DO YOU KNOW?

- One in five of the world’s people lives on less than $1(USD) a day!









- **Poverty is not just a matter of a lack of material wealth – the ability to buy food, say, or basic farming tools.**
- **People do not get access to medicine or healthcare, so their years of healthy life are diminished.**

DO YOU KNOW?

- Every day, one in five of the world's population – some 800 million people – go hungry.
- Two billion people suffer from chronic malnutrition.
- Eighteen million die each year from hunger–related diseases.
- Around half of the deaths of children under five (about 10 million each year) are associated with malnutrition.

DO YOU KNOW?

- **The average Japanese woman can expect to live to up to 84 years old.**
- **The average Botswanan will reach just 39 years old.**

DO YOU KNOW?

- In India, rather than staying at school or receiving training, children are sent out to work.
- There are 44 million child laborers in India.

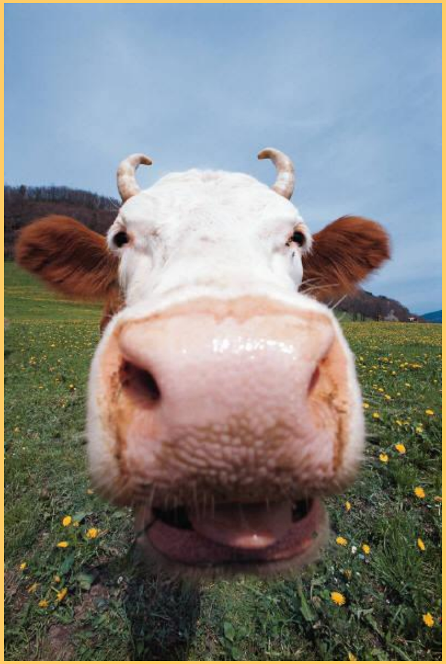
DO YOU KNOW?

- More than 70 per cent of the world's population have never heard a dial tone.
- In Africa, only one in four owns a radio, and one in 40 owns a telephone. Less than 1 per cent of the total population – 800 million – has a computer.
- The average Americans spends 46 per cent of their time accessing information.

DO YOU KNOW?

- In 2003, the US spent $396 billion (USD) on its military.
- Every hour of every day, the world spends more than $90 million (USD) on its military.

DO YOU KNOW?



- Every cow in the European Union is subsidized by $2.50(USD). That's more than 75 per cent of Africans to live on.
- For the money the EU spends protecting its farmers, each of the EU's 21 million cow could go round–the–world trip once a year.

DO YOU KNOW?

- **America spends $10 billion (USD) on pornography every year – the same amount it spends on foreign aid.**

DO YOU KNOW?

Reality TV Programme

POP IDOL!

- **Nearly 26 million people voted in the 2001 British General Election. More than 32 million voted were cast in the first season of *Pop Idol*.**

DO YOU KNOW?

- In 2003, 15 million Americans had some form of plastic surgery.
- This figure includes cosmetic surgery, like nose reshaping, breast augmentation and liposuction; reconstructive surgery, such as scar and tumor removal; and non–surgical procedures, like laser hair removal and cellulite treatment.

- Distribution of wealth across the world's people is unequal.
- In 1960, the per–capita gross domestic product (GDP) of the richest twenty countries was eighteen times that of the poorest twenty.
- In 1995, this gap had increased to 37 times.
- Today (2004), the world's richest 1 per cent receive as much income as the poorest 57 percent.

DO YOU KNOW?

For less than 1 per cent of the income of the wealthiest countries each year, the worst effects of poverty could be greatly diminished.

- The world today has not reached its "<u>EQUILIBRIUM</u>".

Let's struggle to achieve it for BETTER WORLD.

Source:
"*50 FACTS THAT SHOULD CHANGE THE WORLD*"
Jessica Williams, 2004, Icon Books Ltd.

CHEMICAL EQUILIBRIUM

6.1 Dynamic Equilibrium

At the end of the lesson, students should be able to:

i. Explain a reversible reaction, dynamic equilibrium and law of mass action

ii. State the characteristics of a system in equilibrium

iii. Explain the features of a graph of concentration against time for a reversible reaction

LESSON DURATION: 1 hour

REVERSIBLE REACTION

Few chemical reactions proceed in only one direction:

$$A + B \longrightarrow C + D$$

<u>Example:</u>

$$CH_4 + Cl_2 \xrightarrow{UV} CH_3Cl + HCl$$

But, most chemical reactions are **reversible**, at least to some extent

$$A \rightleftharpoons B$$

REVERSIBLE REACTION

$$A \rightleftharpoons B$$

reactant product

- **Forward reaction**: reaction proceeds from left to right
- **Backward reaction**: reaction proceeds from right to left
- **Reversible reaction**: reactions which take place in both forward and reverse directions

