Equilibrium Systems

Chapter 7.1

Equilibrium Systems

$$2NO_{2(g)} \longrightarrow N_2O_{4(g)}$$

- When we look at a chemical equation we tend to think that:
  - the reaction proceeds in only one direction (from reactants to products)
  - the reaction goes to *completion*, or until one of the reactants runs out

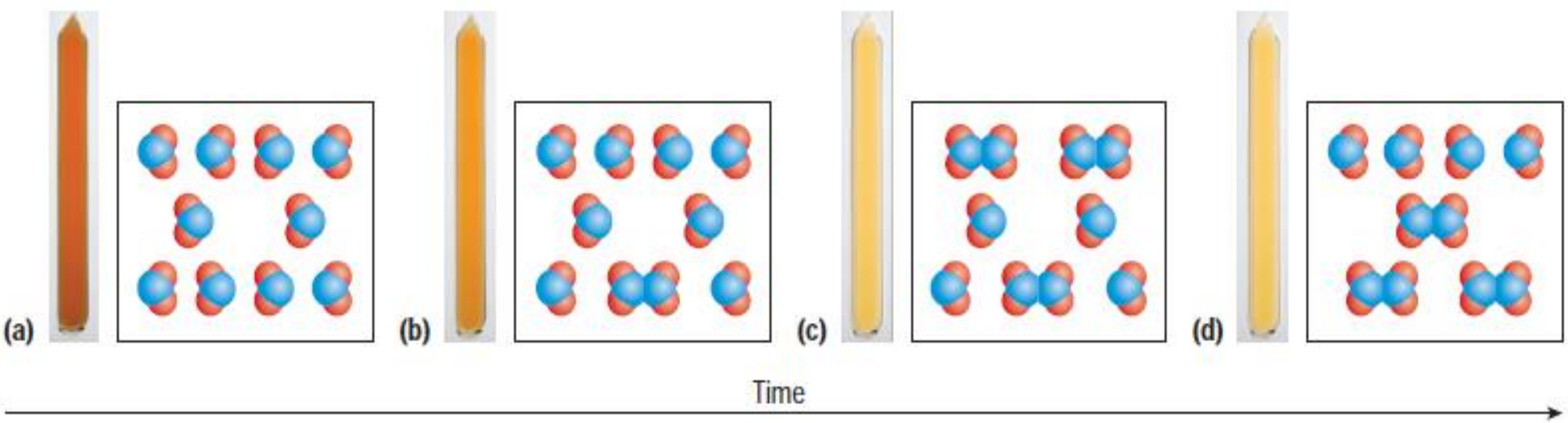
- But chemical reactions are not always like this!

Equilibrium Systems

$$2NO_{2(g)} \longrightarrow N_2O_{4(g)}$$

brown — colourless

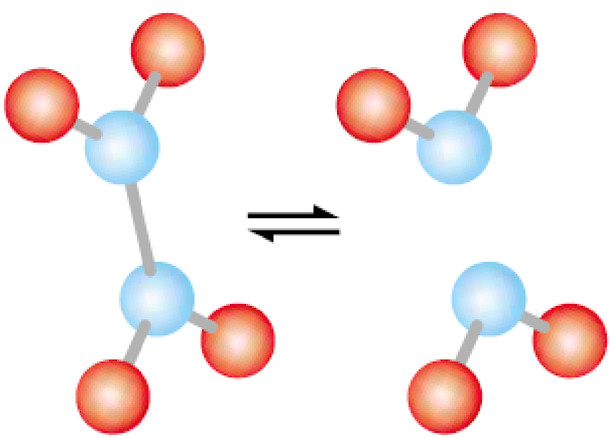
- When nitrogen dioxide is placed in a closed system, the following is observed

