Shifting the Balance

Predict changes in a reacting gas mixture

CHE.11.1 "Enrichment: Construct explanations to explain how to use Le Chatelier's principle to predict the effect of changes in concentration, temperature, and pressure..."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Underline the three rules for predicting a shift, circle the gas-molecule counts on each side of the reaction, and number the two signs that a new equilibrium has been reached.

Inside the Ammonia Vessel

1. At a fertilizer plant, nitrogen and hydrogen react in a sealed vessel: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ + heat. The double arrow means that ammonia can form while ammonia can also break down into nitrogen and hydrogen. The forward reaction releases heat, so heat belongs on the product side. On the left, one nitrogen molecule and three hydrogen molecules give four gas molecules in all. On the right, there are two gas molecules. Counting gas molecules and locating heat will help you predict how the mixture responds when operating conditions change.

2. Le Chatelier's principle predicts the direction of a system's response to a disturbance. A mixture at equilibrium can respond to a change in concentration by favoring the direction that consumes what was added or replaces what was removed. Raising temperature favors the direction that absorbs heat; lowering temperature favors the direction that releases heat. Increasing pressure by squeezing a fixed amount of gas into a smaller volume favors the side with fewer gas molecules. Decreasing pressure by expanding the volume favors the side with more. These shifts describe the net change in composition, not an abrupt halt to either reaction.

3. Inside the vessel, particles continue reacting even after the mixture appears unchanged. At equilibrium, the forward and reverse reactions occur at equal rates, so the concentrations of reactants and products stay constant, although they need not be equal. A sealed vessel held at steady temperature can reach a new equilibrium after its contents or volume changes. During the adjustment, the two rates differ and concentrations change. Once the concentrations level off again, equal opposing rates indicate that equilibrium has been reestablished. This distinction matters in a plant: a steady ammonia reading does not mean that the chemical reactions have stopped.

2 ANSWER WITH EVIDENCE

Use the passage

1. More hydrogen is added to the vessel at a steady temperature and volume. Which direction will the reaction shift, and what will happen to the amount of ammonia?

2. The vessel is heated. Which direction will the reaction shift, and why?

3. The vessel's volume is increased, lowering the pressure. Which direction will the reaction shift? Use the gas-molecule counts to explain.

4. After a change, the vessel is kept sealed at a fixed volume and temperature. Its ammonia concentration changes for a while, then stays constant. What does this indicate about the reaction rates? Have the reactions stopped?

3 YOUR TURN

Your own words

For $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ + heat, invent two separate changes, one to concentration and one to pressure. Predict and explain each shift, then state how you would know a new equilibrium had formed.

Shifting the Balance

PART 1 · READ AND MARK

Underline the three rules for predicting a shift, circle the gas-molecule counts on each side of the reaction, and number the two signs that a new equilibrium has been reached. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	More hydrogen is added to the vessel at a steady temperature and volume. Which direction will the reaction shift, and what will happen to the amount of ammonia?	**The reaction shifts right to consume some added hydrogen, producing more ammonia.**
2	The vessel is heated. Which direction will the reaction shift, and why?	**It shifts left because the reverse reaction absorbs heat.**
3	The vessel's volume is increased, lowering the pressure. Which direction will the reaction shift? Use the gas-molecule counts to explain.	**It shifts left, toward four gas molecules rather than two.**
4	After a change, the vessel is kept sealed at a fixed volume and temperature. Its ammonia concentration changes for a while, then stays constant. What does this indicate about the reaction rates? Have the reactions stopped?	**A new equilibrium has been reached: the forward and reverse rates are equal, but both reactions continue.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

If SO_3 is removed, the reaction shifts right to replace some of it. In a separate trial, squeezing the vessel increases pressure, so the reaction shifts right toward the side with fewer gas molecules, two instead of three. After either change, a new equilibrium has formed when concentrations stay constant and the forward and reverse rates are equal.

Accept left or right in place of reactants or products. For the final task, each proposed change must have a shift and a matching explanation; equilibrium requires equal opposing rates and constant concentrations.