$\rightleftharpoons$ **= indicates reversible reaction**

REVERSIBLE REACTION

$$A \rightleftharpoons B$$

reactant product

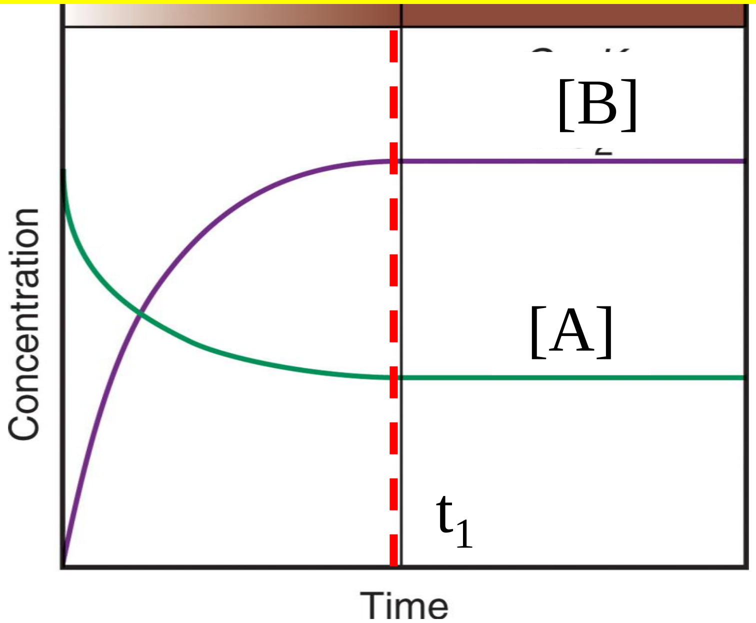
- **In a reversible reaction, initially the reaction proceeds toward the formation of products**
- **As soon as some product molecules formed, the reverse process begins to take place**
- **Reactant molecules are formed from product molecules**

REVERSIBLE REACTION

Consider the following reversible reaction:

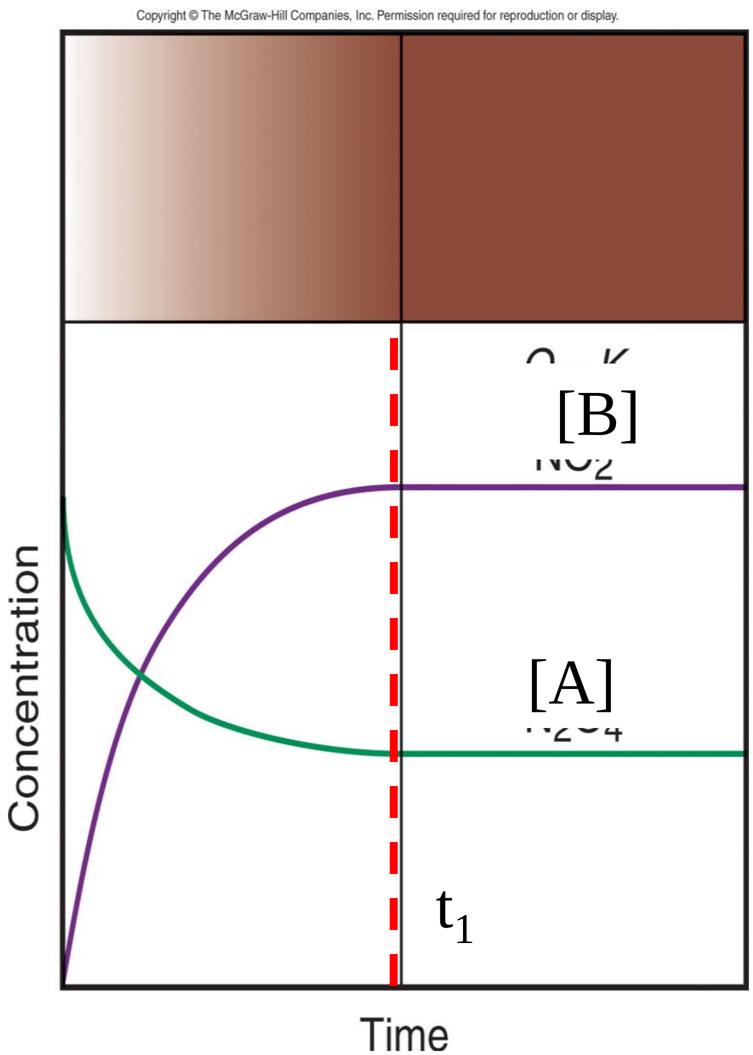
$$A \rightleftharpoons B$$

The graph of the concentration of A and B against time:



