

Factors That Affect Chemical Equilibrium

concentration

pressure

volume

temperature

catalysts have no effect on position of equilibrium

Le Chatelier's Principle

If an external stress is applied to a system at equilibrium, the system adjusts itself in such a way that the stress is partially offset.

Changes in Concentrations

(Le Chatelier's Principle)

Increase the yield of product by

- **increasing concentration of reactant**
- **removing the product from the equilibrium**

Example



at equilibrium:

0.683 M 8.80 M 1.05 M

Increase the concentration NH_3 to 3.65 M

(Le Chatelier's Principle)

the position of equilibrium shifts to the left

Example



at e

0.683 M

Increase

Q is greater than K ; the position of equilibrium shifts to the left

M

3.65 M

$$Q = \frac{[\text{NH}_3]^2}{[\text{N}_2] [\text{H}_2]^3} = \frac{(3.65)^2}{(.683) (8.80)^3}$$

$$Q = 0.0286$$

What about

$$K_c = [\text{Ba}^{2+}] [\text{SO}_4^{2-}]$$



Add $\text{Ba}^{2+} (aq)$

$[\text{SO}_4^{2-}]$ decreases

$\text{BaSO}_4 (s)$ increases

Add $\text{SO}_4^{2-} (aq)$

$[\text{Ba}^{2+}]$ decreases

$\text{BaSO}_4 (s)$ increases

Add $\text{BaSO}_4 (s)$

no change

Changes in Volume and Pressure

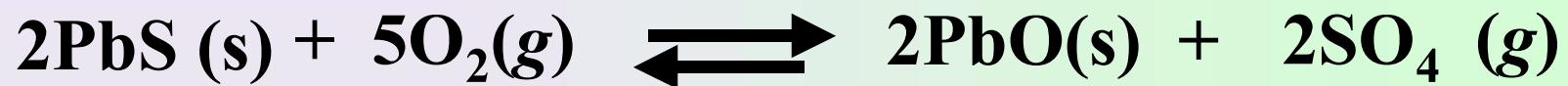
Little effect on reactions in solution

Effect can be large on reactions in the gas phase

- **Increase in pressure shifts the equilibrium to the side with the fewer moles of gas**

Practice Exercise

How does the position of equilibrium change as the pressure is increased?



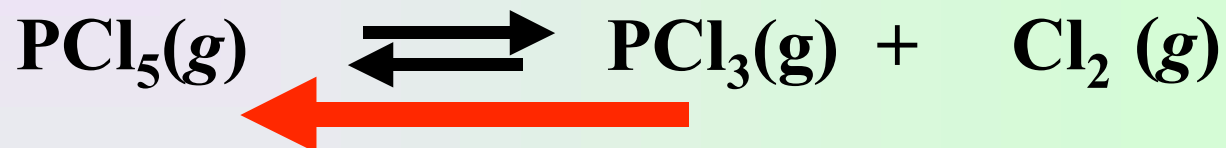
*five moles of
gaseous reactant*

*two moles of
gaseous product*

Increase in pressure causes an increase in products at the expense of reactants

Example

How does the position of equilibrium change as the pressure is increased?



*one mole of
gaseous reactant*

*two moles of
gaseous product*

**Increase in pressure causes some products
to revert to reactants**

Practice Exercise

How does the position of equilibrium change as the pressure is increased?



*two moles of
gaseous reactant*

*two moles of
gaseous product*

Increase in pressure leaves the position of equilibrium unchanged

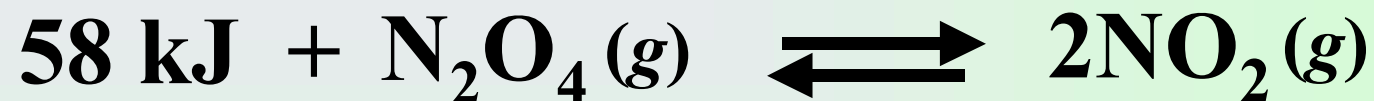
Changes in Temperature

Changes the value of the equilibrium constant

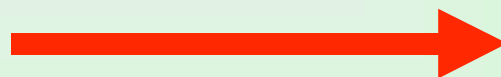
- **A temperature increase favors an endothermic reaction, and a temperature decrease favors an exothermic reaction**

