Using Le Châtelier's Principle
(Student textbook page 439)

21. In which direction does the following reaction shift if the temperature increases? Explain why.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g) + 52\ kJ$$

What Is Required?
You have to determine the direction a system at equilibrium will shift when the temperature increases.

What Is Given?
You know the balanced thermochemical equation for the reaction.

Plan Your Strategy	Act on Your Strategy
Identify the heat term and in which direction the endothermic reaction occurs.	The reverse reaction is endothermic.
Identify how the system will temporarily shift before equilibrium is restored.	The position of equilibrium will shift to use some of the heat that is introduced to the system with an increase in temperature. The reaction will shift to the left, in the direction of the endothermic reaction.

Check Your Solution
The shift in the position of equilibrium agrees with the prediction based on Le Châtelier's principle.

22. In the gaseous equilibrium system shown below, the volume of the container is increased, causing a decrease in pressure. In which direction does the reaction shift? Explain why.

$$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$$

What Is Required?
You have to determine the direction a system at equilibrium will shift when the volume of the container is increased causing a decrease in the pressure.

What Is Given?
You know the balanced equation for the reaction.

Plan Your Strategy	Act on Your Strategy
Determine on which side of the equation there are more particles.	There is the same number of particles on both sides of the reaction.
Identify how the system will temporarily shift before equilibrium is restored.	As the reaction proceeds, there is no change in the number of gas molecules on each side of the equation. Therefore, increasing the volume of the container has no effect on the position of equilibrium.

Check Your Solution
The position of equilibrium changes only when the rate of either the forward or the reverse reaction is favoured. There will be no change in the position of equilibrium.

23. In the gaseous equilibrium system shown below, the volume of the container is increased, causing a decrease in pressure. In which direction does the reaction shift? Explain why.

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

What Is Required?
You have to determine the direction a system at equilibrium will shift when the volume of the container is increased causing a decrease in the pressure.

What Is Given?
You know the balanced equation for the reaction.

Plan Your Strategy	Act on Your Strategy
Determine on which side of the equation there are more particles.	There are more gas molecules on the left side of the equation.
Identify how the system will temporarily shift before equilibrium is restored.	The position of equilibrium will shift to favour the formation of more particles. Therefore, increasing the volume of the container causes the reaction to shift to the left.

Check Your Solution
The shift in the position of equilibrium agrees with the prediction based on Le Châtelier's principle.

24. In the gaseous equilibrium system shown below, the volume of the container is increased, causing a decrease in pressure. In which direction does the reaction shift? Explain why.

$$2CO_2(g) \rightleftharpoons 2CO(g) + O_2(g)$$

What Is Required?
You have to determine the direction a system at equilibrium will shift when the volume of the container is increased causing a decrease in the pressure.

What Is Given?
You know the balanced equation for the reaction.

Plan Your Strategy	Act on Your Strategy
Determine on which side of the equation there are more particles.	There are more gas molecules on the right side of the equation.
Identify how the system will temporarily shift before equilibrium is restored.	The position of equilibrium will shift to favour the formation of more particles. Therefore, increasing the volume of the container causes the reaction to shift to the right.

Check Your Solution
The shift in the position of equilibrium agrees with the prediction based on Le Châtelier's principle.

25. In the gaseous equilibrium system shown below, the volume of the container is increased, causing a decrease in pressure. In which direction does the reaction shift? Explain why.

$$CH_4(g) + 2H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g)$$

What Is Required?
You have to determine the direction a system at equilibrium will shift when the volume of the container is increased causing a decrease in the pressure.

What Is Given?
You know the balanced equation for the reaction.

Plan Your Strategy	Act on Your Strategy
Determine on which side of the equation there are more particles.	There are more gas molecules on the right side of the equation.
Identify how the system will temporarily shift before equilibrium is restored.	The position of equilibrium will shift to favour the formation of more particles. Therefore, increasing the volume of the container causes the reaction to shift to the right.

Check Your Solution
The shift in the position of equilibrium agrees with the prediction based on Le Châtelier's principle.

26. Toluene, $C_7H_8(\ell)$, is an important organic solvent. It is made industrially from methylcyclohexane, $C_7H_{14}(g)$:

$$C_7H_{14}(g) + \text{heat} \rightleftharpoons C_7H_8(g) + 3H_2(g)$$

State three different changes to an equilibrium mixture of these reacting gases that would shift the reaction toward greater production of toluene.

What Is Required?
You need to determine three different changes to an equilibrium mixture of reacting gases that would shift the reaction toward greater production of toluene, $C_7H_8(\ell)$.

What Is Given?
You know the balanced thermodynamic equation for the reaction.