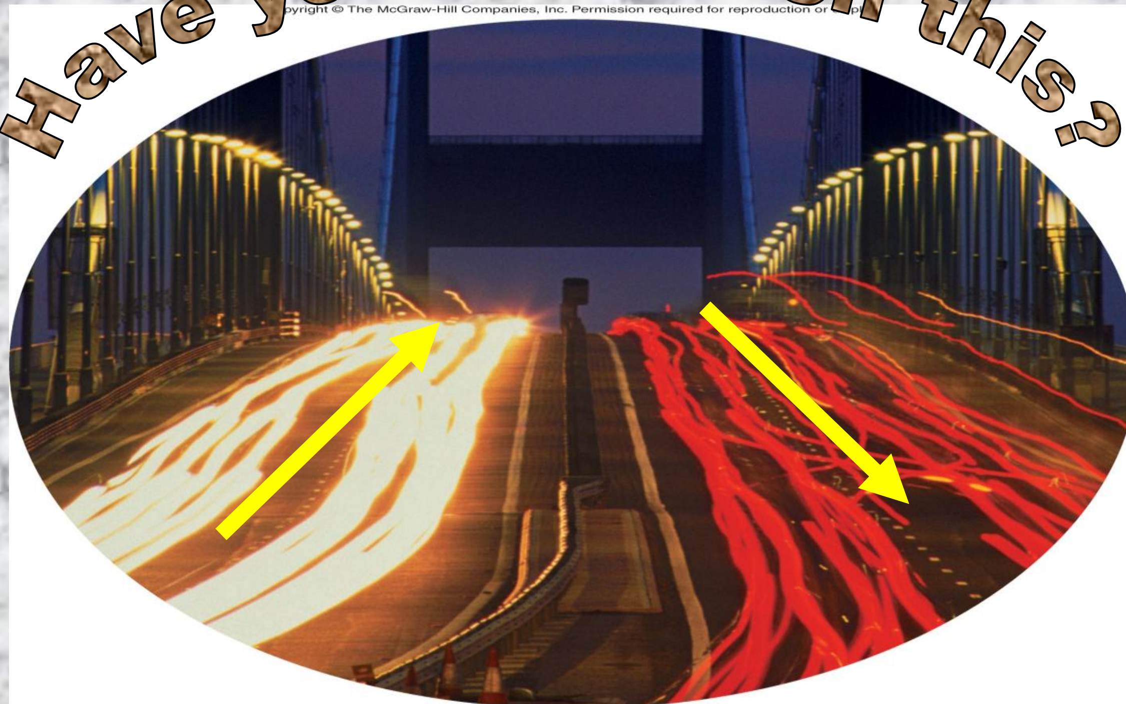
- **[A]** decrease with time
- **[B]** increase with time
- After time, $\mathbf{t_1}$, **[A]** and **[B]** remains unchanged
- **The system is in the state of** **<u>equilibrium</u>**

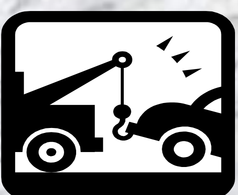
Keep in MIND!!



- The equilibrium is a **dynamic equilibrium**
- Means that **after t_1, the reaction did not stop**
- But, the **rate of forward reaction = rate of reverse reaction**
- There is **no net change in [A] and [B]**

Have you ever seen this?





Traffic equilibrium

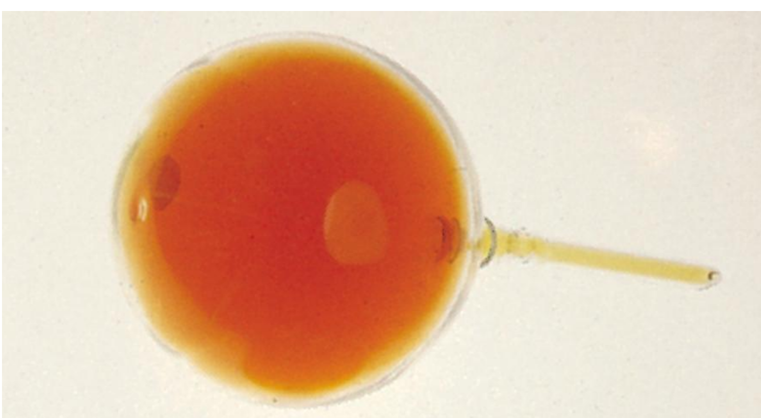
- mimicking the forward and reverse reactions of a chemical system
- the to-and-fro of traffic over this bridge maintains a relatively constant “concentration” of cars on either side

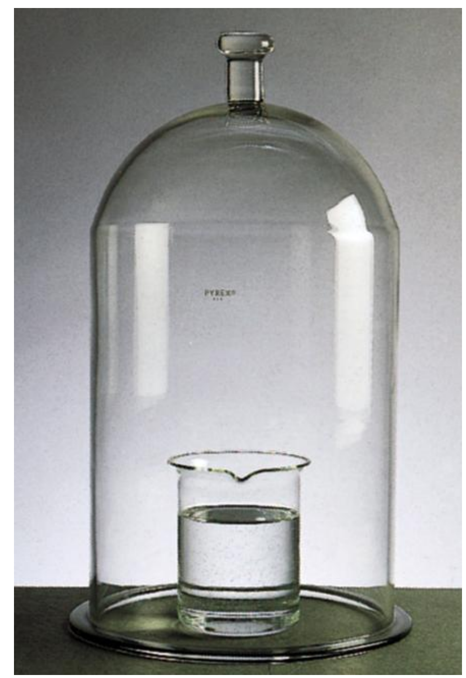
EQUILIBRIUM

☞ **A state in which there are no observable changes as time goes by.**

Two types:

