Simulation: Predicting Shifts in Equilibrium: Q vs K

FOR THE TEACHER

Summary
In this simulation, students will take a 15 question quiz. Each quiz question has two parts. The first part requires the student to calculate the value of the reaction quotient, Q. In the second portion of the question, the students will compare the value of Q to the equilibrium constant, K, and predict which way the reaction will shift to reach equilibrium. The simulation includes five different reactions which each have three scenarios: Q > K, Q = K, and Q < K.

Grade Level
High school

NGSS Alignment
This simulation will help prepare your students to meet the performance expectations in the following standards:

- **HS-PS1-6**: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
- **Scientific and Engineering Practices**:
  - Using Mathematics and Computational Thinking
  - Analyzing and Interpreting Data

AP Chemistry Curriculum Framework
This simulation supports the following unit, topics and learning objectives:

- **Unit 7: Equilibrium**
  - **Topic 7.1**: Introduction to Equilibrium
    - TRA-6.A: Explain the relationship between the occurrence of a reversible chemical or physical process, and the establishment of equilibrium, to experimental observations.
  - **Topic 7.2**: Direction of Reversible Reactions
    - TRA-6.B: Explain the relationship between the direction in which a reversible reaction proceeds and the relative rates of the forward and reverse reactions.
  - **Topic 7.3**: Reaction Quotient and Equilibrium Constant
    - TRA-7.A: Represent the reaction quotient Qc or Qp, for a reversible reaction, and the corresponding equilibrium expressions Kc=Qc or Kp=Qp.
  - **Topic 7.4**: Calculating the Equilibrium Constant
    - TRA-7.B: Calculate Kc or Kp based on experimental observations of concentrations or pressures at equilibrium.
  - **Topic 7.5**: Magnitude of the Equilibrium Constant
    - TRA-7.C: Explain the relationship between very large or very small values of K and the relative concentrations of chemical species at equilibrium.
  - **Topic 7.7**: Calculating Equilibrium Concentrations
    - TRA-7.E: Identify the concentrations or partial pressures of chemical species at equilibrium based on the initial conditions and the equilibrium constant.
  - **Topic 7.9**: Introduction to Le Châtelier’s Principle
  - **Topic 7.10**: Reaction Quotient and Le Châtelier’s Principle
TRA-8.B: Explain the relationships between Q, K, and the direction in which a reversible reaction will proceed to reach equilibrium.

Objectives
By the end of this simulation, students should be able to:
- Calculate the value of the reaction quotient given an initial set of concentrations for the reactants and product.
- Compare the values of the reaction quotient and the equilibrium constant.
- Predict the direction the reaction will shift to reach equilibrium.

Chemistry Topics
This simulation supports students’ understanding of:
- Establishing equilibrium
- Equilibrium constant
- Reaction quotient
- Le Chatelier’s Principle

Time
Teacher Preparation: minimal
Lesson: 30–45 minutes

Materials
- Computer, tablet or phone with internet access

Safety
- No specific safety precautions need to be observed for this activity.

Teacher Notes
- This simulation should be used after a teacher has introduced the concept of equilibrium constants, reactions quotients, and shifts in equilibrium from a set of initial conditions.
- Each quiz includes five different generic reactions. The quiz rotates through them.
- Each reaction has three different conditions: Q > K, Q = K, and Q < K. The quiz rotates through them.
- The quiz is not randomized. All students will see the 15 sets of reactions and conditions in the same order. However, your students may not need to complete all 15 if they have mastered the concept.
- The simulation can be found at either of the following links (note that students can access the simulation without an AACT login):
  - teachchemistry.org/QvsK
FOR THE STUDENT

Lesson

Predicting Shifts in Equilibrium: Q vs K

Background

If only reactants are present at the beginning of a reaction, you know that the reaction will “go right” and produce products until equilibrium is established. However, if both the reactants and products are present at the beginning of a reaction, you must compare the values of the reaction quotient, Q, to the value of the equilibrium constant, K, to determine which way the reaction will shift to reach equilibrium. The value of Q is calculated the same way that K is calculated, except you use the initial concentrations if the reactants and products.

\[
\begin{align*}
\text{A} + \text{B}_2 & \leftrightarrow \text{AB}_2 \\
K &= \frac{[\text{AB}_2]_{\text{final}}}{[\text{A}]_{\text{final}}[\text{B}_2]_{\text{final}}} \\
Q &= \frac{[\text{AB}_2]_{\text{initial}}}{[\text{A}]_{\text{initial}}[\text{B}_2]_{\text{initial}}}
\end{align*}
\]

Figure 1. Sample equations for K and Q for the reaction \( \text{A} + \text{B}_2 \leftrightarrow \text{AB}_2 \)

Comparing Q and K

- If the value of Q is greater than that of K, it means that there are not enough reactants present and the reaction will shift left, towards the reactants until equilibrium is established.
- If the value of Q is equal to that of K, the reaction is at equilibrium.
- If the value of Q is less than that of K, it means that there are not enough products present and the reaction will shift right, towards the products until equilibrium is established.

Instructions

1. Log on to the simulation: teachchemistry.org/QvsK
2. Calculate the value of the reaction quotient and compare it to the value of the equilibrium constant for each of the reactions. Enter the value using scientific notation.
3. Predict which way the reaction will shift to reach equilibrium.

| Write the reaction and the initial concentration of the reactants and products. | Calculate the value of Q and enter it using scientific notation. | In which direction will equilibrium shift? Explain your answer. |