59. a. No effect; Adding more of a pure solid or pure liquid has no effect on the equilibrium position.

b. Shifts left; HF(g) will be removed by reaction with the glass. As HF(g) is removed, the reaction will shift left to produce more HBr(g).

c. Shifts right; As HBr(g) is removed, the reaction will shift right to produce more HCl(g).

60. When the volume of a reaction container is increased, the reaction itself will want to increase its own volume by shifting to the side of the reaction which contains the most molecules of gas. When the molecules of gas are equal on both sides of the reaction, then the reaction will remain at equilibrium no matter what happens to the volume of the container.

a. Reaction shifts left (to reactants) since the reactants contain 4 molecules of gas compared to 2 molecules of gas on the product side.

b. Reaction shifts right (to products) since there are more product molecules of gas (2) as compared to reactant molecules (1).

c. No change since there are equal reactant and product molecules of gas.

d. Reaction shifts right.

e. Reaction shifts right to produce more CO₂(g). One can ignore the solids and only concentrate on the gases since gases occupy a relatively large volume as compared to solids. We make the same assumption when liquids are present (only worry about the gas molecules).

61. a. Right    b. Right    c. No effect; H₂(g) is neither a reactant nor a product.

d. Left; Since the reaction is exothermic, heat is a product:

\[
\text{CO(g)} + \text{H₂O(g)} \rightarrow \text{H₂(g)} + \text{CO₂(g)} + \text{Heat}
\]

Increasing T will add heat. The equilibrium shifts to the left to use up the added heat.

e. No effect; Since there are equal numbers of gas molecules on both sides of the reaction, then a change in volume has no effect on the equilibrium position.

62. a. The moles of SO₃ will increase since the reaction will shift left to use up the added O₂(g).

b. Increase; Since there are fewer reactant gas molecules than product gas molecules, then the reaction shifts left with a decrease in volume.

c. No effect; The partial pressures of sulfur trioxide, sulfur dioxide, and oxygen are unchanged.

d. Increase; Heat + 2 SO₂ = 2 SO₃ + O₂; Decreasing T will remove heat, shifting this endothermic reaction to the left.

e. Decrease

63. a. Left    b. Right    c. Left

d. No effect (reactant and product concentrations are unchanged)

e. No effect; Since there are equal numbers of product and reactant gas molecules, then a change in volume has no effect on the equilibrium position.

f. Right; A decrease in temperature will shift the equilibrium to the right since heat is a product in this reaction (as is true in all exothermic reactions).

64. a. Shift to left

b. Shift to right; Since the reaction is endothermic (heat is a reactant), then an increase in temperature will shift the equilibrium to the right.

c. No effect    d. Shift to right

e. Shift to right; Since there are more gaseous product molecules than gaseous reactant molecules, then the equilibrium will shift right with an increase in volume.

65. In an exothermic reaction, heat is a product. To maximize yield of products, one would want as low a temperature as possible since high temperature would shift the reaction left (away from products). Since temperature changes also change the value of K, then at low temperatures the value of K will be larger which maximizes yield of products.

66. As temperature increases, the value of K decreases. This is consistent with an exothermic reaction. In an exothermic reaction, heat is a product and an increase in temperature shifts the equilibrium to the reactant side (as well as lowering the value of K).