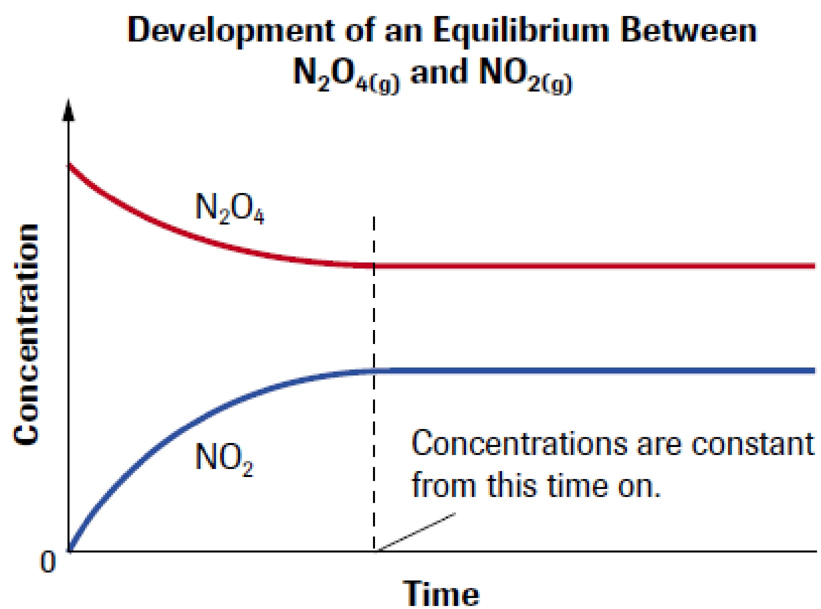


Equilibrium Systems

- **Chemical equilibrium** is the state of a reaction in which all reactants and products have reached constant concentrations in a *closed system*
- The **equilibrium position** is the relative concentrations of reactants and products in a system in dynamic equilibrium

$$N_2O_{4(g)} \leftrightarrow 2NO_{2(g)}$$





Equilibrium Reactions:

This is a reaction that has two directions, a forward and reverse reaction.