Plan Your Strategy	Act on Your Strategy
Identify the side of the equation on which toluene, $C_7H_8(g)$, is found.	Toluene, $C_7H_8(g)$,is on the right side of the reaction
Apply Le Châtelier's principle to determine how the forward reaction can be favoured.	The forward reaction is endothermic. An increase in temperature will cause the position of equilibrium to shift to use some of the heat that is introduced to the system with an increase in temperature. The reaction will shift to the right, in the direction of the endothermic reaction. There are more particles on the right side of the equation. An increase in the volume of the system (or a decrease in the total pressure) will cause the position of equilibrium to shift to favour the formation of more particles. The reaction will shift to the right. An increase in the amount of reactant methylcyclohexane, $C_7H_{14}(g)$, will favour product formation. (Alternatively, product can be removed for the same effect). The reaction will shift to the right.

Check Your Solution
The shift in the position of equilibrium agrees with the predictions based on Le Châtelier's principle.

27. In which direction does the following reaction shift as a result of each of the following changes?

$$2NO(g) + 2H_2(g) \rightleftharpoons N_2(g) + 2H_2O(g) + \text{heat}$$

a. increasing the pressure of gases in the reaction vessel by decreasing the volume
b. increasing the pressure of gases in the reaction vessel by adding inert argon gas while keeping the volume of the vessel constant
c. increasing the temperature

What Is Required?
You need to predict in which direction the reaction will shift as a result of:
a. increasing the pressure of gases in the reaction vessel by decreasing the volume
b. increasing the pressure of gases in the reaction vessel by adding inert argon gas while keeping the volume of the vessel constant
c. increasing the temperature

What Is Given?
You know the balanced thermochemical equation for the reaction.

Plan Your Strategy	Act on Your Strategy
a. Identify on which side of the reaction there are fewer particles. **b.** Identify the effect of adding an inert gas at constant volume. **c.** Identify the heat term and in which direction in which the endothermic reaction occurs.	**a.** There are fewer particles on the right side of the reaction. **b.** At constant volume, there is no change in the concentration of any of the gases in this reaction. **c.** The reverse reaction is endothermic.
For each change, identify how the system will temporarily shift before equilibrium is restored.	**a.** The position of equilibrium will shift to favour the formation of fewer particles. Therefore, decreasing the volume of the container causes the reaction to shift to the right. **b.** There will no change in the position of equilibrium. **c.** The position of equilibrium will shift to use some of the heat that is introduced to the system with an increase in temperature. The reaction will shift to the left, in the direction of the endothermic reaction.

Check Your Solution
The shift in the positions of equilibrium agrees with the predictions based on Le Châtelier's principle.

28. In question 27, how does each of the changes affect K_{eq}? Explain your answers.

What Is Required?
You need to determine how each of the changes in the previous question affects K_{eq}.

What Is Given?
You know the balanced thermochemical equation from the previous question.

Plan Your Strategy	Act on Your Strategy
a. Identify the mole ratio of the components in the reaction.	The equation remains the same and the products and reactants are in the same mole ratio. Since the ratio of products to reactants does not change, the value of K_{eq} does not change.
b. Identify the mole ratio of the components in the reaction.	The equation remains the same and the products and reactants are in the same mole ratio. Since the ratio of products to reactants does not change, the value of K_{eq} does not change.
c. Identify which reaction is endothermic.	The reverse reaction is endothermic. An increase in temperature results in the formation of more reactant. A temperature change affects the forward and reverse reactions differently. The value of K_{eq} decreases when the temperature increases.

Check Your Solution
The answers agree with the predictions based on Le Châtelier's principle.

29. The following reaction is endothermic when read from left to right $N_2O_4(g) \rightleftharpoons 2NO_2(g)$. In which direction does the reaction shift as a result of each of the following changes?
a. adding $NO_2(g)$
b. adding a catalyst

What Is Required?
You need to determine in which direction the reaction shift as a result of each of:
a. adding $NO_2(g)$
b. adding a catalyst

What Is Given?
You know the balanced equation for the reaction and that the heat term is on the left.

Plan Your Strategy	Act on Your Strategy
a. Identify on which side of the reaction $NO_2(g)$ is found.	$NO_2(g)$ is on the right.
Identify how the system will temporarily shift before equilibrium is restored.	Increasing the concentration of $NO_2(g)$ will favour the formation of reactant. Therefore, adding more $NO_2(g)$ causes the reaction to shift to the left.
b. Identify how a catalyst affects the rate of reaction.	A catalyst increases the rate of both the forward and reverse reactions in the same way. There is no effect on the position of equilibrium.

Check Your Solution
The shift in the position of equilibrium agrees with the predictions based on Le Châtelier's principle.