubility Product Constants at 298 K					
Compound	K_{sp}	Compound	K_{sp}	Compound	K_{sp}
Carbonates		Halides		Hydroxides	
BaCO ₃	2.6×10^{-9}	CaF ₂	3.5×10^{-11}	Al(OH) ₃	4.6×10^{-33}
CaCO ₃	3.4×10^{-9}	PbBr ₂	6.6×10^{-6}	Ca(OH) ₂	5.0×10^{-6}
CuCO ₃	2.5×10^{-10}	PbCl ₂	1.7×10^{-5}	Cu(OH) ₂	2.2×10^{-20}
PbCO ₃	7.4×10^{-14}	PbF ₂	3.3×10^{-8}	Fe(OH) ₂	4.9×10^{-17}
MgCO ₃	6.8×10^{-6}	PbI ₂	9.8×10^{-9}	Fe(OH) ₃	2.8×10^{-39}
Ag ₂ CO ₃	8.5×10^{-12}	AgCl	1.8×10^{-10}	Mg(OH) ₂	5.6×10^{-12}
ZnCO ₃	1.5×10^{-10}	AgBr	5.4×10^{-13}	Zn(OH) ₂	3×10^{-17}
Hg ₂ CO ₃	3.6×10^{-17}	AgI	8.5×10^{-17}	Sulfates	
Chromates		Phosphates		BaSO ₄	1.1×10^{-10}
BaCrO ₄	1.2×10^{-10}	AlPO ₄	9.8×10^{-21}	CaSO ₄	4.9×10^{-5}
PbCrO ₄	2.3×10^{-13}	Ca ₃ (PO ₄) ₂	2.1×10^{-33}	PbSO ₄	2.5×10^{-8}
Ag ₂ CrO ₄	1.1×10^{-12}	Mg ₃ (PO ₄) ₂	1.0×10^{-24}	Ag ₂ SO ₄	1.2×10^{-5}

Table 3 – Page 69

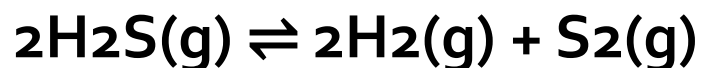
[20.a](#) – [20.b](#) – [20.c](#) – [22.a](#) – [22.b](#) – [22.c](#)

2.3 Using Equilibrium Constants

Example 4

01

At a temperature of **1405 K**, hydrogen sulfide, which has a foul odor resembling rotten eggs, decomposes to form hydrogen and diatomic sulfur. The equilibrium constant for the reaction is **2.27×10^{-3}** .

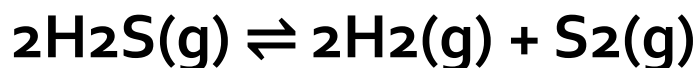


What is the concentration of hydrogen gas if **$[\text{S}_2] = 0.0540 \text{ mol/L}$** and **$[\text{H}_2\text{S}] = 0.184 \text{ mol/L}$** ?

Example 4

01

At a temperature of **1405 K**, hydrogen sulfide, which has a foul odor resembling rotten eggs, decomposes to form hydrogen and diatomic sulfur. The equilibrium constant for the reaction is **2.27×10^{-3}** .



What is the concentration of hydrogen gas if **$[\text{S}_2] = 0.0540 \text{ mol/L}$** and **$[\text{H}_2\text{S}] = 0.184 \text{ mol/L}$** ?

$$\frac{[\text{H}_2]^2[\text{S}_2]}{[\text{H}_2\text{S}]^2} = K_{\text{eq}}$$

State the equilibrium constant expression.

Solve the equation for $[\text{H}_2]$.

$$[\text{H}_2]^2 = K_{\text{eq}} \times \frac{[\text{H}_2\text{S}]^2}{[\text{S}_2]}$$

Multiply both sides by $[\text{H}_2\text{S}]^2$. Divide both sides by $[\text{S}_2]$.

$$[\text{H}_2] = \sqrt{K_{\text{eq}} \times \frac{[\text{H}_2\text{S}]^2}{[\text{S}_2]}}$$

Take the square root of both sides.

$$[\text{H}_2] = \sqrt{(2.27 \times 10^{-3}) \times \frac{(0.184)^2}{(0.0540)}}$$

Substitute $K_{\text{eq}} = 2.27 \times 10^{-3}$, $[\text{H}_2\text{S}] = 0.184 \text{ mol/L}$, and $[\text{S}_2] = 0.0540 \text{ mol/L}$.

$$[\text{H}_2] = 0.0377 \text{ mol/L}$$

Multiply, divide, and take the square root.

The equilibrium concentration of H_2 is 0.0377 mol/L .

Example 4 – Page 67

2.3 Using Equilibrium Constants

Applications 18

02

At a certain temperature, $K_{eq} = 10.5$ for the equilibrium $\text{CO(g)} + 2\text{H}_2\text{(g)} \rightleftharpoons \text{CH}_3\text{OH(g)}$. Calculate the following concentrations.

- a. $[\text{CO}]$ in an equilibrium mixture containing 0.933 mol/L H_2 and $1.32 \text{ mol/L CH}_3\text{OH}$

Applications 18

02

At a certain temperature, $K_{eq} = 10.5$ for the equilibrium $\text{CO(g)} + 2\text{H}_2\text{(g)} \rightleftharpoons \text{CH}_3\text{OH(g)}$. Calculate the following concentrations.

- a. $[\text{CO}]$ in an equilibrium mixture containing 0.933 mol/L H_2 and 1.32 mol/L CH_3OH

$$K_{eq} = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2}$$

$$10.5 = \frac{(1.32)}{[\text{CO}](0.933)^2}$$

$$[\text{CO}] = 0.144M$$

Applications 18

02

At a certain temperature, $K_{eq} = 10.5$ for the equilibrium $\text{CO(g)} + 2\text{H}_2\text{(g)} \rightleftharpoons \text{CH}_3\text{OH(g)}$. Calculate the following concentrations.

- b.** $[\text{H}_2]$ in an equilibrium mixture containing 1.09 mol/L CO and 0.325 mol/L CH_3OH

Applications 18

02

At a certain temperature, $K_{eq} = 10.5$ for the equilibrium $\text{CO(g)} + 2\text{H}_2\text{(g)} \rightleftharpoons \text{CH}_3\text{OH(g)}$. Calculate the following concentrations.