An equilibrium reaction is reversible

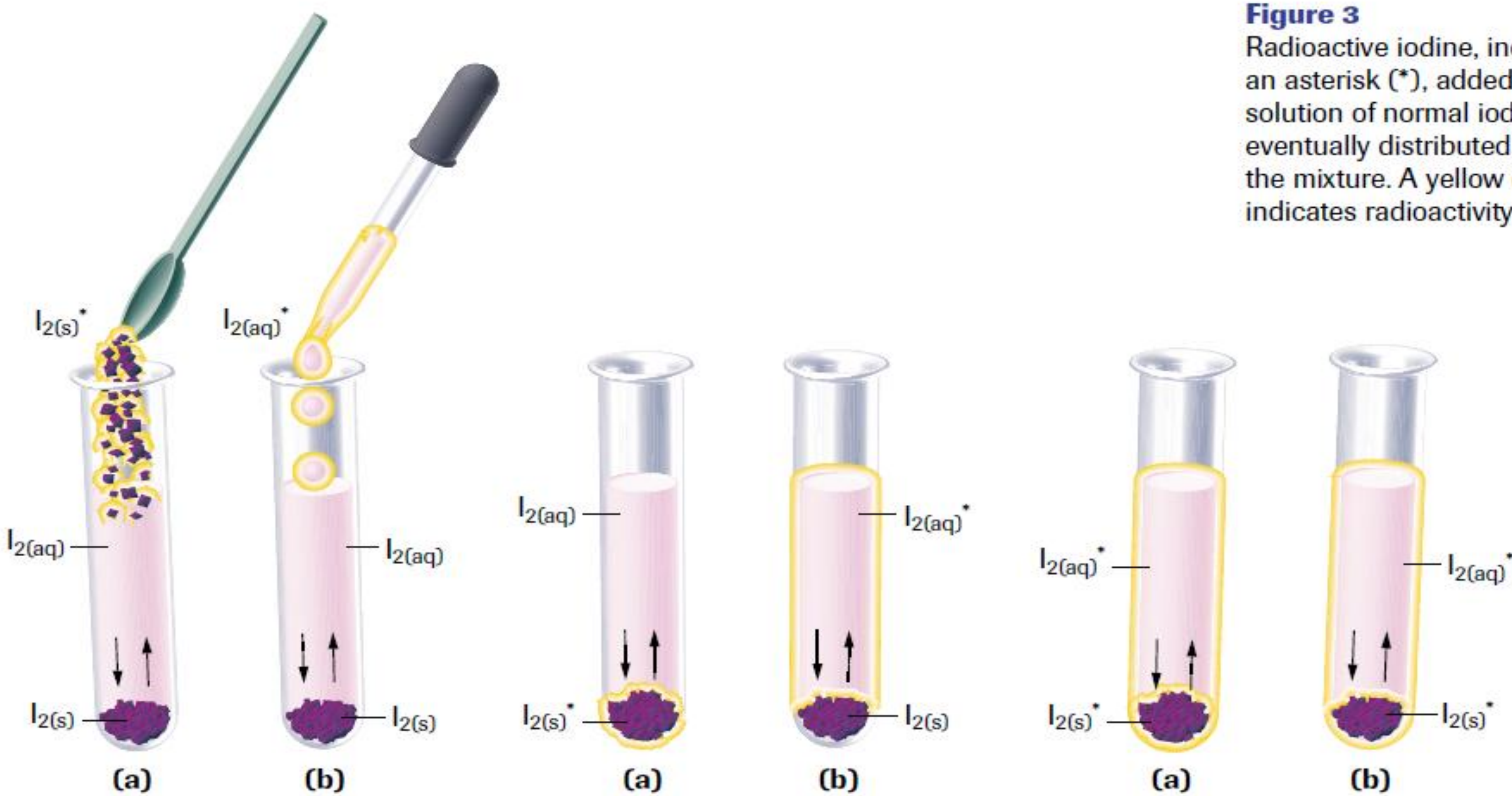
Forward reaction

$$H_2O_{(g)} + CO_{(g)} \rightleftharpoons H_{2\,(g)} + CO_{2\,(g)}$$

Reverse reaction

A **reversible reaction** is a chemical reaction that proceeds in both the forward and reverse directions, setting up an equilibrium in a closed system

