

Equilibria

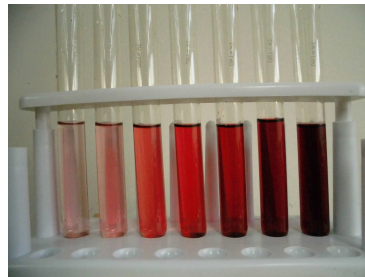
A-Level Chemistry ■ Topic 7

A-Level Chemistry



What we will cover

- 1 Dynamic equilibrium
- 2 Le Chatelier's principle
- 3 Equilibrium constants
- 4 Haber & Contact
- 5 Brønsted–Lowry acids
- 6 Strong/weak & titrations



a shifting equilibrium



Dynamic equilibrium

A **dynamic equilibrium** is a closed system where the forward and reverse rates are equal. Concentrations stay constant, but both reactions still run.



It is **dynamic**: molecules keep reacting. It is **equilibrium**: nothing measurable changes.

Le Chatelier's principle

the equilibrium shifts to *oppose* the change you make

increase [reactant] → towards the **products**

increase pressure → to the **fewer-gas-molecules** side

increase temperature → in the **endothermic** direction

a **catalyst** speeds both directions equally, so it gives *no shift*

Le Chatelier's principle : the equilibrium shifts to **oppose** a change.

- more reactant → towards products
- more pressure → fewer-gas side
- more heat → endothermic way
- a **catalyst** → no shift

Equilibrium constants

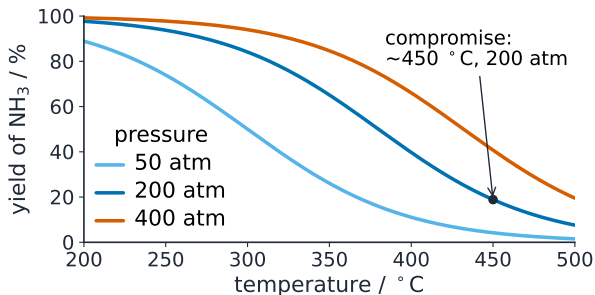
$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$



$$K_c = \frac{1.6^2}{0.20 \times 0.20} = 64 \text{ (no units here)}$$

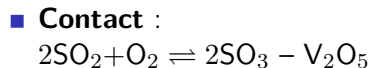
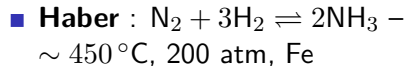
Only **temperature** changes K_c or K_p . For gases use **partial pressure** = **mole fraction** $\times$ total pressure.

The Haber and Contact processes



exothermic: lower $T \uparrow$ yield · higher $P \uparrow$ yield

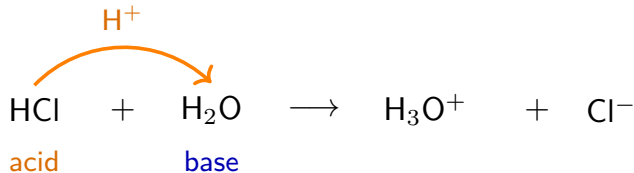
Conditions balance yield, rate & cost:



Low temperature gives more yield but too slowly.



Brønsted–Lowry acids and bases



conjugate acid–base pairs:
 HCl / Cl^- and $\text{H}_2\text{O} / \text{H}_3\text{O}^+$

- an **acid** is a **proton donor**
- a **base** is a **proton acceptor**

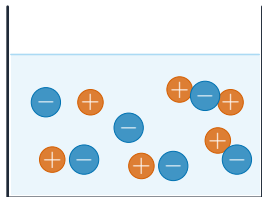
The reaction makes two
conjugate acid–base pairs.

Strong and weak acids

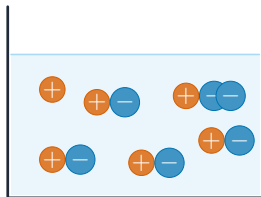
This is about **ionisation**, not concentration:

- **strong acid** – fully **dissociated**
- **weak acid** – only partly dissociated

A strong acid has a lower pH & conducts better.



strong acid



weak acid

fully dissociated: many ions mostly molecules: few ions

Bronsted-Lowry, and telling strong from weak

an acid

a **proton donor** – it gives H^+

a base

a **proton acceptor** – it takes H^+ . A base that dissolves in water is an **alkali**

the acids to know

hydrochloric HCl , sulfuric H_2SO_4 , nitric HNO_3 , and ethanoic CH_3COOH

a strong base

fully dissociated – NaOH , KOH ; a **weak base** such as ammonia only partly

test 1: reactive metal

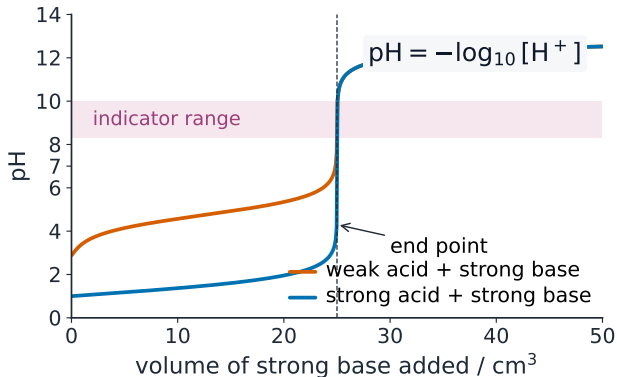
a **strong** acid fizzes faster at the same concentration

test 2: pH

measured with a pH meter or **universal indicator** – strong acids give a lower pH at equal concentration