- b.** $[\text{H}_2]$ in an equilibrium mixture containing 1.09 mol/L CO and 0.325 mol/L CH_3OH

$$K_{eq} = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2}$$

$$10.5 = \frac{(0.325)}{(1.09)[\text{H}_2]^2}$$

$$[\text{H}_2] = 0.169\text{M}$$

Applications 18

02

At a certain temperature, $K_{eq} = 10.5$ for the equilibrium $\text{CO(g)} + 2\text{H}_2\text{(g)} \rightleftharpoons \text{CH}_3\text{OH(g)}$. Calculate the following concentrations.

- c. $[\text{CH}_3\text{OH}]$ in an equilibrium mixture containing 0.0661 mol/L H_2 and 3.85

Applications 18

02

At a certain temperature, $K_{eq} = 10.5$ for the equilibrium $\text{CO(g)} + 2\text{H}_2\text{(g)} \rightleftharpoons \text{CH}_3\text{OH(g)}$. Calculate the following concentrations.

- c. $[\text{CH}_3\text{OH}]$ in an equilibrium mixture containing 0.0661 mol/L H_2 and 3.85 mol/L CO .

$$K_{eq} = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2}$$

$$10.5 = \frac{[\text{CH}_3\text{OH}]}{(3.85)(0.0661)^2}$$

$$[\text{CH}_3\text{OH}] = (10.5)(3.85)(0.0661)^2 = 0.177M$$

Applications 19

03

CHALLENGE In a generic reaction of $A + B \rightleftharpoons C + D$, **1.00 mol** of **A** and **1.00 mol** of **B** are allowed to react in a **1-L** flask until equilibrium is established. If the equilibrium concentration of **A** is **0.450 mol/L**, what is the equilibrium concentration of each of the other substances? What is **K_{eq}**?

Applications 19

03

CHALLENGE In a generic reaction of $A + B \rightleftharpoons C + D$, **1.00 mol** of **A** and **1.00 mol** of **B** are allowed to react in a **1-L** flask until equilibrium is established. If the equilibrium concentration of **A** is **0.450 mol/L**, what is the equilibrium concentration of each of the other substances? What is K_{eq} ?

According to the stoichiometry of the equation, the concentration of B is **0.450M**; C and D are **1.00 – 0.450 = 0.550M**.

$$K_{eq} = \frac{(0.550)(0.550)}{(0.450)(0.450)} = 1.49$$

Example 5

04

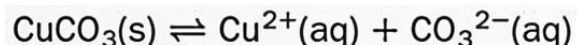
The **K_{sp}** of **copper(II) carbonate** is 2.5×10^{-10} at **298 K**. Calculate the solubility in **mol/L** of **copper(II) carbonate (CuCO₃)** at **298 K**.

Example 5 – Page 70

2.3 Using Equilibrium Constants

Example 5

The **K_{sp}** of **copper(II) carbonate** is 2.5×10^{-10} at **298 K**. Calculate the solubility in **mol/L** of **copper(II) carbonate (CuCO₃)** at **298 K**.



$$K_{\text{sp}} = [\text{Cu}^{2+}][\text{CO}_3^{2-}] = 2.5 \times 10^{-10}$$

$$s = [\text{Cu}^{2+}] = [\text{CO}_3^{2-}]$$

$$(s)(s) = s^2 = 2.5 \times 10^{-10}$$

$$s = \sqrt{2.5 \times 10^{-10}} = 1.6 \times 10^{-5} \text{ mol/L}$$

State the balanced chemical equation for the solubility equilibrium.

State the solubility product constant expression.

Relate $[\text{Cu}^{2+}]$ and $[\text{CO}_3^{2-}]$ to the solubility of CuCO_3 , s .

Substitute s for $[\text{Cu}^{2+}]$ and $[\text{CO}_3^{2-}]$ in the expression for K_{sp} .

Solve for s , and calculate the answer.

The molar solubility of CuCO_3 in water at 298 K is $1.6 \times 10^{-5} \text{ mol/L}$.

Applications 20

05

Use the data in [Table 3](#) to calculate the **solubility** in **mol/L** of the following ionic compounds at **298 K**.

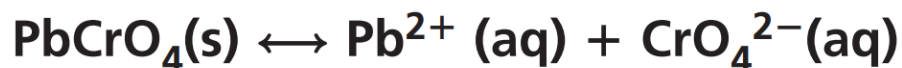
a. PbCrO_4

Applications 20

05

Use the data in [Table 3](#) to calculate the **solubility** in **mol/L** of the following ionic compounds at **298 K**.

a. PbCrO_4



s mol/L dissolves s mol/L s mol/L

$$K_{\text{sp}} = [\text{Pb}^{2+}][\text{CrO}_4^{2-}]$$

$$2.33 \times 10^{-13} = (s)(s) = s^2$$

$$s = \sqrt{2.3 \times 10^{-13}} = 4.8 \times 10^{-7} \text{ M}$$

Applications 20

05

Use the data in [Table 3](#) to calculate the **solubility** in **mol/L** of the following ionic compounds at **298 K**.

b. AgCl

Applications 20

05

Use the data in [Table 3](#) to calculate the **solubility** in **mol/L** of the following ionic compounds at **298 K**.

b. AgCl



s mol/L dissolves s mol/L s mol/L

$$K_{\text{sp}} = [\text{Ag}^+][\text{Cl}^-]$$

$$1.8 \times 10^{-10} = (s)(s) = s^2$$

$$s = \sqrt{1.8 \times 10^{-10}} = 1.3 \times 10^{-5} M$$

Applications 20

05

Use the data in [Table 3](#) to calculate the **solubility** in **mol/L** of the following ionic compounds at **298 K**.

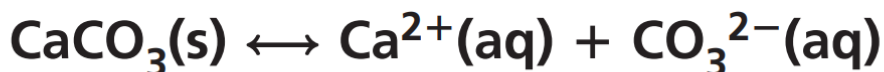


Applications 20

05

Use the data in [Table 3](#) to calculate the **solubility** in **mol/L** of the following ionic compounds at **298 K**.

c. CaCO_3



s mol/L dissolves

s mol/L

s mol/L

$$K_{\text{sp}} = [\text{Ca}^{2+}][\text{CO}_3^{2-}]$$

$$3.4 \times 10^{-9} = (s)(s) = s^2$$

$$s = \sqrt{3.4 \times 10^{-9}} = 5.8 \times 10^{-5} M$$

Applications 21

o6

CHALLENGE The K_{sp} of lead (II) carbonate (PbCO_3) is 7.40×10^{-14} at 298 K. What is the solubility of lead (II) carbonate in g/L?

(267.2 PbCO_3 g/mol)

Applications 21

o6

CHALLENGE The K_{sp} of lead (II) carbonate (PbCO_3) is 7.40×10^{-14} at 298 K. What is the solubility of lead (II) carbonate in g/L?