- **physical equilibrium**
- **chemical equilibrium**





PHYSICAL EQUILIBRIUM

☞ **Physical change**

$$H_2O(l) \rightleftharpoons H_2O(g)$$

Number of H_2O molecules leaving
= Number of H_2O molecules returning to liquid phase

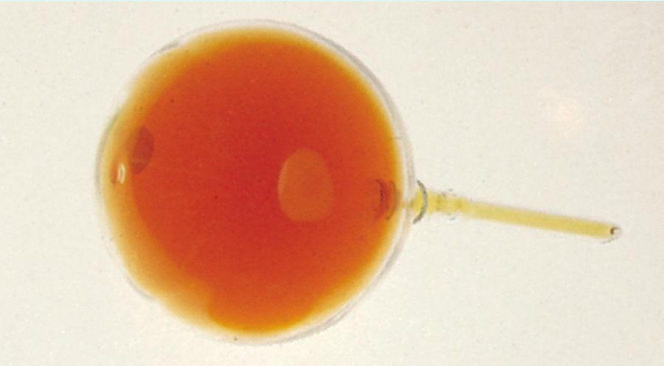
CHEMICAL EQUILIBRIUM

Most chemical reactions are reversible.

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

colorless — brown

$rate_{fwd} = rate_{rev}$

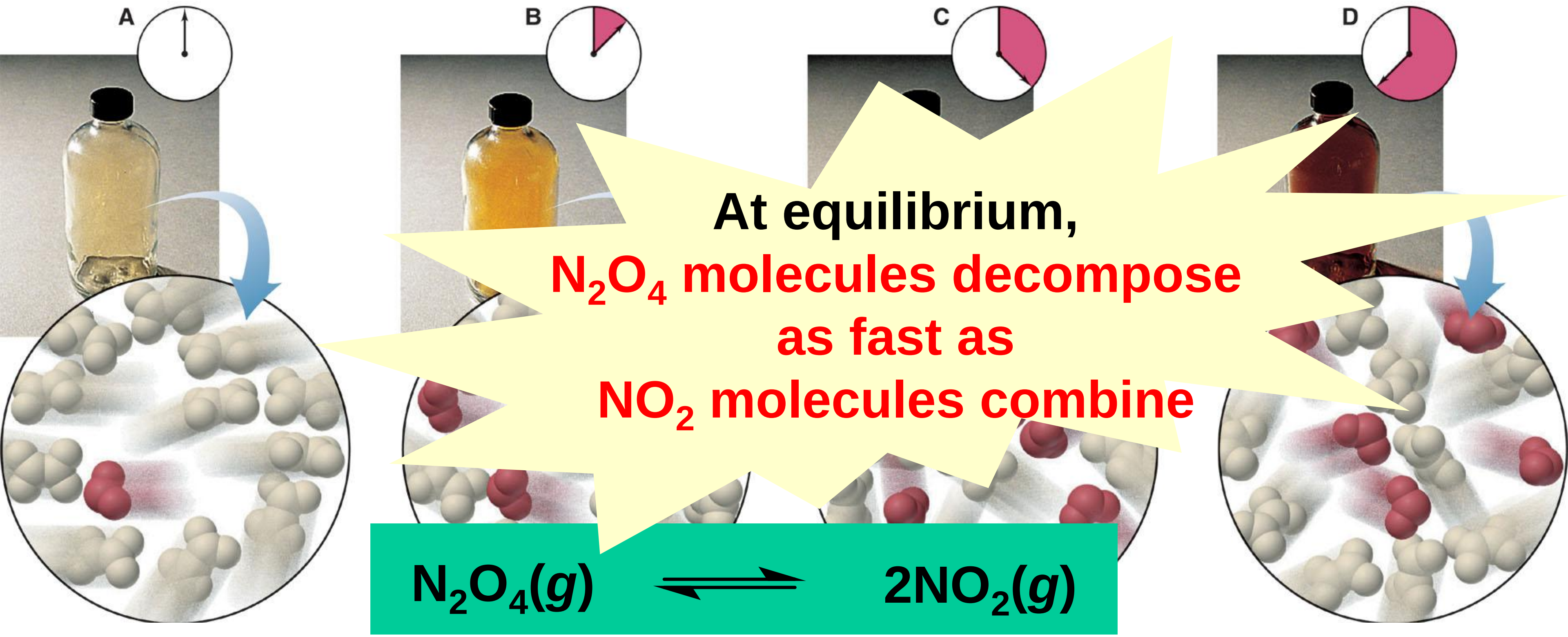


- **When we introduce some $N_2O_4(l)$ into a sealed flask kept at 100°C, a change occurs immediately.**
- **The liquid vaporizes (bp = 21°C) and the gas begins to turn pale brown.**
- **The color slowly darkens, but after a few moments, no further color change can be seen.**