Strong is about how far it dissociates; **concentrated** is about how much is dissolved. A concentrated weak acid is entirely possible.

Titration curves



Neutralisation : $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$, forming a **salt** .

A **titration curve** has a steep pH jump at the end point – pick an **indicator** that changes colour inside it.

Neutralisation and the shape of a titration curve

neutralisation

$\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ – the same ionic equation whichever acid and alkali

a titration

add one solution to another and follow the pH

the titration curve

has a **steep, almost vertical** section at the end point

strong–strong

the vertical section is long, and centred near pH 7

weak acid–strong base

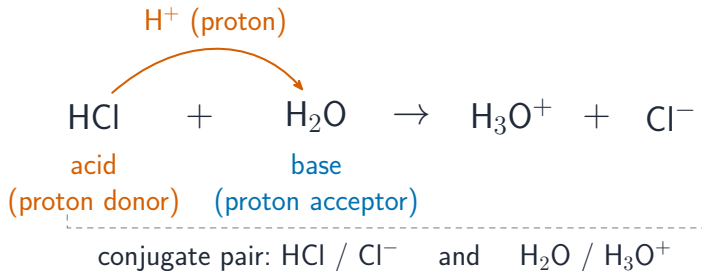
shorter, and centred **above** 7; the reverse case is centred below it

choosing an indicator

its colour change must fall **inside** the vertical section

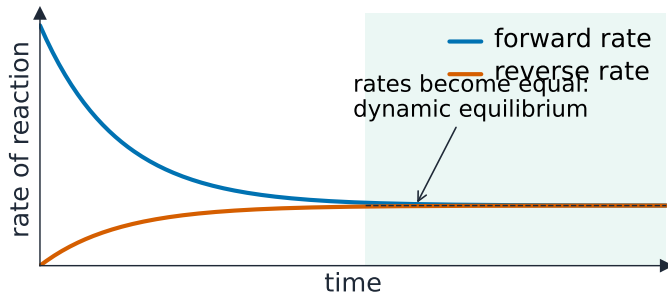
The indicator is chosen from the *curve*, not from the acid. That is why phenolphthalein suits a weak acid and methyl orange does not.

Acids and bases: the Brønsted–Lowry theory



Brønsted–Lowry: the acid donates a proton (H^+) to the base, making two conjugate acid–base pairs

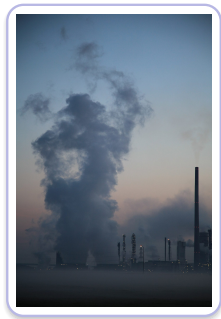
Reversible reactions and dynamic equilibrium



at equilibrium: $\text{rate}_f = \text{rate}_r \cdot K_c = \frac{[\text{products}]}{[\text{reactants}]}$ (stoich. powers)

At dynamic equilibrium the forward and reverse rates have become equal, so the concentrations stay constant

The Haber and Contact processes, continued



Ammonia for fertiliser is made by the Haber process in large industrial plants like this one.

Exam tips

- Define **dynamic equilibrium** with all three points: forward and reverse rates equal, concentrations constant, closed system.
- Answer **Le Chatelier** questions by stating the change, the direction of shift, and the reason; a **catalyst does not shift** the position (it speeds both rates).
- Write K_c as **products over reactants**, each raised to its balancing number; include state symbols to decide what appears.
- Justify Haber/Contact conditions as a **compromise** between yield, rate and cost – do not just quote them.
- Brønsted: acid = **proton donor**, base = proton acceptor; conjugate pairs differ by one H^+ .



Topic 7 – key takeaways

1

Equilibrium

equal forward & reverse rates

2

Le Chatelier

the equilibrium opposes any change

3

 K_c

products over reactants; only T changes it

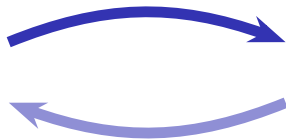
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Acids

donate protons; strong = fully dissociated

Check yourself

- 1 At equilibrium, how do the forward & reverse rates compare?
- 2 Raising pressure shifts to which side?
- 3 What only changes the value of K_c ?
- 4 A proton donor is an acid or a base?



Answers 1. they are equal 2. the side with fewer gas molecules 3. temperature
4. an acid