Endothermic reaction

Shifts in the equilibrium position for the reaction:



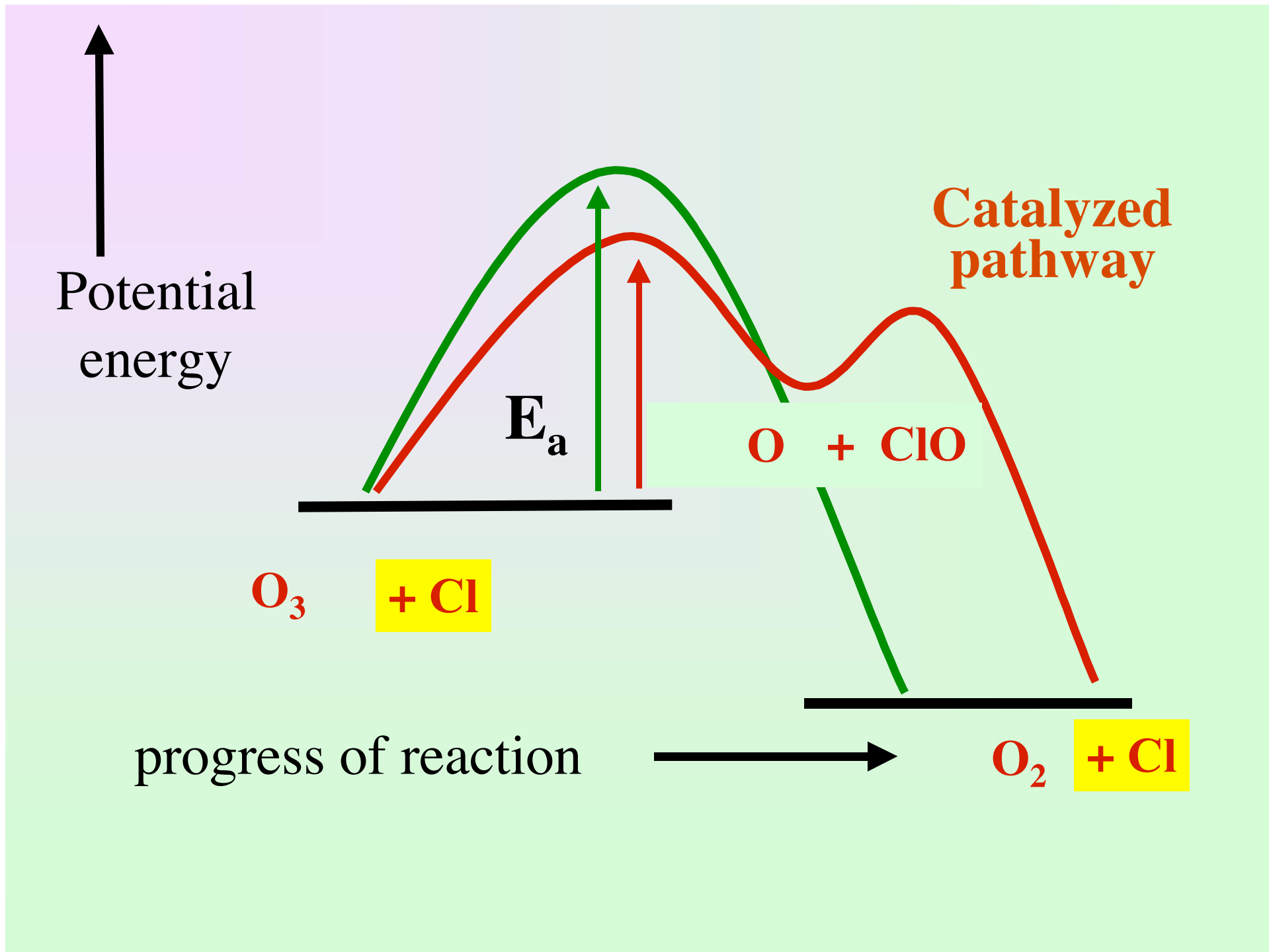
Increase
temperature:



