

Equilibrium Systems: Le Chatelier's Principle and the Equilibrium Law

30 minutes, 3 stages

Chemical equilibrium describes a balance of opposing reactions, not a stoppage of reaction ([Topic](#)). This assignment checks that you can state the criteria for equilibrium, write equilibrium-law expressions, and predict shifts using Le Chatelier's principle ([Outcome](#), [Outcome](#), [Outcome](#)).

Stage 1: Recall the criteria and write expressions (10 min)

Answer in full sentences where indicated.

1. State the three criteria that must all be true for a chemical system to be at equilibrium ([Outcome](#)).
2. A student claims that "equilibrium means the reaction has stopped." Explain why this statement is incorrect, using the term dynamic equilibrium and the idea of forward and reverse reaction rates ([Outcome](#)).
3. Write the equilibrium-law expression (K_c) for each equation below. Use lowest whole-number coefficients ([Outcome](#)).
 - a. $\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g})$
 - b. $2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g})$
 - c. $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$
4. For the equilibrium in question 3a, if the concentrations at equilibrium are $[\text{N}_2] = 0.20 \text{ mol/L}$, $[\text{H}_2] = 0.40 \text{ mol/L}$, and $[\text{NH}_3] = 0.60 \text{ mol/L}$, calculate the value of K_c .

Stage 2: Predict shifts with Le Chatelier's principle (12 min)

For each scenario, state the direction of the shift (toward reactants, toward products, or no shift), and explain your reasoning in one or two sentences. Then state what happens to the value of K_c ([Outcome](#)).

5. $\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g})$, $\Delta H = -92 \text{ kJ/mol}$ (exothermic).
The temperature of the system is increased. Predict the shift and the effect on K_c .
6. $2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g})$
The volume of the container is decreased at constant temperature. Predict the shift and explain using the total number of moles of gas on each side.
7. $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$
Additional $\text{Cl}_2(\text{g})$ is injected into the container at constant temperature and volume. Predict the shift and the effect on K_c .
8. A catalyst is added to the system in question 7. Predict the effect on the position of equilibrium and on the value of K_c , and explain the difference between the two.
9. Sketch a simple graph (concentration on the y-axis, time on the x-axis) showing $[\text{PCl}_3]$ before and after a stress that shifts the equilibrium toward products. Label the point where equilibrium is re-established ([Outcome](#)).

Stage 3: Apply equilibrium to a real system (8 min)

The Haber-Bosch process, $\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g})$, $\Delta H = -92 \text{ kJ/mol}$, is carried out industrially under high pressure and a moderate temperature rather than room temperature ([Outcome](#), [Outcome](#)).

10. Using Le Chatelier's principle, explain why running this process at high pressure favours a higher yield of ammonia.
11. Increasing temperature speeds up the reaction but Le Chatelier's principle predicts it lowers the yield of ammonia in this exothermic reaction. Explain why an industrial plant would still choose a moderate, rather than a low, operating temperature. Consider both yield and rate in your answer.

Self-check

1. Can you name all three criteria for a system at equilibrium without looking back at Stage 1?
2. If you increase the concentration of a reactant in an equilibrium mixture, does K_c change? Explain why or why not.
3. In your own words, explain the difference between a shift in equilibrium position and a change in the value of K_c .