LECHÂTELIER - GENERAL 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 first-order, reversible reaction at equilibrium in a reaction vessel:

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

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 volume of the reaction vessel is reduced.	Increase	Decrease	Increase	Reactant	When the volume decreases, the pressure increases. 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 reactants. The decreased volume also increases collisions and thus increases the reaction rates.
The temperature of the reaction is increased by submerging the vessel in warm water.	Decrease	Increase	Increase	Products	As demonstrated by the 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.

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.
A catalyst is added to the reaction vessel that speeds up both the forward and reverse reactions to the same extent.	No Change	No Change	Increase	No Shift	As the statement tells us, the catalyst increases the rate of the reaction in both directions. Since it does so to the same extent, NO_2 and N_2O_4 will be formed at the same rate. This means that there will be no change in the equilibrium concentration.
The volume of the reaction vessel is increased.	Decrease	Increase	Decrease	Products	Increasing the volume of the vessel decreases the partial pressures. According to LeChâtelier's Principle, a decrease in pressure shifts the reaction towards the side with more moles of gas. In this case, the reaction stoichiometry shows us that 2 moles of N_2O are produced from 1 mole of N_2O_4. Accordingly, the number of N_2O molecules will increase although the reaction rate will decrease due to a lower frequency of collisions.
The temperature of the reaction is decreased by submerging the vessel in cold water.	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.
NO_2 is selectively removed from the reaction chamber as it is generated.	Decrease*	Decrease*	Decrease	Products	If NO_2 is selectively removed from the reaction chamber as it is generated, the reaction rates in both directions will decrease due to decreased concentrations. The reaction, however, will never have the opportunity to reach a new equilibrium because it will continuously be shifting to the product.

***The equilibrium concentrations in this case are not exactly decreasing so much as they are just never achieved due to the constant shifting of the reaction. If the removal of NO2 were suddenly stopped part way and the reaction were allowed to reach equilibrium, the equilibrium concentrations would indeed be lower than the initial ones but shifted towards the product.**