Evidence for Equilibrium

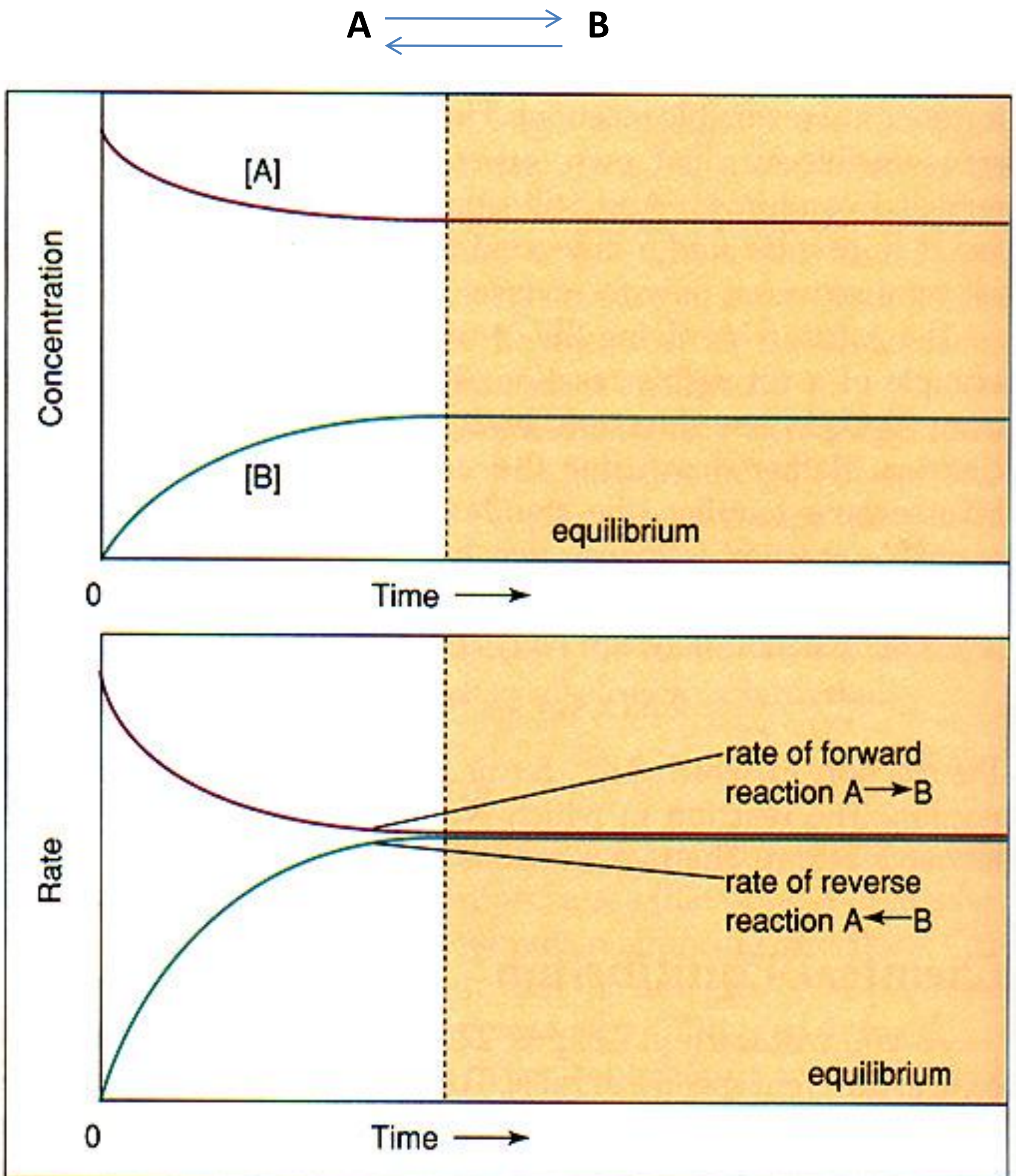


Radioactive iodine crystals are added to sample (a), and a saturated solution of radioactive iodine is added to sample (b).

At first, radioactivity is confined to the solid in (a) and the solution in (b).

After several hours, the radioactivity can be detected in both solutions and in both samples of solid iodine.

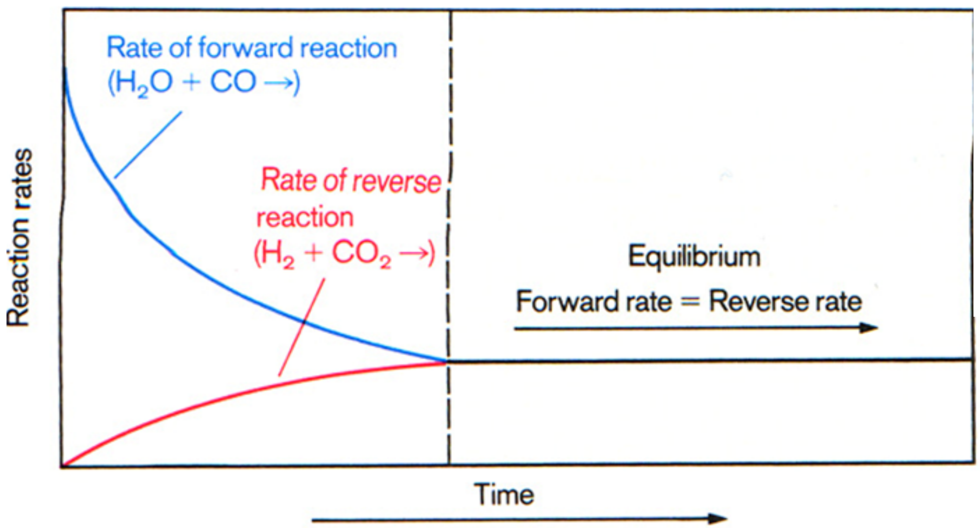
Figure 3
Radioactive iodine, indicated with an asterisk (*), added to a saturated solution of normal iodine (I_2), is eventually distributed throughout the mixture. A yellow outline indicates radioactivity.



