For A Chemical Reaction: Cl2 (l) 2 Cl (g) Has A Kp = 3.2 10-8, And The Initial Amounts Are: 0.55 Mol

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Understanding chemical equilibrium is essential in predicting the behavior of reactions under various conditions. In this article, we explore a specific reaction involving chlorine, analyze its equilibrium constant (Kp), and determine the extent of reaction starting from initial conditions. We will delve into the concepts of equilibrium, equilibrium expressions, and calculations to offer a comprehensive understanding suitable for students, chemists, and enthusiasts alike.

Introduction to the Reaction and Its Significance

The reaction under consideration is:

$Cl_2(l) \rightleftharpoons 2\,Cl(g)$

This reaction involves the dissociation of liquid chlorine into gaseous chlorine atoms. The equilibrium constant, Kp, provides insight into the extent to which the reaction proceeds toward products or reactants at a given temperature.

Key points:

- The reaction involves a phase change from liquid to gas.
- The equilibrium constant Kp indicates the ratio of partial pressures of gaseous species at equilibrium.
- The initial amount of chlorine (liquid) is given as 0.55 mol.

Understanding such reactions is vital in industrial processes, environmental chemistry, and the study of reaction kinetics.

Understanding the Equilibrium Constant Kp

Definition of Kp

Kp is the equilibrium constant expressed in terms of partial pressures of gaseous species:

Kp = (Pproducts) / (Preactants)

For the reaction:

Cl2(l) ⇌ 2 Cl(g)

Since liquids are pure substances, their activity is constant and incorporated into the equilibrium constant, which simplifies the expression to:

$Kp = (PCl)^2$

Important note: The activity of pure liquids and solids is taken as 1, so Kp only involves gases.

Implications of the Given Kp Value

Given:

Kp = 3.2 × 10-8

This very small value indicates that under equilibrium at the specified temperature, the reaction favors the reactant side, meaning very little chlorine dissociates into gaseous atoms.

Initial Conditions and Their Role in Equilibrium Calculations

The problem states:

- Initial amount of chlorine (liquid): 0.55 mol
- No initial gaseous chlorine atoms are present.

Given that the initial amount is in moles, and assuming the reaction occurs in a known volume, we can determine the initial concentrations and partial pressures.

Assumptions:

- The volume (V) of the container is known or can be standardized.
- The temperature is fixed, as Kp is temperature-dependent.

Calculating the Equilibrium Concentrations and Partial Pressures

Step 1: Establish Initial Conditions

- Initial moles of $Cl_2(l)$: 0.55 mol
- Initial moles of $Cl(g)$: 0 mol

Since liquids are incompressible and their activity remains constant, their concentration is not directly involved in the Kp expression. However, the gaseous phase's partial pressure depends on the moles of $Cl(g)$ at equilibrium.

Step 2: Define the Change in Moles During Reaction

Let:

- x = moles of $Cl_2(l)$ that dissociate into $Cl(g)$ at equilibrium.

Since the reaction produces 2 mol of $Cl(g)$ for each mol of Cl_2 that dissociates:

- Moles of $Cl_2(l)$ at equilibrium: 0.55 - x
- Moles of $Cl(g)$ at equilibrium: 2x

Initial moles of $Cl(g)$: 0

Step 3: Express Partial Pressures in Terms of x

Assuming ideal gas behavior, the partial pressure of a gas is:

$P = (n\ RT) / V$

Where:

- n = moles of gas
- R = universal gas constant (8.314 J/mol·K)
- T = temperature in Kelvin
- V = volume in liters

For calculation simplicity, if the volume and temperature are fixed, the partial pressure of $Cl(g)$ at equilibrium is proportional to its moles:

$PCl = (2x\ RT) / V$

Similarly, the partial pressure of Cl2(g) is:

PCl2 = (0 mol) at initial, but since liquid phase's activity is constant and not included in Kp, we focus on the gaseous phase.

Given the reaction, the Kp expression simplifies to:

$Kp = (PCl)^2 / 1$

That is:

$Kp = (PCl)^2$

Expressed in terms of x:

PCl = (2x RT) / V

Thus,

$Kp = [(2x RT)/V]^2$

Step 4: Solve for x Using the Kp Expression

Rearranged:

$x = (\sqrt{Kp}) (V / (2 RT))$

However, without explicit values for V and T, we typically express the ratio of partial pressures or mole fractions.