DYNAMIC EQUILIBRIUM

- ☞ **Reactant and product concentrations stop changing because the forward and reverse rates have become equal.**

$$\text{rate}_{fwd} = \text{rate}_{rev}$$



A: Start

B: Mixture becomes pale brown

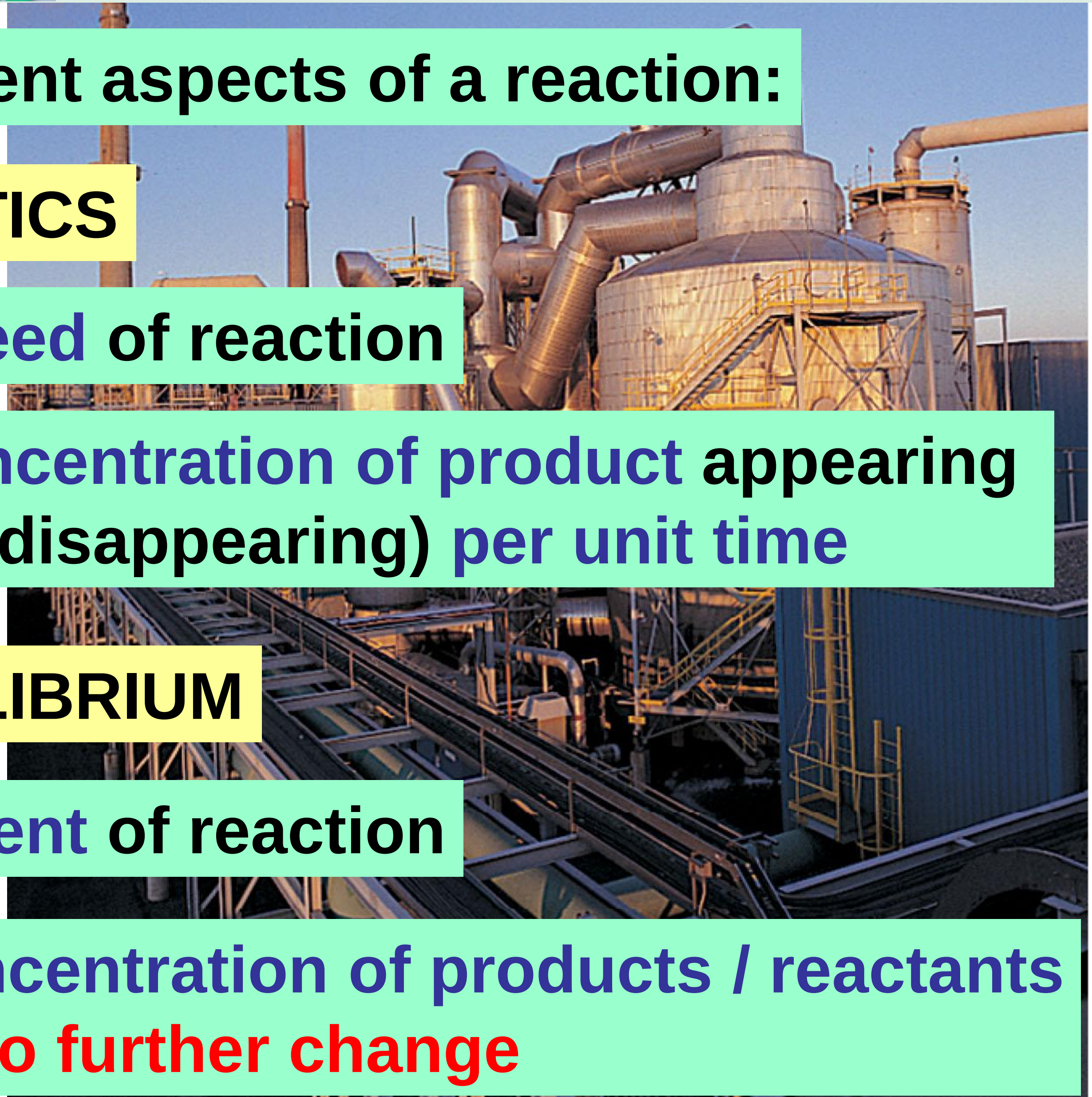
☞ **N_2O_4 decompose to reddish brown NO_2**

C: Mixture reaches final color

☞ **reaction reaches equilibrium**

D: Concentrations (and color) remain constant

KINETICS Vs. EQUILIBRIUM



Different aspects of a reaction:

KINETICS

- ☞ **speed of reaction**
- ☞ **concentration of product appearing (or disappearing) per unit time**

EQUILIBRIUM

- ☞ **extent of reaction**
- ☞ **concentration of products / reactants – no further change**

Keep in MIND

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

At equilibrium,

Rate of forward reaction: $N_2O_4(g) \rightarrow 2NO_2(g)$
= Rate of reverse reaction: $2NO_2(g) \rightarrow N_2O_4(g)$

☞ **$[N_2O_4(g)]$ and $[NO_2(g)]$ remain constant**

But!