(267.2 PbCO_3 g/mol)

$$K_{sp} = [\text{Pb}^{2+}][\text{CO}_3^{2-}] = 7.40 \times 10^{-14}$$

$$(s)(s) = 7.40 \times 10^{-14}$$

$$s = \sqrt{7.40 \times 10^{-14}} = 2.72 \times 10^{-7} M$$

$$\begin{aligned} s &= 2.72 \times 10^{-7} \text{ mol/L} \times 267.2 \text{ g/mol} \\ &= 7.27 \times 10^{-5} \text{ g/L} \end{aligned}$$

Example 6

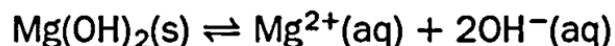
07

Determine the hydroxide ion concentration in a saturated solution of $\text{Mg}(\text{OH})_2$ at 298 K. The K_{sp} equals 5.6×10^{-12} .

Example 6

07

Determine the hydroxide ion concentration in a saturated solution of $\text{Mg}(\text{OH})_2$ at 298 K. The K_{sp} equals 5.6×10^{-12} .



State the equation for the solubility equilibrium.

$$K_{\text{sp}} = [\text{Mg}^{2+}][\text{OH}^{-}]^2 = 5.6 \times 10^{-12}$$

State the K_{sp} expression.

Let $x = [\text{Mg}^{2+}]$. Because there are two OH^{-} ions for every Mg^{2+} ion, $2x = [\text{OH}^{-}]$.

$$(x)(2x)^2 = 5.6 \times 10^{-12}$$

Substitute $x = [\text{Mg}^{2+}]$ and $2x = [\text{OH}^{-}]$

$$(x)(4)(x)^2 = 5.6 \times 10^{-12}$$

Square the terms.

$$4x^3 = 5.6 \times 10^{-12}$$

Combine the terms.

$$x^3 = \frac{5.6 \times 10^{-12}}{4} = 1.4 \times 10^{-12}$$

Divide.

$$x = [\text{Mg}^{2+}] = \sqrt[3]{1.4 \times 10^{-12}} = 1.1 \times 10^{-4} \text{ mol/L}$$

Use your calculator to determine the cube root.

Multiply $[\text{Mg}^{2+}]$ by 2 to obtain $[\text{OH}^{-}]$.

$$[\text{OH}^{-}] = 2[\text{Mg}^{2+}] = 2(1.1 \times 10^{-4} \text{ mol/L}) = 2.2 \times 10^{-4} \text{ mol/L}$$

Example 6 – Page 71

2.3 Using Equilibrium Constants

Applications 22

o8

Use the data in [Table 3](#) to calculate the following.

a. $[\text{Ag}^+]$ in a solution of AgBr at equilibrium

Applications 22

o8

Use the data in [Table 3](#) to calculate the following.

- a.** $[\text{Ag}^+]$ in a solution of AgBr at equilibrium



s mol/L dissolves

s mol/L

s mol/L

$$K_{\text{sp}} = [\text{Ag}^+][\text{Br}^-]$$

$$5.4 \times 10^{-13} = (s)(s) = s^2$$

$$s = \sqrt{5.4 \times 10^{-13}} = 7.3 \times 10^{-7} \text{M} = [\text{Ag}^+]$$

Applications 22

o8

Use the data in [Table 3](#) to calculate the following.

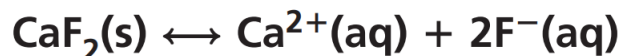
b. $[\text{F}^-]$ in a saturated solution of CaF_2

Applications 22

o8

Use the data in [Table 3](#) to calculate the following.

b. $[F^-]$ in a saturated solution of CaF_2



s mol/L dissolves s mol/L $2s$ mol/L

$$s = \frac{1}{2} [F^-]$$

$$K_{sp} = [Ca^{2+}][F^-]^2$$

$$3.5 \times 10^{-11} = (s)(2s)^2 = 4s^3$$

$$s = \sqrt[3]{\frac{3.5 \times 10^{-11}}{4}} = 2.1 \times 10^{-4}M$$

$$\frac{1}{2} [F^-] = 2.1 \times 10^{-4}M$$

$$[F^-] = 4.2 \times 10^{-4}M$$

Applications 22

o8

Use the data in [Table 3](#) to calculate the following.

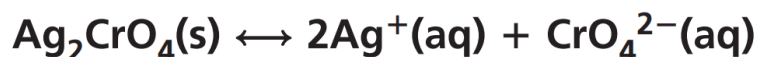
- c. $[\text{Ag}^+]$ in a solution of Ag_2CrO_4 at equilibrium

Applications 22

o8

Use the data in [Table 3](#) to calculate the following.

- c. $[\text{Ag}^+]$ in a solution of Ag_2CrO_4 at equilibrium



s mol/L dissolves $2s$ mol/L s mol/L

$$s = \frac{1}{2} [\text{Ag}^+]$$

$$K_{\text{sp}} = [\text{Ag}^+]^2[\text{CrO}_4^{2-}]$$

$$1.1 \times 10^{-12} = (2s)^2(s) = 4s^3$$

$$s = \sqrt[3]{\frac{1.1 \times 10^{-12}}{4}} = 6.5 \times 10^{-5} M$$

$$\frac{1}{2} [\text{Ag}^+] = 6.5 \times 10^{-5} M$$

$$[\text{Ag}^+] = 1.3 \times 10^{-4} M$$

Applications 23

09

Calculate the solubility of Ag_3PO_4 ($K_{\text{sp}} = 2.6 \times 10^{-18}$)

Applications 23

Calculate the solubility of Ag_3PO_4 ($K_{\text{sp}} = 2.6 \times 10^{-18}$)

$$K_{\text{sp}} = [\text{Ag}^+]^3[\text{PO}_4^{3-}] = 2.6 \times 10^{-18}$$

$$[\text{PO}_4^{3-}] = s, [\text{Ag}^+] = 3s$$

$$(3s)^3(s) = (27s^3)(s) = 27s^4 = 2.6 \times 10^{-18}$$

$$s = \sqrt[4]{\frac{2.6 \times 10^{-18}}{27}} = 1.8 \times 10^{-5} \text{ mol/L}$$

Applications 24

10

CHALLENGE The solubility of silver chloride (AgCl) is $1.86 \times 10^{-4} \text{ g/100 g}$ of H_2O at 298 K. Calculate the K_{sp} for AgCl . (143 AgCl g/mol)