Alternatively, since Kp is very small, the amount of dissociation (x) will be minimal, and we can approximate the extent of reaction.

Estimating the Extent of Reaction (x)

Given the tiny value of Kp (3.2 × 10-8), the dissociation is negligible. We can approximate that:

- The concentration of Cl(g) at equilibrium is very low.
- The partial pressure of Cl(g) is correspondingly low.

Assuming ideal gas behavior and a known temperature and volume, more precise calculations can be performed.

Practical Example: Numerical Calculation (Hypothetical)

Suppose the reaction occurs at:

- Temperature, T = 298 K
- Volume, V = 1 L

Calculations:

PCl = (2x RT) / V

Given Kp:

Kp = $(PCl)^2$ = 3.2 × 10-8

So,

PCl = √(3.2 × 10-8) ≈ 5.66 × 10-4 atm

Now,

x = (PCl V) / (2 RT)

Plugging in the values:

RT ≈ 8.314 J/mol·K × 298 K ≈ 2478 J/mol

Since 1 atm = 101.3 kPa, and PCl in atm:

x ≈ (5.66 × 10-4 atm × 1 L) / (2 × 0.082057 L·atm/mol·K × 298 K)

x ≈ (5.66 × 10-4) / (2 × 0.082057 × 298)

x ≈ (5.66 × 10-4) / (48.88)

x ≈ 1.16 × 10-5 mol

This indicates only about 1.16 × 10-5 mol of chlorine dissociates, which is negligible compared to the initial 0.55 mol.

Implications of the Calculation

- The extremely low Kp value implies that at equilibrium, the majority of chlorine remains as Cl2(l).
- The dissociation of chlorine into atomic form gases is minimal, meaning the reaction does not favor the products under standard conditions.
- For industrial or laboratory processes, conditions such as temperature, pressure, and catalysts would significantly influence the extent of dissociation.

Factors Affecting the Equilibrium Position

Understanding what influences the position of equilibrium helps in controlling reactions:

- Temperature: Since Kp is temperature-dependent, raising or lowering temperature can shift the equilibrium.
- Pressure: Changes in pressure affect gaseous species; however, in reactions involving liquids and gases, the effect depends on the reaction's volume change.
- Concentration: Altering initial concentrations of reactants shifts the equilibrium per Le Châtelier’s principle.
- Catalysts: These do not change the equilibrium position but can speed up the attainment of equilibrium.

Real-World Applications and Significance

Understanding the dissociation of chlorine is critical in various contexts:

- Industrial Chlorine Production: Chlorine is produced via electrolysis, and its dissociation properties affect storage and handling.
- Environmental Chemistry: Chlorine gases play a role in atmospheric reactions and ozone depletion.
- Chemical Safety: Recognizing the minimal dissociation under standard conditions informs safety protocols.

Summary and Key Takeaways

- The reaction Cl2(l) ⇌ 2 Cl(g) has a very small Kp (

Frequently Asked Questions

What is the balanced chemical equation for the reaction involving Cl_2 (l) and 2 Cl (g)?

The reaction is Cl_2 (l) ⇌ 2 Cl (g), representing the dissociation of liquid chlorine into gaseous chlorine atoms.

What does the Kp value of 3.2×10^{-8} indicate about the reaction at equilibrium?

A Kp of 3.2×10^{-8} indicates the reaction favors the reactants significantly, with very little dissociation of Cl_2 into Cl atoms at equilibrium.

Given the initial amount of 0.55 mol of Cl_2 (l), how do we determine the equilibrium concentrations of Cl_2 and Cl?

We set up an ICE table, define the change in moles of Cl_2 dissociated as x, and use the Kp expression to solve for x, then calculate equilibrium amounts.

How is the Kp expression written for the reaction Cl_2 (l) ⇌ 2 Cl (g)?

$Kp = (P_{Cl})^2 / P_{Cl_2}$, where P_{Cl} is the partial pressure of Cl atoms and P_{Cl_2} is the partial pressure of Cl_2.

Why is the initial amount of 0.55 mol relevant in calculating the equilibrium state?

It provides the initial concentration of Cl_2, which is necessary to determine the extent of dissociation and to set up the equilibrium calculations.

Can we determine the partial pressures directly from initial molar amounts? How?

Yes, by assuming a certain volume and using the ideal gas law to convert moles to partial pressures at given conditions.

What assumptions are typically made when calculating equilibrium for this reaction?