Dynamic Equilibrium

- A chemical equilibrium is always a dynamic equilibrium
- A **dynamic equilibrium** is a balance in the *rates* between forward and reverse processes that are occurring simultaneously

Changes in reaction rates of the forward and reverse reaction for: $H_2O + CO \rightleftharpoons H_2 + CO_2$



Rate of forward reaction decreases while reverse increases till the concentrations reach a level at which the rate of the forward and reverse reactions is the same. The system has reached **equilibrium**.

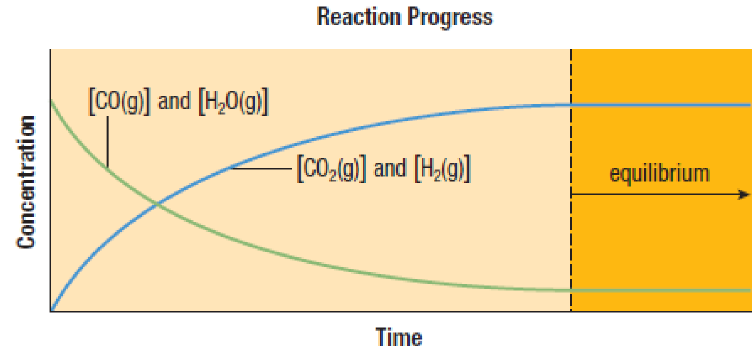


Figure 2 Changes in concentrations over time, when equal amounts of carbon monoxide gas and water vapour are allowed to react in a closed vessel

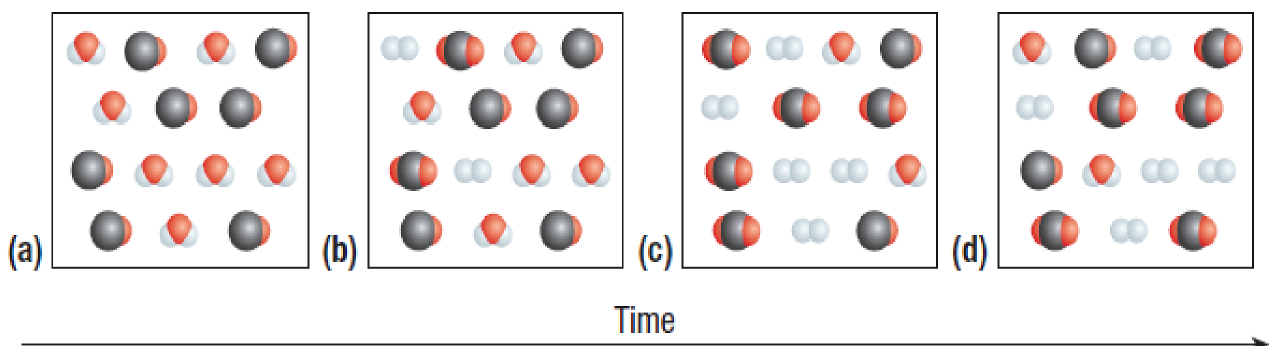


Figure 3 (a) Water vapour and carbon monoxide gas are mixed in equal amounts and (b) begin to react to form gaseous carbon dioxide and hydrogen. After some time, (c) equilibrium is reached and from that point on (d) the numbers of reactant and product molecules then remain constant over time.

