

(though they are not necessarily equal).

Key features

- Forward and reverse rates are equal.
- Concentrations stay constant.
- Happens in a closed system.
- Dynamic (reactions continue in both directions).

Chemical Equilibrium

Chemistry 30, Unit D: Equilibrium and Acid-Base Systems

Real example data

In a closed container at 450°C, the concentrations of the reactants and products level off after some time, showing equilibrium is reached.

$$[\text{N}_2] = 0.32 \text{ M}$$

$$[\text{H}_2] = 0.96 \text{ M}$$

$$[\text{NH}_3] = 0.18 \text{ M}$$

How to identify it



Concentrations become constant over time.

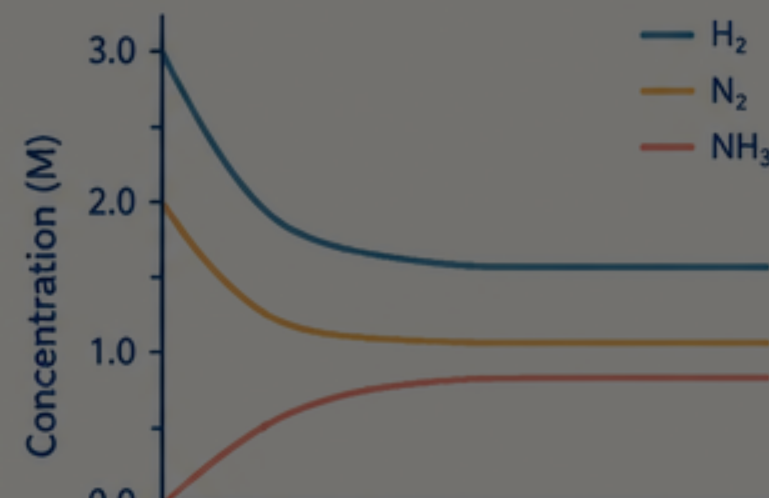


Temperature remains steady (if the system is insulated).

Sample data over time

Time (min)	$[\text{N}_2]$ (M)	$[\text{H}_2]$ (M)	$[\text{NH}_3]$ (M)
0	1.00	3.00	0.00
5	0.62	1.86	0.52
10	0.43	1.29	0.73
20	0.34	1.02	0.82
30	0.32	0.96	0.85

Graph of concentrations



What Is Chemical Equilibrium?

- A chemical system at equilibrium is closed to matter exchange with its surroundings
- Macroscopic properties such as colour and concentration remain constant over time
- The forward and reverse reaction rates are equal at equilibrium
- Equilibrium is dynamic: both reactions continue, but with no net change in concentrations
- Chemical equations for equilibrium systems are written and interpreted using a double arrow

Le Chatelier's Principle: Predicting a Shift

1

System at equilibrium

Forward and reverse rates are equal; properties are constant

2

Stress applied

Change in concentration, temperature, pressure, volume, or a catalyst is introduced

3

System shifts

The reaction favouring the forward or reverse direction proceeds to relieve the stress

4

New equilibrium established

Rates become equal again; K_c may or may not change depending on the stress

Brønsted-Lowry Acids and Bases

Definitions

A Brønsted-Lowry acid is a proton donor. A Brønsted-Lowry base is a proton acceptor. Conjugate acid-base pairs differ by a single proton, and amphiprotic substances such as HCO_3^- can act as either acid or base depending on the reaction partner.

Writing and Predicting

Brønsted-Lowry equations, including those involving indicators, are written to identify conjugate pairs. Comparing the relative strengths of the acids and bases involved predicts whether reactants or products are favoured, for both monoprotic and polyprotic systems.

Equilibrium at Work: Buffers and Industry

Buffers and industrial equilibrium applications

A buffer contains relatively large amounts of a weak acid or base and its conjugate, allowing the system to resist pH change when small amounts of strong acid or base are added. Titration curves reveal buffering regions for combinations of strong and weak acids and bases. Equilibrium principles also guide large-scale industrial processes such as the Haber-Bosch process for ammonia and the Solvay process for sodium carbonate, where conditions are chosen to maximize product yield.

Bringing It Together

Chemical equilibrium describes a closed system with equal forward and reverse reaction rates and constant macroscopic properties. Le Chatelier's principle predicts how stresses shift that balance, while the equilibrium constant K_c quantifies the extent of a reaction. Brønsted-Lowry theory extends these ideas to acid-base systems, including buffers that stabilize pH and industrial processes that apply equilibrium principles at scale.

If the Haber-Bosch process is run at high pressure and moderate temperature rather than at equilibrium-favoured low temperature, what trade-off between reaction rate and equilibrium yield is the industry accepting?