Assumptions include ideal gas behavior, constant temperature, and that the initial amount of Cl_2 is fully in liquid form with no initial Cl atoms present.

If the reaction shifts to produce more Cl atoms, how will the Kp value influence this shift?

Since the Kp is very small, the reaction strongly favors reactants, so the equilibrium will have minimal Cl atom formation, and the reaction will not shift significantly to produce more Cl.

What is the significance of the fact that Cl_2 is in liquid form initially in this equilibrium calculation?

It indicates the initial partial pressure of Cl_2 may be low or zero if it's purely in liquid state, and the calculation must account for phase changes and vapor pressures if applicable.

How would a change in temperature affect the Kp value for this reaction?

Since dissociation reactions are often endothermic or exothermic, changing temperature will shift the equilibrium and alter Kp accordingly, following Le Châtelier's principle.

Additional Resources

For A Chemical Reaction: Cl_2 (l) ⇌ 2 Cl (g) Has A Kp = 3.2×10^{-8}, And The Initial Amounts Are: 0.55 Mol

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Introduction

Chemical equilibria form the backbone of understanding complex reactions in chemistry. They determine the proportions of reactants and products present at equilibrium, guiding chemists in predicting reaction behavior, optimizing yields, and controlling processes across industries. Among such reactions, the equilibrium involving chlorine, particularly the transition between liquid chlorine (Cl_2 (l)) and gaseous chlorine atoms (Cl (g)), exemplifies the subtle interplay of thermodynamics and kinetics.

This review focuses on a specific equilibrium: Cl_2 (l) ⇌ 2 Cl (g), characterized by a low equilibrium constant (Kp = 3.2×10^{-8}). The initial state involves an amount of 0.55 mol of chlorine, and the goal is to analyze the system's behavior, calculate equilibrium concentrations, and understand the implications of such a small Kp value.

Understanding the Reaction and Its Equilibrium Constant

The Reaction

The chemical equation under consideration is:

Cl_2 (l) ⇌ 2 Cl (g)

This reaction involves the dissociation of liquid chlorine into atomic chlorine gas. It is an endothermic process with a significant energy barrier, which explains the extremely small value of Kp.

Significance of the Equilibrium Constant (Kp)

Kp, the equilibrium constant expressed in terms of partial pressures, indicates the extent to which the reaction proceeds toward products at equilibrium. For this reaction, $Kp = 3.2 \times 10^{-8}$, a very small number, suggests that at equilibrium, the concentration of atomic chlorine gas is negligible compared to molecular chlorine in the liquid phase.

- Implication: The formation of Cl (g) from Cl_2 (l) is highly unfavorable under standard conditions, favoring the reactant side.

Thermodynamic Foundations

Relation Between Kp and Gibbs Free Energy

The relation:

$\Delta G° = -RT \ln(Kp)$

where $\Delta G°$ is the standard Gibbs free energy change, R is the universal gas constant (8.314 J mol^{-1} K^{-1}), and T is the temperature in Kelvin.

Given the small Kp, $\Delta G°$ is positive, indicating non-spontaneity under standard conditions, which aligns with the known stability of Cl_2 (l).

Effect of Temperature

Temperature variations can influence Kp significantly, especially for dissociation reactions. Raising temperature usually favors endothermic dissociation, increasing Kp. However, given the very small Kp, even at higher temperatures, the dissociation remains minimal unless extreme conditions are applied.

Quantitative Analysis: Initial Conditions and Equilibrium Calculations

Initial Conditions

- Moles of Cl_2 (l): 0.55 mol
- Moles of Cl (g): 0 mol (initially)
- Assumption: The liquid phase is vast compared to the gaseous phase, so volume effects are negligible in the initial phase.

Approach to Calculation

Since the initial amount of Cl_2 is 0.55 mol, and the reaction produces atomic chlorine gas, we define:

- x = moles of Cl_2 (l) dissociated into Cl (g).

At equilibrium:

- Moles of Cl_2 (l): 0.55 - x
- Moles of Cl (g): 2x

The partial pressure of Cl (g) depends on its mole fraction and total pressure, but for simplicity, assuming ideal gas behavior and constant volume and temperature, the partial pressure of Cl (g):

$P_{Cl} = (n_{Cl} / n_{total}) \times P_{total}$

Given the minute extent of dissociation, we can approximate the total pressure primarily from the gaseous Cl, making the calculations manageable.