Applications 24

10

CHALLENGE The solubility of silver chloride (AgCl) is $1.86 \times 10^{-4} \text{ g/100 g}$ of H_2O at 298 K. Calculate the K_{sp} for AgCl . (143 AgCl g/mol)

$$s = \frac{1.86 \times 10^{-4} \text{ g}}{100 \text{ g H}_2\text{O}} \times \frac{1000 \text{ g H}_2\text{O}}{1 \text{ L}}$$
$$= 1.86 \times 10^{-3} \text{ g/L}$$

$$s = \frac{1.86 \times 10^{-3} \text{ g}}{1 \text{ L}} \times \frac{1 \text{ mol}}{143.4 \text{ g}} = 1.30 \times 10^{-5} \text{ mol/L}$$

$$K_{\text{sp}} = [\text{Ag}^+][\text{Cl}^-] = (s)(s)$$

$$K_{\text{sp}} = (1.30 \times 10^{-5} \text{ mol/L})(1.30 \times 10^{-5} \text{ mol/L})$$
$$= 1.7 \times 10^{-10}$$

Example 7

11

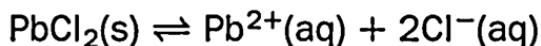
Predict whether a precipitate of PbCl_2 will form if **100 mL** of **0.0100M NaCl** is added to **100 mL** of **0.0200M $\text{Pb}(\text{NO}_3)_2$** . ($K_{\text{sp}} = 1.7 \times 10^{-5}$)

Example 7 – Page 73

2.3 Using Equilibrium Constants

Example 7

Predict whether a precipitate of **PbCl₂** will form if **100 mL** of **0.0100M NaCl** is added to **100 mL** of **0.0200M Pb(NO₃)₂**. (**K_{sp} = 1.7 × 10⁻⁵**)



State the equation for the dissolving of PbCl₂.

$$Q_{\text{sp}} = [\text{Pb}^{2+}][\text{Cl}^{-}]^2$$

State the ion product expression, Q_{sp} .

Mixing the solutions dilutes their concentrations by one-half.

$$[\text{Pb}^{2+}] = \frac{0.0200\text{M}}{2} = 0.0100\text{M}$$

Divide [Pb²⁺] by 2.

$$[\text{Cl}^{-}] = \frac{0.0100\text{M}}{2} = 0.00500\text{M}$$

Divide [Cl⁻] by 2.

$$Q_{\text{sp}} = (0.0100)(0.00500)^2 = 2.5 \times 10^{-7}$$

Substitute [Pb²⁺] = 0.0100M and [Cl⁻] = 0.00500M into Q_{sp} .

$$Q_{\text{sp}} (2.5 \times 10^{-7}) < K_{\text{sp}} (1.7 \times 10^{-5})$$

Compare Q_{sp} with K_{sp} .

A precipitate will not form.

Example 7 – Page 73

2.3 Using Equilibrium Constants

Applications 25

12

Use the data in [Table 3](#) predict whether a precipitate will form when equal volumes of the following solutions are mixed.

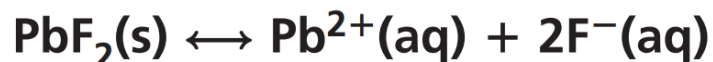
a. $0.10M$ $Pb(NO_3)_2$ and $0.030M$ NaF

Applications 25

12

Use the data in [Table 3](#) predict whether a precipitate will form when equal volumes of the following solutions are mixed.

a. $0.10M$ $Pb(NO_3)_2$ and $0.030M$ NaF



$$Q_{sp} = [Pb^{2+}][F^{-}]^2 = (0.050M)(0.015M)^2 \\ = 1.12 \times 10^{-5}$$

$$K_{sp} = 3.3 \times 10^{-8}$$

$Q_{sp} > K_{sp}$ so a precipitate of PbF_2 will form.

Applications 25

12

Use the data in [Table 3](#) predict whether a precipitate will form when equal volumes of the following solutions are mixed.

b. $0.25M$ K_2SO_4 and $0.010M$ $AgNO_3$

Applications 25

12

Use the data in [Table 3](#) predict whether a precipitate will form when equal volumes of the following solutions are mixed.

b. $0.25M$ K_2SO_4 and $0.010M$ $AgNO_3$



$$Q_{sp} = [Ag^+]^2[SO_4^{2-}] = (0.0050 M)^2(0.125M) \\ = 3.1 \times 10^{-6}$$

$$K_{sp} = 1.2 \times 10^{-5}$$

$Q_{sp} < K_{sp}$, so a precipitate will not form.

Applications 26

13

CHALLENGE Will a precipitate form when **250 mL** of **0.20M MgCl_2** is added to **750 mL** of **0.0025M NaOH** ?

Applications 26

13

CHALLENGE Will a precipitate form when **250 mL** of **0.20M MgCl₂** is added to **750 mL** of **0.0025M NaOH**?

$$[\text{Mg}^{2+}] = 0.20M \times \frac{250 \text{ mL}}{1000 \text{ mL}} = 0.050M$$

$$[\text{OH}^-] = 0.0025M \times \frac{750 \text{ mL}}{1000 \text{ mL}} = 0.0019M$$

$$Q_{\text{sp}} = [\text{Mg}^{2+}][\text{OH}^-]^2 = (0.050M)(0.0019M)^2 \\ = 1.8 \times 10^{-7}$$

$$K_{\text{sp}} = 5.6 \times 10^{-12}$$

$Q_{\text{sp}} > K_{\text{sp}}$, so a precipitate of $\text{Mg}(\text{OH})_2$ will form.

Review 29

14

How the presence of a common ion reduces the solubility of an ionic compound?

- a) by shifting the solubility equilibrium to the right.
- b) by shifting the solubility equilibrium to the left.
- c) by shifting the solubility equilibrium to the products.
- d) by shifting the solubility equilibrium in the direction of the solid.

Review 29

14

How the presence of a common ion reduces the solubility of an ionic compound?

- a) by shifting the solubility equilibrium to the right.
- b) by shifting the solubility equilibrium to the left.
- c) by shifting the solubility equilibrium to the products.
- d) by shifting the solubility equilibrium in the direction of the solid.**

Review 30

15

What is the difference between **K_{sp}** and **Q_{sp}**?

- a) K_{sp} is an equilibrium constant; Q_{sp} is not.
- b) K_{sp} and Q_{sp} are equilibrium constants.
- c) Q_{sp} is an equilibrium constant; K_{sp} is not.
- d) None of the above

Review 30

15

What is the difference between **K_{sp}** and **Q_{sp}**?