Forward and Reverse Reactions

- For a closed chemical system in constant environmental conditions, the same equilibrium concentrations are reached regardless of the direction by which equilibrium was reached

Table 1 Changes in Concentrations of $NO_2(g)$ and $N_2O_4(g)$ by the Forward or Reverse Reactions

	Initial concentrations (mol/L)		Final concentrations (mol/L)	
	$N_2O_4(g)$	$NO_2(g)$	$N_2O_4(g)$	$NO_2(g)$
Experiment 1	0.750	0	0.721	0.0580
Experiment 2	0	1.50	0.721	0.0580

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

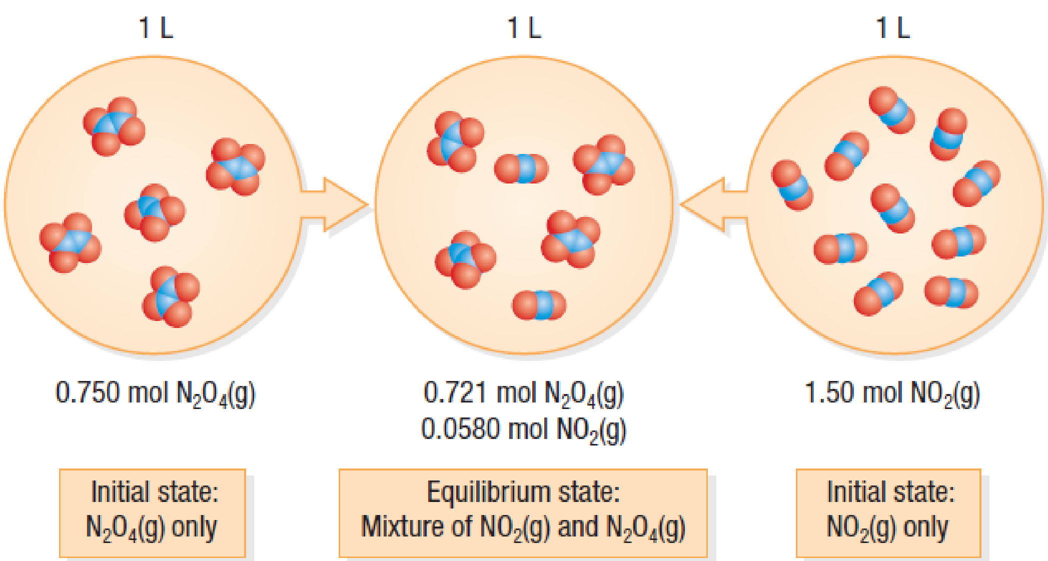


Figure 5 The composition of the mixture at dynamic equilibrium is the same regardless of whether the system started with gaseous nitrogen dioxide or with gaseous dinitrogen tetroxide.