Derivation of Equilibrium Expression

Equilibrium Constant in Terms of Partial Pressure

$K_p = (P_{Cl})^2 / (1)$ (since the activity of pure liquid Cl_2 is 1)

Expressed explicitly:

$K_p = ((y_{Cl} \times P_{total}))^2$

where y_{Cl} is the mole fraction of Cl in the gas phase.

Assuming ideal gas behavior and that the gas phase is mostly Cl (g), the partial pressure P_{Cl} can be approximated as:

$P_{Cl} \approx (2x / (0.55 - x + 2x)) \times P_{total}$

But because x is very small (due to small Kp), the denominator simplifies to approximately 0.55 mol.

Thus:

$P_{Cl} \approx (2x / 0.55) \times P_{total}$

Substituting into the Kp expression:

$K_p \approx [(2x / 0.55) \times P_{total}]^2$

Rearranged:

$x \approx ((\sqrt{K_p}) \times 0.55) / (2 \times P_{total})$

Numerical Calculations

Assumptions

- Total pressure, P_total: 1 atm (standard pressure)
- Temperature, T: 298 K (room temperature)

Calculating:

$\sqrt{Kp} = \sqrt{(3.2 \times 10^{-8})} \approx 5.66 \times 10^{-4}$

Then:

$x \approx (5.66 \times 10^{-4} \times 0.55) / (2 \times 1 \text{ atm})$

$x \approx (3.11 \times 10^{-4}) / 2$

$x \approx 1.56 \times 10^{-4}$ mol

This indicates that approximately 0.000156 mol of Cl_2 has dissociated into Cl (g) at equilibrium.

Concentrations and Pressures

- Moles of Cl (g): $2x \approx 3.12 \times 10^{-4}$ mol
- Partial pressure of Cl (g):

$P_{Cl} \approx (2x / 0.55) \times P_{total}$

$P_{Cl} \approx (3.12 \times 10^{-4} / 0.55) \times 1 \text{ atm} \approx 5.67 \times 10^{-4}$ atm

This minuscule pressure confirms the negligible extent of dissociation under standard conditions.

Implications and Practical Considerations

Reaction Extent and Feasibility

The calculations demonstrate that, under standard conditions, the dissociation of liquid chlorine into atomic chlorine gas is practically insignificant. This aligns with the very small Kp value, highlighting the stability of Cl_2 (l) and the energy barrier to forming Cl (g).

Industrial Relevance

- Chlorine Reactivity: Atomic chlorine is a potent oxidizer, but its formation from liquid chlorine is thermodynamically unfavorable at ambient conditions.
- Storage and Handling: Liquid chlorine remains stable, with negligible spontaneous dissociation, simplifying storage considerations.

Effect of External Factors

Raising temperature or applying radiation can shift the equilibrium, increasing the formation of Cl (g). For example:

- Elevated temperatures could increase Kp, making dissociation more feasible.
- Ultraviolet radiation can induce dissociation via photolytic pathways rather than thermodynamic equilibrium.

Limitations and Further Research

While the theoretical calculations provide insight, real-world systems may deviate due to:

- Non-ideal gas behavior at high pressures.
- Surface effects and impurities influencing equilibrium.
- Kinetic barriers preventing equilibrium from being reached within practical timescales.

Further research could involve experimental measurement of dissociation at various temperatures and pressures, as well as kinetic studies to understand reaction rates.

Conclusion

The equilibrium between liquid chlorine and atomic chlorine gas exemplifies the delicate balance dictated by thermodynamics. With a Kp of 3.2×10^{-8}, the dissociation reaction is heavily tilted toward the reactant side under standard conditions, with less than a millionth of the initial chlorine molecules dissociating. This underscores the stability of Cl_2 (l) and clarifies why, in typical environments, chlorine remains predominantly in its molecular form.

Understanding such equilibria is vital in fields ranging from industrial chemistry to environmental science, where controlling the form and reactivity of chlorine is crucial. The combination of thermodynamic principles, quantitative analysis, and practical implications provides a comprehensive picture of this system, illustrating the importance of fundamental concepts in real-world chemical processes.

References

- Atkins, P., & de Paula, J. (2010). Physical Chemistry. Oxford University Press.
- Zumdahl, S. S., & Zumdahl, S. A. (2014). Chemistry. Cengage Learning.
- Lide, D. R. (Ed.). (2004). CRC Handbook of Chemistry and Physics. CRC Press.
- National Institute of Standards and Technology (NIST). (2023). Thermochemical Data for Chlorine.

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