- a) **K_{sp} is an equilibrium constant; Q_{sp} is not.**
- b) K_{sp} and Q_{sp} are equilibrium constants.
- c) Q_{sp} is an equilibrium constant; K_{sp} is not.
- d) None of the above

Review 31

16

The **K_{sp}** of magnesium carbonate (**MgCO₃**) is **2.6 x 10⁻⁹**. What is the solubility of **MgCO₃** in water?

Review 31

16

The **K_{sp}** of magnesium carbonate (**MgCO₃**) is **2.6 × 10⁻⁹**. What is the solubility of **MgCO₃** in water?

$$[\text{Mg}^{2+}][\text{CO}_3^{2-}] = 2.6 \times 10^{-9};$$

$$s^2 = 2.6 \times 10^{-9}$$

$$s = \sqrt{2.6 \times 10^{-9}} = 5.1 \times 10^{-5}\text{M}$$

Mastering Concepts 64

17

If two solution have a _____, both contain the same ion.

- a) solubility product constant
- b) common ion
- c) common ion effect
- d) reversible reaction

Mastering Concepts 64

17

If two solution have a _____, both contain the same ion.

- a) solubility product constant
- b) common ion**
- c) common ion effect
- d) reversible reaction

Mastering Concepts 65

18

Why are compounds such as **sodium chloride** usually not given **K_{sp}** values?

- a) Non-soluble compounds are usually not given K_{sp}
- b) The value of K_{sp} would be a large number
- c) Such compounds are likely to precipitate from solutions
- d) Even if ion concentrations are very high, a precipitate will not form

Mastering Concepts 65

18

Why are compounds such as **sodium chloride** usually not given **K_{sp}** values?

- a) Non-soluble compounds are usually not given K_{sp}
- b) The value of K_{sp} would be a large number**
- c) Such compounds are likely to precipitate from solutions
- d) Even if ion concentrations are very high, a precipitate will not form

Mastering Concepts 67

19

Explain what is happening in the figure in terms of **Q_{sp}** and **K_{sp}**.

- a) A precipitate forms because $Q_{sp} > K_{sp}$.
- b) A precipitate doesn't form because $Q_{sp} > K_{sp}$.
- c) A precipitate forms because $Q_{sp} < K_{sp}$.
- d) A precipitate doesn't form because $Q_{sp} < K_{sp}$.



Mastering Concepts 67

19

Explain what is happening in the figure in terms of Q_{sp} and K_{sp} .

- a) A precipitate forms because $Q_{sp} > K_{sp}$.
- b) A precipitate doesn't form because $Q_{sp} > K_{sp}$.
- c) A precipitate forms because $Q_{sp} < K_{sp}$.
- d) A precipitate doesn't form because $Q_{sp} < K_{sp}$.



Mastering Concepts 69

20

A solution results when two solutions are mixed and Q_{sp} is found to equal K_{sp} . Which statement is correct?

- a) The new solution is saturated.
- b) A precipitate might form.
- c) The new solution is unsaturated.
- d) A precipitate will form.

Mastering Concepts 69

20

A solution results when two solutions are mixed and Q_{sp} is found to equal K_{sp} . Which statement is correct?

- a) The new solution is saturated.
- b) A precipitate might form.
- c) The new solution is unsaturated.
- d) A precipitate will form.

Mastering Problems 70

21

Write the **K_{sp}** expression for **lead chromate (PbCrO₄)**, and calculate its solubility in **mol/L**. **K_{sp} = 2.3 × 10⁻¹³**

Mastering Problems 70

21

Write the **K_{sp}** expression for **lead chromate (PbCrO₄)**, and calculate its solubility in **mol/L**. **K_{sp} = 2.3 × 10⁻¹³**

$$K_{sp} = [\text{Pb}^{2+}] [\text{CrO}_4^{2-}] = 2.3 \times 10^{-13}$$

$$s = [\text{Pb}^{2+}] = [\text{CrO}_4^{2-}]$$

$$s^2 = 2.3 \times 10^{-13}$$

$$s = 4.8 \times 10^{-7} \text{ M}$$

Mastering Problems 71

22

At 350 °C, $K_{eq} = 1.67 \times 10^{-2}$ for the reversible reaction $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$. What is the concentration of **HI** at equilibrium if $[H_2]$ is $2.44 \times 10^{-3} M$ and $[I_2]$ is $7.18 \times 10^{-5} M$?

Mastering Problems 71

22

At 350 °C, $K_{eq} = 1.67 \times 10^{-2}$ for the reversible reaction $2\text{HI(g)} \rightleftharpoons \text{H}_2\text{(g)} + \text{I}_2\text{(g)}$. What is the concentration of **HI** at equilibrium if $[\text{H}_2]$ is $2.44 \times 10^{-3} \text{ M}$ and $[\text{I}_2]$ is $7.18 \times 10^{-5} \text{ M}$?

$$\frac{[\text{H}_2] [\text{I}_2]}{[\text{HI}]^2} = 1.67 \times 10^{-2}$$

$$[\text{HI}] = \sqrt{\frac{[\text{H}_2] [\text{I}_2]}{(1.67 \times 10^{-2})}}$$

$$= \sqrt{\frac{(2.44 \times 10^{-3})(7.18 \times 10^{-5})}{(1.67 \times 10^{-2})}}$$

$$= 3.24 \times 10^{-3} \text{ M}$$

Mastering Problems 72

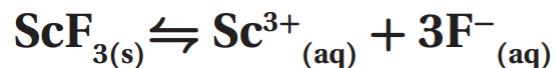
23

K_{sp} for **scandium fluoride (ScF₃)** at **298 K** is **4.2×10^{-18}** . Write the chemical equation for the solubility equilibrium of scandium fluoride in water. What concentration of **Sc³⁺** ions is required to cause a precipitate to form if the fluoride-ion concentration is **0.076M**?

