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# Topic 7.2: Direction of Reversible Reactions

Revision Notes · AP Chemistry

UNIT 7 · EQUILIBRIUM

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## Direction Means Net Change

Whenever both sides of a reversible reaction are present, both reactions run at the same time: reactants turn into products while products turn back into reactants.

The direction of the reaction names the **net** change: which of the two conversions is winning. During a net forward reaction, product molecules still break back down, but they are formed faster.

Only the difference between the two rates shows in the concentrations, and a system not at equilibrium always has a net direction, toward equilibrium.

## The Decision Rule: Compare the Two Rates

If the forward rate is greater, the net reaction is forward: reactants are consumed faster than they are re-formed, so reactant concentrations fall and product concentrations rise. If the reverse rate is greater, everything runs in mirror image: products are consumed net, reactant concentrations rise and product concentrations fall. If the two rates are equal, there is no net change: that is equilibrium.

Net forward reaction drains reactants and builds products, so the forward rate falls and the reverse rate rises.

## Starting Composition Sets the Opening Rates

Each rate is driven by its own side: the forward rate needs reactants, the reverse rate needs products.

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Start with reactants only, and the reverse rate is zero, because there is no product to react back: the forward rate, at its maximum, forces a net forward start. Start with products only, and the forward rate is zero instead, so the system turns products back into reactants. Start with a mixture, and neither rate is zero: compare the two rates rather than asking which side holds more. A mixture already at the equilibrium composition shows no net change.

## Which Concentrations Rise, and by How Much

In a net forward reaction every reactant concentration falls and every product concentration rises; net reverse flips both.

Changes follow the coefficients, so species do not change by equal amounts. In $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, every 0.10 mol $L^{-1}$ of $N_2$ consumed takes 0.30 mol $L^{-1}$ of $H_2$ with it and produces 0.20 mol $L^{-1}$ of $NH_3$.

Read the direction off any one species whose change is known and the equation fixes every other change; changes that refuse to fit the ratios cannot belong to one closed-vessel reaction.

## Reading Direction From Particle Pictures

Two snapshots of one sealed box show the direction directly: the species whose count rose was formed net; the species whose count fell was consumed net.

The counts are not free numbers: every snapshot of the same box holds the same total of each element, and changes between snapshots must fit the coefficients. For $2NO_2(g) \rightleftharpoons N_2O_4(g)$, a fall of four $NO_2$ particles pairs with a rise of two $N_2O_4$; identical counts mean no net change, so with both sides present the system was at equilibrium.

## Forward and Reverse Belong to the Equation as Written

Forward means left to right as written; reverse means right to left.

Rewrite the reaction the other way round and the labels swap, while nothing inside the flask changes. $NO_2$ dimerizing, $2NO_2(g) \rightleftharpoons N_2O_4(g)$, is net forward as written; the same flask written as $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ is undergoing a net reverse reaction. Take the direction from the printed equation.

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## A Disturbed Equilibrium, Read From Rates

Remove some product from a mixture at equilibrium: the reverse rate drops at once, because there is less product to react back, while the forward rate is untouched at that instant. The forward rate is now the larger, so the system runs net forward until the rates match again at a new equilibrium. Removing reactant flips the story: the forward rate drops and the system runs net reverse. These responses are named as a general principle in Topic 7.9.

## Worked Examples

**Example 1: Direction and concentration changes from two rates. For $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, suppose the forward reaction consumes $N_2$ at 0.30 mol $L^{-1}$ $min^{-1}$ while the reverse reaction produces $N_2$ at 0.10 mol $L^{-1}$ $min^{-1}$. The forward rate is larger, so the net reaction is forward, with a net rate of $0.30 - 0.10 = 0.20$ mol $L^{-1}$ $min^{-1}$. Following the coefficients, $[N_2]$ falls at 0.20, $[H_2]$ at $3 \times 0.20 = 0.60$, and $[NH_3]$ rises at $2 \times 0.20 = 0.40$ mol $L^{-1}$ $min^{-1}$. With the reverse rate at 0.45 instead, the net direction would be reverse at 0.15 mol $L^{-1}$ $min^{-1}$: $[NH_3]$ falling at 0.30, $[N_2]$ rising at 0.15, $[H_2]$ rising at 0.45.**