Stoichiometry and Chemical Equilibria

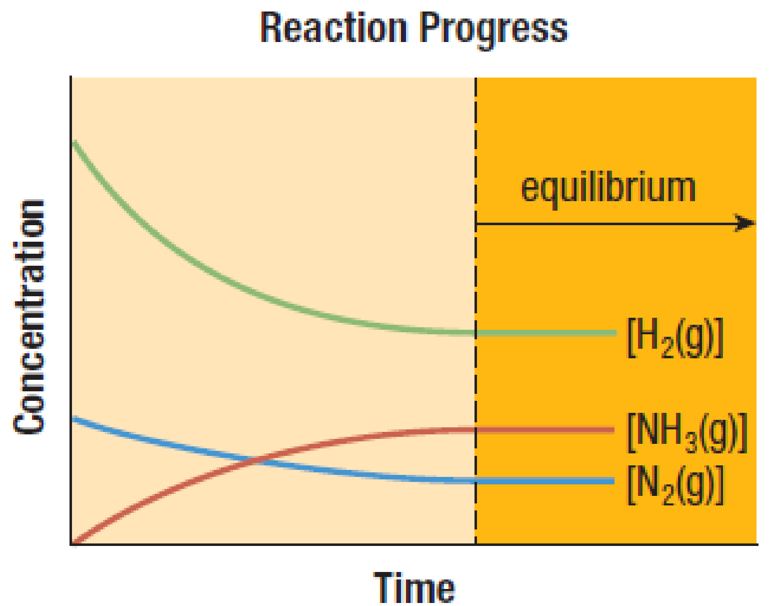
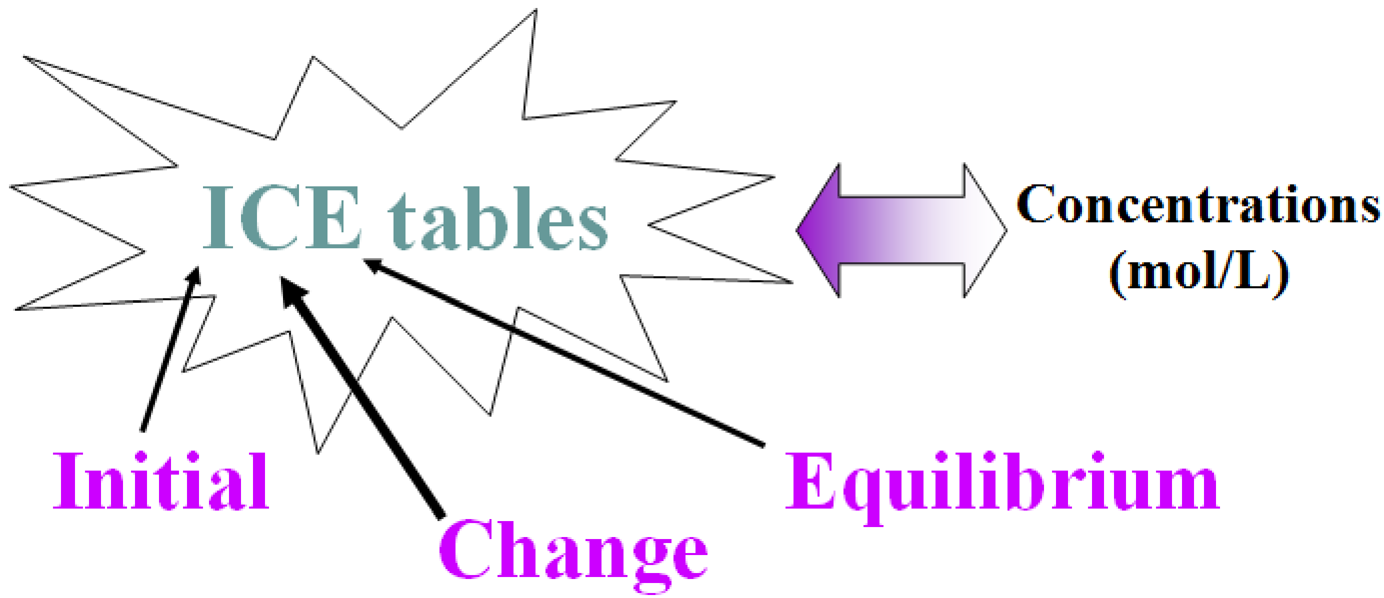


Figure 6 Concentration changes over time for the reaction $N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$ when only nitrogen gas and hydrogen gas are mixed initially.

Determining Concentrations for Chemical Equilibria



Example

- Consider the following equation at SATP

$$H_{2(g)} + F_{2(g)} \rightleftharpoons 2HF_{(g)}$$

- If the reaction begins with 1.00mol/L of hydrogen gas and fluorine gas and no hydrogen fluoride gas, calculate the concentration of hydrogen gas and hydrogen fluoride gas at equilibrium if the equilibrium concentration of fluorine gas is measured to be 0.24mol/L

Practice

- In a gaseous reaction system 0.8mol of hydrogen iodide, $HI_{(g)}$, is added to a rigid 2L container at 448^{o}C. At equilibrium, the system contains 0.2mol of iodine vapour, $I_{2(g)}$. Determine the equilibrium concentrations of hydrogen gas, $H_{2(g)}$, and hydrogen iodide, $HI_{(g)}$.

HOMEWORK

Required Reading:

p. 418-428

(remember to supplement your notes!)

Questions:

p. 418 #1-4

p. 427 #1-3

p. 428 #1-6a