Mastering Problems 72

23

K_{sp} for **scandium fluoride (ScF₃)** at **298 K** is **4.2 × 10⁻¹⁸**. Write the chemical equation for the solubility equilibrium of scandium fluoride in water. What concentration of **Sc³⁺** ions is required to cause a precipitate to form if the fluoride-ion concentration is **0.076M**?



$$K_{sp} = [\text{Sc}^{3+}] [\text{F}^{-}]^3;$$

$$4.2 \times 10^{-18} = [\text{Sc}^{3+}] [0.076]^3$$

$$[\text{Sc}^{3+}] = \frac{4.2 \times 10^{-18}}{(0.076)^3} = 9.6 \times 10^{-15} \text{ M}$$

Mastering Problems 73

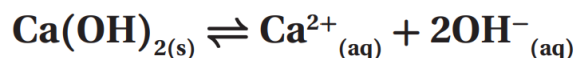
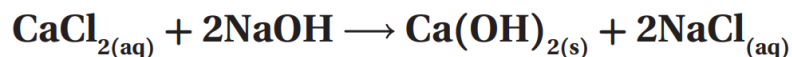
24

Will a precipitate form when **62.6 mL** of **0.0322 M** CaCl_2 and **31.3 mL** of **0.0145 M** NaOH are mixed? ($K_{sp} = 5.0 \times 10^{-6}$)

Mastering Problems 73

24

Will a precipitate form when **62.6 mL** of **0.0322 M CaCl₂** and **31.3 mL** of **0.0145 M NaOH** are mixed? ($K_{sp} = 5.0 \times 10^{-6}$)



$$K_{sp} = [\text{Ca}^{2+}] [\text{OH}^{-}]^2 = 5.0 \times 10^{-6}$$

$$[\text{Ca}^{2+}] = \frac{(0.0626 \text{ L}) (0.0322 \text{ mol / L})}{(0.0626 \text{ L} + 0.0313 \text{ L})} = 2.15 \times 10^{-2} \text{ M}$$

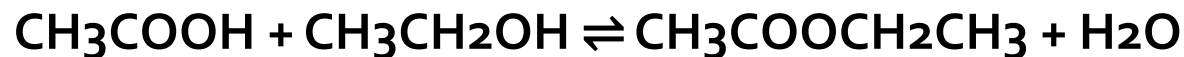
$$[\text{OH}^{-}] = \frac{(0.0313 \text{ L}) (0.0145 \text{ mol / L})}{(0.0626 \text{ L} + 0.0313 \text{ L})} = 4.83 \times 10^{-3} \text{ M}$$

$$Q_{sp} = [2.15 \times 10^{-2}] [4.83 \times 10^{-3}]^2 = [5.02 \times 10^{-7}]$$

لا، لا يتكوّن راسب؛ لأن $Q_{sp} = 5.02 \times 10^{-7}$ وهذا أقلّ من قيمة K_{sp} لهيدروكسيد الكالسيوم التي تساوي 5.0×10^{-6} .

Mastering Problems 74

25



Calculate **K_{eq}** using these equilibrium concentrations:

$[\text{CH}_3\text{COOCH}_2\text{CH}_3] = 2.90 \text{ M}$,

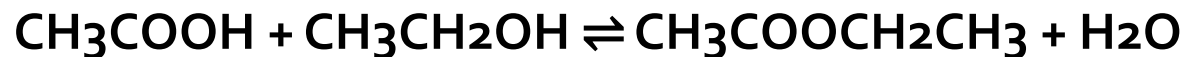
$[\text{CH}_3\text{COOH}] = 0.316 \text{ M}$,

$[\text{CH}_3\text{CH}_2\text{OH}] = 0.313 \text{ M}$,

and $[\text{H}_2\text{O}] = 0.114 \text{ M}$.

Mastering Problems 74

25



Calculate **K_{eq}** using these equilibrium concentrations:

$$[\text{CH}_3\text{COOCH}_2\text{CH}_3] = 2.90 \text{ M},$$

$$[\text{CH}_3\text{COOH}] = 0.316 \text{ M},$$

$$[\text{CH}_3\text{CH}_2\text{OH}] = 0.313 \text{ M},$$

$$\text{and } [\text{H}_2\text{O}] = 0.114 \text{ M}.$$

$$\begin{aligned} K_{\text{eq}} &= \frac{[\text{CH}_3\text{COOCH}_2\text{CH}_3][\text{H}_2\text{O}]}{[\text{CH}_3\text{COOH}][\text{CH}_3\text{CH}_2\text{OH}]} \\ &= \frac{(2.90 \text{ M})(0.114 \text{ M})}{(0.316 \text{ M})(0.313 \text{ M})} \\ &= 3.34 \end{aligned}$$

Mixed Review 78

26

The solubility product constant for **lead(II) arsenate** ($\text{Pb}_3(\text{AsO}_4)_2$) is 4.0×10^{-36} at **298 K**. Calculate the molar solubility of the compound at this temperature.

Mixed Review 78

26

The solubility product constant for **lead(II) arsenate** ($\text{Pb}_3(\text{AsO}_4)_2$) is 4.0×10^{-36} at **298 K**. Calculate the molar solubility of the compound at this temperature.



$$K_{\text{sp}} = [\text{Pb}^{2+}]^3 [\text{AsO}_4^{3-}]^2$$

$$4.0 \times 10^{-36} = (3s)^3 (2s)^2$$

$$4.0 \times 10^{-36} = 108 s^5$$

$$s^5 = \frac{4.0 \times 10^{-36}}{108} = 3.7 \times 10^{-38}$$

$$s = \sqrt[5]{3.7 \times 10^{-38}} = 3.3 \times 10^{-8} \text{ M}$$

Mixed Review 8o

27

CHALLENGE Benzaldehyde, known as artificial almond oil, is used in food flavorings. What is the molar concentration of benzaldehyde ($\text{C}_7\text{H}_6\text{O}$) at **298 K**, when its density is **1.043 g/mL**?

Mixed Review 8o

27

CHALLENGE Benzaldehyde, known as artificial almond oil, is used in food flavorings. What is the molar concentration of benzaldehyde ($\text{C}_7\text{H}_6\text{O}$) at **298 K**, when its density is **1.043 g/mL**?

The molar mass for $\text{C}_7\text{H}_6\text{O}$ is **106.13 g/mol**

$$M = 1.04 \frac{\text{g}}{\text{mL}} \text{C}_7\text{H}_6\text{O} \times \frac{1 \text{ mol}}{106.13 \text{ g}} \text{C}_7\text{H}_6\text{O} \times \frac{1000 \text{ mL}}{1 \text{ L}}$$
$$= \mathbf{9.8 \text{ mol/L}}$$

Mixed Review 82

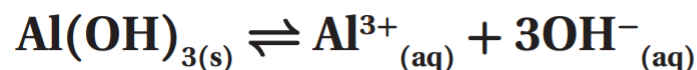
28

Describe the process by which adding **potassium hydroxide** to a saturated **aluminum hydroxide** solution reduces the concentration of aluminum ions. Write the solubility equilibrium equation and solubility product constant expression for a saturated aqueous solution of aluminum hydroxide.