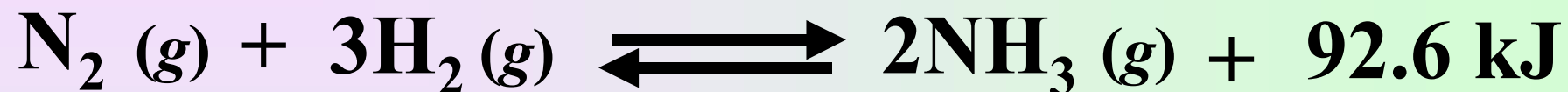
The Effect of a Catalyst

Increases rate, but has no effect on position of equilibrium

- effect of forward and reverse processes is the same**
- a catalyst increases both the rate of both the forward and reverse reactions**



The Haber Process

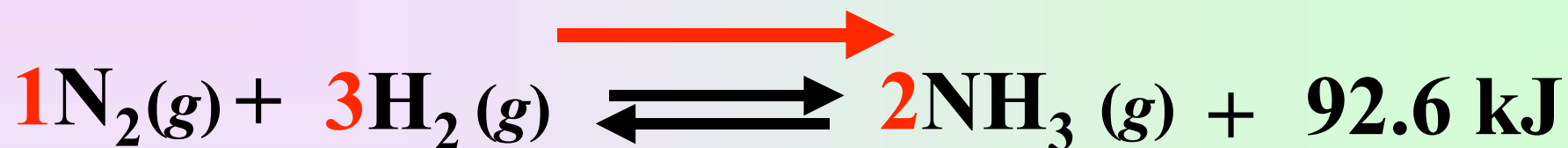


Maximize the yield of ammonia by:

carrying out the reaction at high pressure

$$K_p = \frac{P_{\text{NH}_3}^2}{P_{\text{N}_2} P_{\text{H}_2}^3}$$

The Haber Process



*four moles of
gaseous reactant*

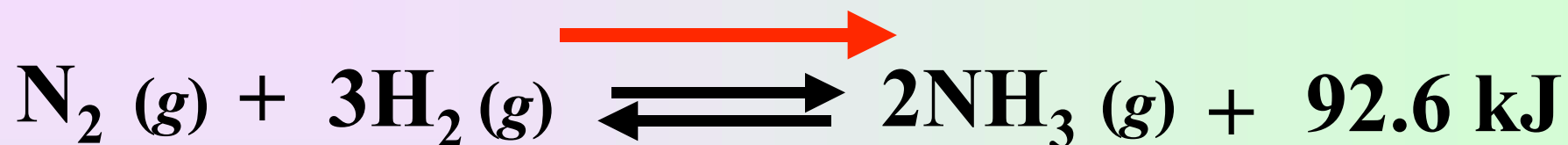
*two moles of
gaseous product*

Maximize the yield of ammonia by:

carrying out the reaction at high pressure

$$K_p = \frac{P_{\text{NH}_3}^2}{P_{\text{N}_2} P_{\text{H}_2}^3}$$

The Haber Process

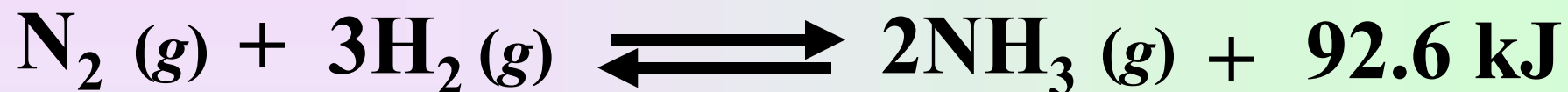


$$\Delta H^\circ = -92.6 \text{ kJ/mol}$$

Maximize the yield of ammonia by:

carrying out the reaction at low temperatures

The Haber Process



In practice the reaction is carried out at 500 °C because the rate is too slow at lower temperatures