$$[N_2O_4(g)] \neq [NO_2(g)]$$

CHARACTERISTICS OF A SYSTEM IN EQUILIBRIUM

i. **Reactant and product concentrations are constant over time.**

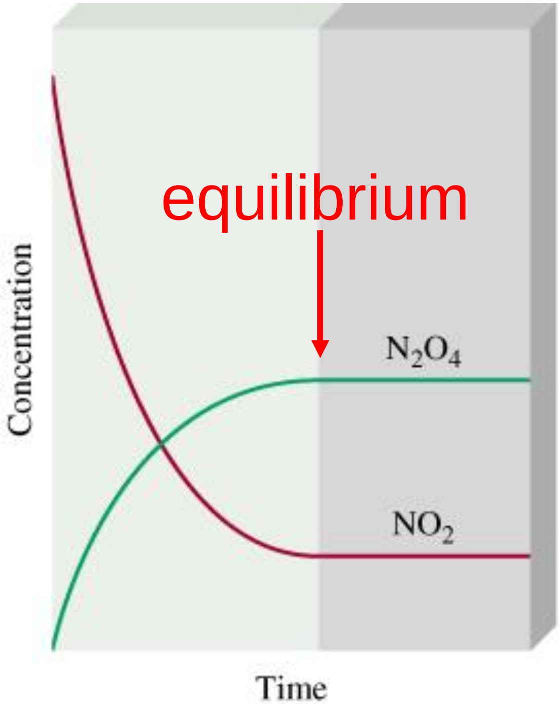
ii. **Forward reaction rate = reverse reaction rate**

iii. **The reaction quotient (*Q*) = The equilibrium constant (*K*)**

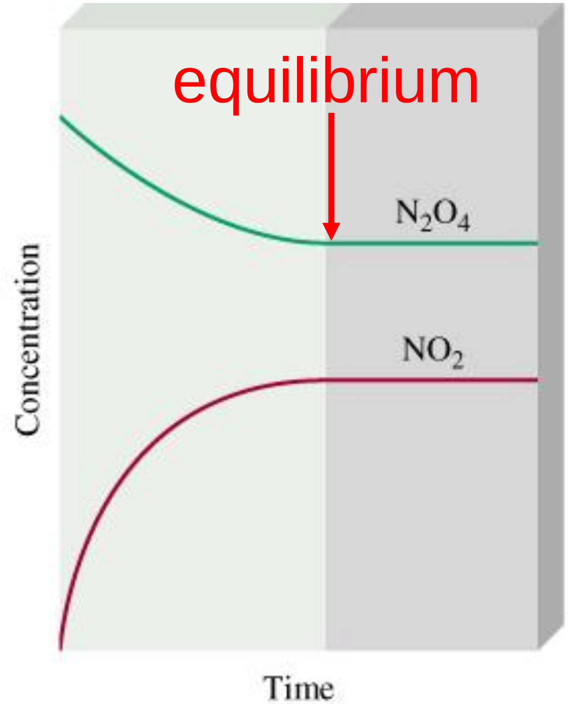
$$Q = K$$

(Will be discuss later in Topic 6.2)

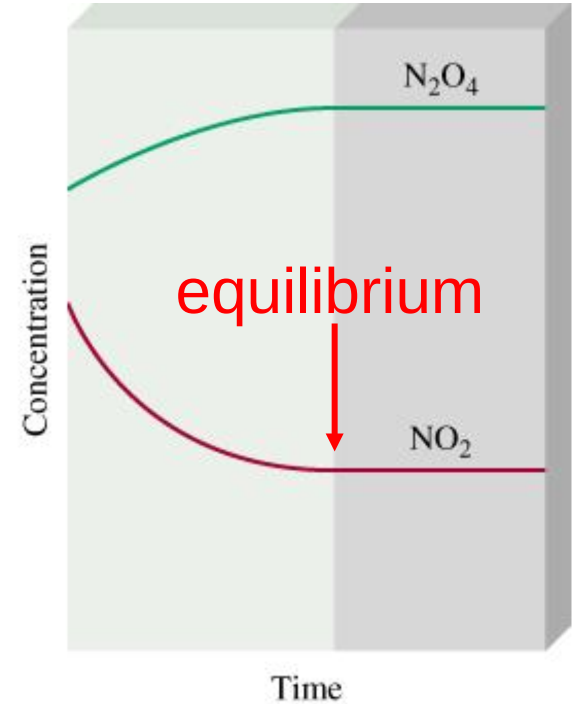
$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$