Mixed Review 82

28

Describe the process by which adding **potassium hydroxide** to a saturated **aluminum hydroxide** solution reduces the concentration of aluminum ions. Write the solubility equilibrium equation and solubility product constant expression for a saturated aqueous solution of aluminum hydroxide.



$$K_{sp} = [\text{Al}^{3+}][\text{OH}^{-}]^3$$

تؤدي إضافة هيدروكسيد البوتاسيوم إلى زيادة تركيز أيونات الهيدروكسيد في المحلول. لذا، يتطلب K_{sp} الثابت تخفيض تركيز أيونات الألمنيوم موضحاً أثر الأيون المشترك.

Mixed Review 83

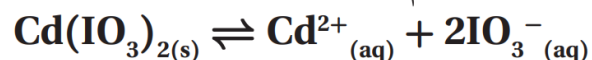
29

At 298 K, K_{sp} for cadmium iodate ($\text{Cd}(\text{IO}_3)_2$) equals 2.3×10^{-8} . What are the molar concentrations of cadmium ions and iodate ions in a saturated solution at 298 K?

Mixed Review 83

29

At 298 K, K_{sp} for cadmium iodate ($\text{Cd}(\text{IO}_3)_2$) equals 2.3×10^{-8} . What are the molar concentrations of cadmium ions and iodate ions in a saturated solution at 298 K?



$$s \text{ mol/L } \text{Cd}(\text{IO}_3)_2$$

$$[\text{Cd}^{2+}] = s \text{ mol/L}$$

$$[\text{IO}_3^{-}] = 2s \text{ mol/L}$$

$$K_{sp} = [\text{Cd}^{2+}][\text{IO}_3^{-}]^2$$

$$2.3 \times 10^{-8} = s(2s)^2 = 4s^3$$

$$s = \sqrt[3]{\frac{2.3 \times 10^{-8}}{4}} = 1.8 \times 10^{-3}$$

$$[\text{Cd}^{2+}] = s \text{ mol/L} = 1.8 \times 10^{-3} \text{ mol/L}$$

$$[\text{IO}_3^{-}] = 2s \text{ mol/L} = 3.6 \times 10^{-3} \text{ mol/L}$$

Mixed Review 83 – Page 82

2.3 Using Equilibrium Constants

Think Critically 84

30

Suppose that an equilibrium system at a given temperature has a **K_{eq}** equal to **1.000**. Which statement is not correct?

- a) The system is made up of 50% reactants and 50% products.
- b) The system can be made up of 50% reactants and 50% products.
- c) The concentrations of products and reactants are equal.
- d) The concentrations of individual reactants and products are not necessarily equal.

Think Critically 84

30

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Think Critically 86

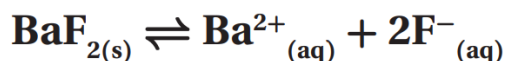
31

CHALLENGE What compound would precipitate first if a **0.500 M sodium fluoride** solution were added gradually to a solution already containing **0.500 M** concentrations of both barium ions and magnesium ions? Use the data in Table 6. Write the solubility equilibrium equations and solubility product constant expressions for both compounds. Explain your answer.

Think Critically 86

31

CHALLENGE What compound would precipitate first if a **0.500 M sodium fluoride** solution were added gradually to a solution already containing **0.500 M** concentrations of both barium ions and magnesium ions? Use the data in Table 6. Write the solubility equilibrium equations and solubility product constant expressions for both compounds. Explain your answer.



$$K_{sp} = [\text{Ba}^{2+}][\text{F}^{-}]^2$$

$$\begin{aligned} \text{BaF}_2 \text{ الذائبية المولارية} = s &= \frac{1.1 \text{ g/L}}{175.33 \text{ g/mol}} \\ &= 6.3 \times 10^{-3} \text{ mol/L} \end{aligned}$$

$$K_{sp} = [\text{Ba}^{2+}][\text{F}^{-}]^2 = 4s^3 = 4(6.3 \times 10^{-3})^3 = 1.0 \times 10^{-6}$$

– Continued

Table 6 Data for Two Compounds		
Compound	Molar Mass (g/mol)	Solubility at 25°C (g/L)
BaF ₂	175.33	1.1
MgF ₂	62.30	0.13

Think Critically 86 – Page 82

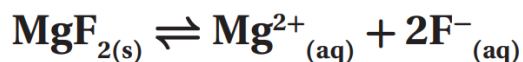
2.3 Using Equilibrium Constants

Think Critically 86

31

CHALLENGE What compound would precipitate first if a **0.500 M sodium fluoride** solution were added gradually to a solution already containing **0.500 M** concentrations of both barium ions and magnesium ions? Use the data in Table 6. Write the solubility equilibrium equations and solubility product constant expressions for both compounds. Explain your answer.

سيترسب فلوريد الماغنسيوم أولاً؛ لأن قيمة K_{sp} المحسوبة له التي تساوي 3.7×10^{-8} أقل من قيمة K_{sp} لفلوريد الباريوم التي تساوي 1.0×10^{-6} .



$$K_{sp} = [\text{Mg}^{2+}][\text{F}^{-}]^2$$

$$\begin{aligned} \text{MgF}_2 \text{ الذائبية المولارية } s &= \frac{0.13 \text{ g/L}}{62.30 \text{ g/mol}} \\ &= 2.1 \times 10^{-3} \text{ mol/L} \end{aligned}$$

$$K_{sp} = [\text{Ba}^{2+}][\text{F}^{-}]^2 = 4s^3 = 4(2.1 \times 10^{-3})^3 = 3.7 \times 10^{-8}$$

Table 6 Data for Two Compounds		
Compound	Molar Mass (g/mol)	Solubility at 25°C (g/L)
BaF ₂	175.33	1.1
MgF ₂	62.30	0.13

Think Critically 86 – Page 82

2.3 Using Equilibrium Constants

Challenge Problem 90

32

Phosgene can be produced by the reaction between carbon monoxide and chlorine described by the equation $\text{CO(g)} + \text{Cl}_2\text{(g)} \rightleftharpoons \text{COCl}_2\text{(g)}$. Initially **1.0000 mol CO** and **1.0000 mol Cl₂**, are introduced into a **10.00 L** reaction vessel. When equilibrium is established, both of their molar concentrations are found to be **0.0086 mol/L**. What is the molar concentration of phosgene at equilibrium? What is K_{eq} for the system?

Challenge Problem 90

32

Phosgene can be produced by the reaction between carbon monoxide and chlorine described by the equation $\text{CO(g)} + \text{Cl}_2\text{(g)} \rightleftharpoons \text{COCl}_2\text{(g)}$. Initially **1.0000 mol CO** and **1.0000 mol Cl₂**, are introduced into a **10.00 L** reaction vessel. When equilibrium is established, both of their molar concentrations are found to be **0.0086 mol/L**. What is the molar concentration of phosgene at equilibrium? What is K_{eq} for the system?

