# LECHÂTELIER - INTRODUCTION TO COLLEGE CHEMISTRY
# FORMATIVE ASSESSMENT - KEY

## STUDENT CHECK FOR UNDERSTANDING

**Concepts:**
Relative Reaction Rates, Equilibrium Constant, LeChatelier's Principle (concentration, pressure, and temperature)

**DIRECTIONS:**
Consider the following endothermic, reversible reaction at equilibrium in a reaction vessel:

$N_2O_4(g) + \text{Heat} \rightleftharpoons 2NO_2(g)$ $\quad \Delta H = +58 \text{ kJ mol}^{-1}$

For each change to the system, determine what happens to the **number of molecules of the reactant, number of molecules of the product, and reaction rates (both directions)** at equilibrium compared to initial conditions. Use the terms "increase", "decrease", and "no change" for each scenario. For the "Shift Towards" column use the terms "reactant", "product", or "no shift". Explain your reasoning in the "Justification" column.

| Scenario | Number of $N_2O_4$ molecules at equilibrium | Number of $NO_2$ molecules at equilibrium | Equilibrium Reaction Rates | Shift Towards... | Justification |
|---|---|---|---|---|---|
| The partial pressures of $N_2O_4$ and $NO_2$ in the vessel are reduced. | Decrease | Increase | Decrease | Reactant | According to LeChâtelier's Principle, a decrease in partial pressures drives the reaction towards the side with more moles of gas. In this case, that is the product since the reaction stoichiometry tells us that 2 moles of $NO_2$ are produced from 1 mole of $N_2O_4$. A decrease in partial pressures also reduces collisions and thus reaction rates. |
| The temperature of the reaction is increased by submerging it in a warm water bath. | Decrease | Increase | Increase | Products | As demonstrated by the equation and positive enthalpy, this reaction is endothermic. Treating heat as a reactant makes increasing the temperature equivalent to increasing the concentration of a reactant. In this case, the reaction will shift towards the products and lead to an increase in the number of product particles and a decrease in the number of reactant particles. The increased temperature also increases collisions and thus increases the reaction rates. |

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| The number of moles of $N_2O_4$ in the reaction vessel is doubled. | Increase | Increase | Increase | Products | Assuming that the volume of the vessel remains the same, increasing the number of moles of $N_2O_4$ is an increase in the concentration of the reactant. According to LeChâtelier's Principle, an increase in the concentration of the reactant will shift it towards the products. Although addition of $N_2O_4$ directly increases its equilibrium concentration, the new equilibrium will also have a larger concentration of product due to the shift toward the products. The increased concentrations increase collisions and thus increase the reaction rate. |
| The partial pressures of $N_2O_4$ and $NO_2$ in the vessel are increased. | Increase | Decrease | Increase | Reactants | According to LeChâtelier's Principle, an increase in partial pressures drives the reaction towards the side with fewer moles of gas. In this case, that is the reactant since the reaction stoichiometry tells us that 2 moles of $NO_2$ are produced from 1 mole of $N_2O_4$. An increase in partial pressures increases collisions and thus reaction rates. |
| The temperature of the reaction is decreased by submerging it in a cold water bath. | Increase | Decrease | Decrease | Reactants | As demonstrated by the positive enthalpy, this reaction is endothermic. Treating heat as a reactant makes decreasing the temperature equivalent to decreasing the concentration of a reactant. In this case, the reaction will shift towards the reactants and lead to an increase in the concentration of the reactant and a decrease in the concentration of the product. The decreased temperature decreases collisions and thus decreases the reaction rates. |
| The number of moles of $NO_2$ in the reaction vessel is doubled. | Increase | Increase | Increase | Reactants | Assuming that the volume of the vessel remains the same, doubling the number of moles of $NO_2$ is an increase in the concentration of the product. According to LeChâtelier's Principle, an increase in the concentration of the product will shift it towards the reactants. Although addition of $NO_2$ directly increases its equilibrium concentration, the new equilibrium will also have a larger concentration of $N_2O_4$ due to the shift toward the reactants. |