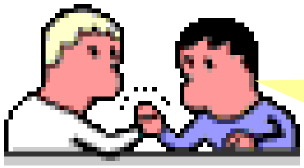
Start with NO_2



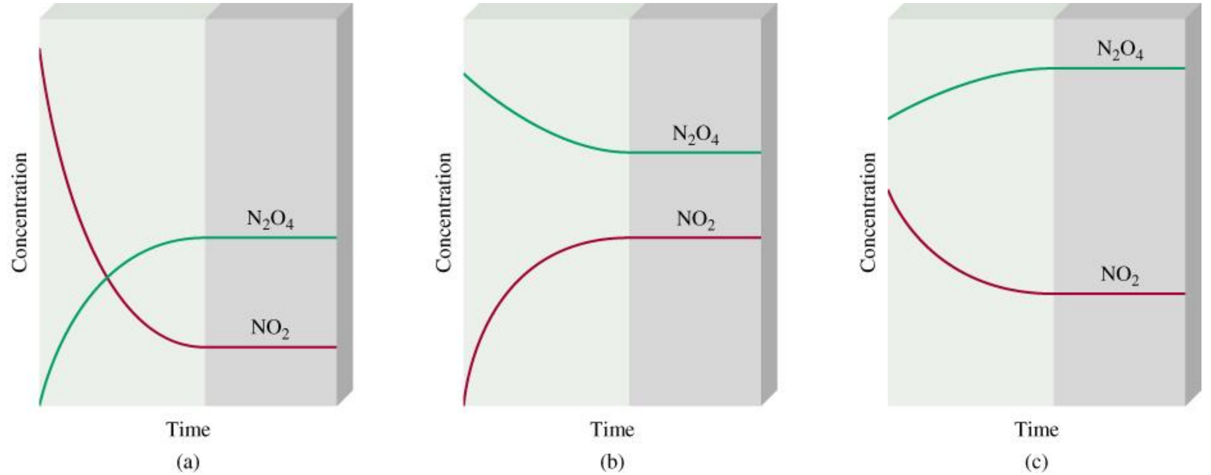
Start with N_2O_4



Start with NO_2 & N_2O_4



Even though equilibrium is reached in all cases, the equilibrium concentrations of NO_2 and N_2O_4 are not the same.



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

constant

The NO_2–N_2O_4 System at 25°C

Initial Concentrations (*M*)		Equilibrium Concentrations (*M*)		Ratio of Concentrations at Equilibrium	
$[NO_2]$	$[N_2O_4]$	$[NO_2]$	$[N_2O_4]$	$\frac{[NO_2]}{[N_2O_4]}$	$\frac{[NO_2]^2}{[N_2O_4]}$
0.000	0.670	0.0547	0.643	0.0851	4.65×10^{-3}
0.0500	0.446	0.0457	0.448	0.102	4.66×10^{-3}
0.0300	0.500	0.0475	0.491	0.0967	4.60×10^{-3}
0.0400	0.600	0.0523	0.594	0.0880	4.60×10^{-3}
0.200	0.000	0.0204	0.0898	0.227	4.63×10^{-3}

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

$$K = \frac{[NO_2]^2}{[N_2O_4]} = 4.63 \times 10^{-3}$$

The ratio $\frac{[NO_2]^2}{[N_2O_4]}$ are constant

K ☞ equilibrium constant

The NO_2–N_2O_4 System at 25°C

Initial Concentrations (*M*)		Equilibrium Concentrations (*M*)		Ratio of Concentrations at Equilibrium	
$[NO_2]$	$[N_2O_4]$	$[NO_2]$	$[N_2O_4]$	$\frac{[NO_2]}{[N_2O_4]}$	$\frac{[NO_2]^2}{[N_2O_4]}$
0.000	0.670	0.0547	0.643	0.0851	4.65×10^{-3}
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0.200	0.000	0.0204	0.0898	0.227	4.63×10^{-3}

LAW OF CHEMICAL EQUILIBRIUM

Also known as law of mass action.

At a given temperature, a chemical system reaches a state in which particular ratio of reactant and product concentrations has a constant value.

For a particular system and temperature, the same equilibrium state is attained regardless of how the reaction is run.

Cato Maximilian Guldberg (1839 – 1902). Norwegian chemist and Mathematician

Peter Waage (1833 – 1900). Norwegian chemist.

LAW OF CHEMICAL EQUILIBRIUM

Consider this general reaction equation:

$$aA + bB \rightleftharpoons cC + dD$$

At equilibrium:

$$\frac{[C]^c [D]^d}{[A]^a [B]^b} = K$$

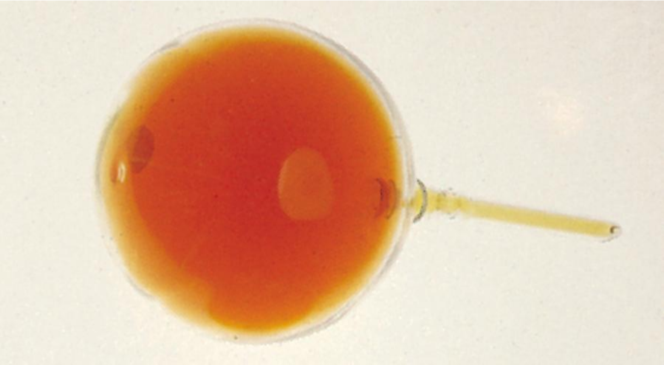
Where:

a, **b**, **c** and **d**: **stoichiometric coefficients for the reacting species A, B, C and D**

***K* = Equilibrium constant**, **[ ] = concentration**

EQUILIBRIUM CONSTANT (*K*)

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



$$K = \frac{[NO_2]^2}{[N_2O_4]}$$

$$aA + bB \rightleftharpoons cC + dD$$

$$K = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

EQUILIBRIUM CONSTANT (*K*)

$$aA + bB \rightleftharpoons cC + dD \qquad K = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

Magnitude of *K* indicates how far a reaction proceeds toward product at a given temperature.