التركيز المولاري الابتدائي لكل من CO و Cl₂ هو:

$$1.0000 \text{ mol} / 10.00 \text{ L} = 0.1000 \text{ mol/L}$$

وإذا كان تركيز CO و Cl₂ عند الاتزان يساوي
0.0086 mol/L فإن تركيز COCl₂ :

$$0.1000 \text{ mol/L} - 0.0086 \text{ mol/L} = 0.0914 \text{ mol/L}$$

لذلك، فإن هذه القيمة قد نتجت من خلال التفاعل حيث
تمثل قيمة COCl₂.

$$K_{\text{eq}} = \frac{[\text{COCl}_2]}{[\text{CO}][\text{Cl}_2]} = \frac{(0.0914)}{(0.0086)(0.0086)} = 1.2 \times 10^3$$

Multiple Choice 5

33

What is the K_{sp} for $MnCO_3$ at 298 K?

- a) 2.24×10^{-11}
- b) 4.00×10^{-11}
- c) 1.12×10^{-9}
- d) 5.60×10^{-9}

Concentration Data for the Equilibrium System $MnCO_3(s) \rightarrow Mn^{2+}(aq) + CO_3^{2-}(aq)$ at 298 K				
Trial	$[Mn^{2+}]_0$ (M)	$[CO_3^{2-}]_0$ (M)	$[Mn^{2+}]_{eq}$ (M)	$[CO_3^{2-}]_{eq}$ (M)
1	0.0000	0.00400	5.60×10^{-9}	4.00×10^{-3}
2	0.0100	0.0000	1.00×10^{-2}	2.24×10^{-9}
3	0.0000	0.0200	1.12×10^{-9}	2.00×10^{-2}

Multiple Choice 5 – Page 84

2.3 Using Equilibrium Constants

Multiple Choice 5

33

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- c) 1.12×10^{-9}
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1	0.0000	0.00400	5.60×10^{-9}	4.00×10^{-3}
2	0.0100	0.0000	1.00×10^{-2}	2.24×10^{-9}
3	0.0000	0.0200	1.12×10^{-9}	2.00×10^{-2}

Multiple Choice 5 – Page 84

2.3 Using Equilibrium Constants

Multiple Choice 6

34

What is the molar solubility of MnCO_3 at 298 K?

- a) $4.73 \times 10^{-6} M$
- b) $6.32 \times 10^{-2} M$
- c) $7.48 \times 10^{-5} M$
- d) $3.35 \times 10^{-5} M$

Concentration Data for the Equilibrium System $\text{MnCO}_3(\text{s}) \rightarrow \text{Mn}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq})$ at 298 K				
Trial	$[\text{Mn}^{2+}]_0$ (M)	$[\text{CO}_3^{2-}]_0$ (M)	$[\text{Mn}^{2+}]_{\text{eq}}$ (M)	$[\text{CO}_3^{2-}]_{\text{eq}}$ (M)
1	0.0000	0.00400	5.60×10^{-9}	4.00×10^{-3}
2	0.0100	0.0000	1.00×10^{-2}	2.24×10^{-9}
3	0.0000	0.0200	1.12×10^{-9}	2.00×10^{-2}

Multiple Choice 6 – Page 84

2.3 Using Equilibrium Constants

Multiple Choice 6

34

What is the molar solubility of MnCO_3 at 298 K?

- a) $4.73 \times 10^{-6} \text{ M}$
- b) $6.32 \times 10^{-2} \text{ M}$
- c) $7.48 \times 10^{-5} \text{ M}$
- d) $3.35 \times 10^{-5} \text{ M}$

Concentration Data for the Equilibrium System $\text{MnCO}_3(\text{s}) \rightarrow \text{Mn}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq})$ at 298 K				
Trial	$[\text{Mn}^{2+}]_0$ (M)	$[\text{CO}_3^{2-}]_0$ (M)	$[\text{Mn}^{2+}]_{\text{eq}}$ (M)	$[\text{CO}_3^{2-}]_{\text{eq}}$ (M)
1	0.0000	0.00400	5.60×10^{-9}	4.00×10^{-3}
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3	0.0000	0.0200	1.12×10^{-9}	2.00×10^{-2}

Multiple Choice 6 – Page 84

2.3 Using Equilibrium Constants

Multiple Choice 7

35

A 50.0-mL volume of $3.00 \times 10^{-6} \text{ M K}_2\text{CO}_3$ is mixed with 50.0 mL of MnCl_2 . A precipitate of MnCO_3 will form only when the concentration of the MnCl_2 solution is greater than which of the following?

- a) $7.47 \times 10^{-6} \text{ M}$
- b) $1.49 \times 10^{-5} \text{ M}$
- c) $2.99 \times 10^{-5} \text{ M}$
- d) $1.02 \times 10^{-5} \text{ M}$

Concentration Data for the Equilibrium System $\text{MnCO}_3(\text{s}) \rightarrow \text{Mn}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq})$ at 298 K				
Trial	$[\text{Mn}^{2+}]_0$ (M)	$[\text{CO}_3^{2-}]_0$ (M)	$[\text{Mn}^{2+}]_{\text{eq}}$ (M)	$[\text{CO}_3^{2-}]_{\text{eq}}$ (M)
1	0.0000	0.00400	5.60×10^{-9}	4.00×10^{-3}
2	0.0100	0.0000	1.00×10^{-2}	2.24×10^{-9}
3	0.0000	0.0200	1.12×10^{-9}	2.00×10^{-2}

Multiple Choice 7 – Page 84

2.3 Using Equilibrium Constants

Multiple Choice 7

35

A **50.0-mL** volume of **$3.00 \times 10^{-6} \text{ M}$** **$\text{K}_2\text{CO}_3$** is mixed with **50.0 mL** of **MnCl_2** . A precipitate of **MnCO_3** will form only when the concentration of the **MnCl_2** solution is greater than which of the following?

- a) $7.47 \times 10^{-6} \text{ M}$
- b) $1.49 \times 10^{-5} \text{ M}$
- c) **$2.99 \times 10^{-5} \text{ M}$**
- d) $1.02 \times 10^{-5} \text{ M}$

Concentration Data for the Equilibrium System $\text{MnCO}_3(\text{s}) \rightarrow \text{Mn}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq})$ at 298 K				
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Multiple Choice 7 – Page 84

2.3 Using Equilibrium Constants

Chapter 2 – Revision Paper

Resources

- *Chemical Equilibrium, Chapter 17, from Glencoe Chemistry: Matter and Change ©2017*

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