**Example 2: Direction from particle snapshots. Snapshots of a sealed box holding $2NO_2(g) \rightleftharpoons N_2O_4(g)$ show 12 $NO_2$ particles and 2 $N_2O_4$ particles, then 8 $NO_2$ and 4 $N_2O_4$. Nitrogen is conserved: $12 + 2 \times 2 = 16$ atoms, then $8 + 2 \times 4 = 16$. The changes, $NO_2$ down by 4 and $N_2O_4$ up by 2, fit the 2 : 1 coefficients, and since $NO_2$ is consumed net, the direction is forward as written. Equilibrium for this box is 6 $NO_2$ and 5 $N_2O_4$.**

**Example 3: Starting from products only. A flask is charged with $NH_3$ alone at $[NH_3] = 1.20$ mol $L^{-1}$, for the reaction written $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$. With no $N_2$ and no $H_2$ present, the forward rate starts at zero and the reverse rate at its maximum, so the net reaction is reverse. It settles at $[NH_3] = 0.80$, $[N_2] = 0.20$ and $[H_2] = 0.60$ mol $L^{-1}$: the 0.40 mol $L^{-1}$ of $NH_3$ consumed formed 0.20 of $N_2$ and 0.60 of $H_2$, in the 2 : 1 : 3 ratio of the equation read backwards. A flask starting from $[N_2] = 0.60$ and $[H_2] = 1.80$ mol $L^{-1}$ reaches the same equilibrium from the forward side.**

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**Example 4: A disturbed equilibrium. A mixture at equilibrium for A ⇌ B holds [A] = 0.30 mol $L^{-1}$ and [B] = 0.70 mol $L^{-1}$. Extra B is injected, raising [B] to 1.00 mol $L^{-1}$ at once. The reverse rate jumps because [B] rose, while the forward rate is unchanged at that instant, so the net reaction runs reverse until the rates meet again. The new equilibrium holds [A] = 0.39 mol $L^{-1}$ and [B] = 0.91 mol $L^{-1}$, keeping [B] / [A] = 2.33 with [A] + [B] = 1.30 mol $L^{-1}$.**

## Traps That Cost Marks in Topic 7.2

**"More product than reactant means the net direction is reverse." Not necessarily.** A flask with $[H_2]$ = $[I_2]$ = 0.50 mol $L^{-1}$ and [HI] = 1.00 mol $L^{-1}$ holds more product than either reactant, yet its equilibrium sits at [HI] = 1.56 mol $L^{-1}$, so it still runs net forward. Direction compares rates, not head counts.

**"During a net forward reaction, no reactants are being formed."** The reverse reaction runs whenever any product exists; net forward means only that product formation outpaces breakdown, with reactants re-formed throughout.

**"All the concentrations change by the same amount."** Changes follow the coefficients: in the ammonia reaction, a fall of 0.20 mol $L^{-1}$ in $[N_2]$ comes with 0.60 down in $[H_2]$ and 0.40 up in $[NH_3]$.

**"Removing product makes the system react backwards to restore it."** Removing product lowers the reverse rate, so the forward reaction wins and replaces the product: the opposite of the claim.

**"The system overshoots equilibrium and swings back and forth."** As the system moves, the winning rate falls and the losing rate rises; when they meet, net change stops: no overshoot, no oscillation.

**"This reaction runs in the forward direction, full stop."** Direction belongs to a starting mixture and a written equation, not to the reaction alone: one system can run forward from one start and reverse from another.

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**Key Relationships to Remember**

- Net direction follows the larger rate, forward or reverse
- Forward rate greater: reactant concentrations fall, product concentrations rise; reverse rate greater: the mirror image
- Equal rates mean no net change: the system is at equilibrium
- An absent side has a rate of zero, so a one-sided start forces the opening direction
- Concentration changes in a net reaction always follow the coefficients
- Snapshots of a closed system conserve element totals, and count changes obey the coefficients
- Forward and reverse are defined by the equation as written; rewriting swaps the labels
- Comparing a mixture with the equilibrium composition is made quantitative with Q and K in Topic 7.3

**Continue Revising**

Topic 7.2 Quiz: Direction of Reversible Reactions

Topic 7.2 Worksheet

Unit 7: All Topics

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