Large *K*

Equilibrium will:

- ☞ **lie forward (to the right).**
- ☞ **favour products.**
- ☞ **reaction "goes to completion".**

$$2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g) \qquad K = 2.2 \times 10^{22}$$

EQUILIBRIUM CONSTANT (*K*)

$$aA + bB \rightleftharpoons cC + dD \qquad K = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$

Small *K* — **Equilibrium will:**

- **lie reverse (to the left).**
- **favour reactants.**
- **almost "no reaction".**

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad K = 1 \times 10^{-30}$$

EQUILIBRIUM CONSTANT (*K*)

$$aA + bB \rightleftharpoons cC + dD \qquad K = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

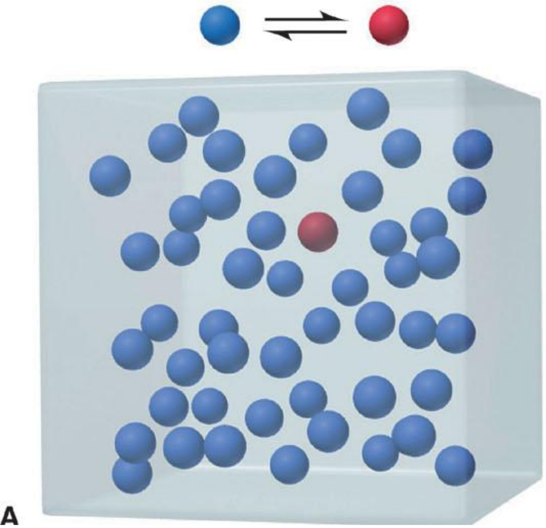
Intermediate *K*

At equilibrium:

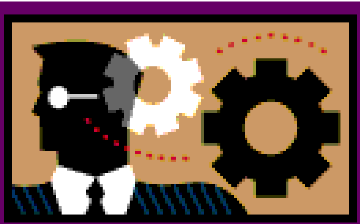
☞ **significant amounts of both reactant and product**

$$2BrCl(g) \rightleftharpoons Br_2(g) + Cl_2(g) \qquad K = 5$$

At equilibrium:



Small *K*	Large *K*	Intermediate *K*
☞ very little amount of products formed	☞ nearly all products are formed	☞ significant amount of reactants and products



EXERCISE - 1

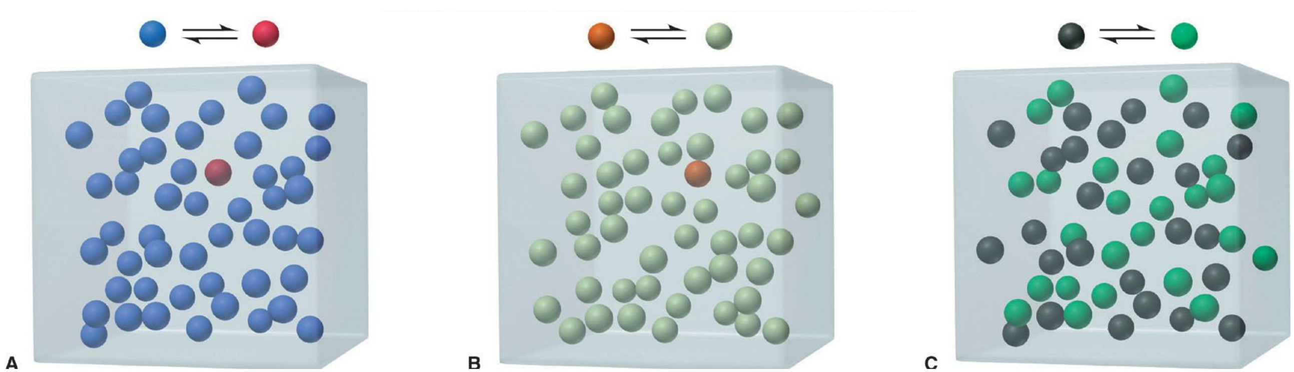
5.1

Which of the following reactions will tend to proceed farthest toward completion?

a) $H_2(g) + Br_2(g) \rightleftharpoons 2HBr(g)$ $\quad K_C = 7.9 \times 10^{18}$

b) $2NO(g) \rightleftharpoons N_2(g) + O_2(g)$ $\quad K_C = 2.1 \times 10^{30}$

c) $2BrCl \rightleftharpoons Br_2 + Cl_2$(in CCl_4 solution) $\quad K_C = 0.145$



KEEP IN MIND

$$aA + bB \rightleftharpoons cC + dD \qquad K = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

REACTANTS PRODUCTS

By convention,

substances on the left ☞ "reactants"

substances on the right ☞ "products"

$$cC + dD \rightleftharpoons aA + bB \qquad K = \frac{[A]^a [B]^b}{[C]^c [D]^d}$$

REACTANTS PRODUCTS





END OF SLIDE SHOW