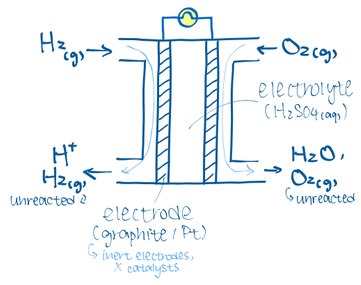
Fuel cells

1 Principle

- Combustion of fuel (fuel + O_2 → ...)
- hazard warning labels: flammable (fuel 燃料) + oxidizing (O_2 助燃料)
- advantages
  - > environmentally as water (eg. for hydrogen fuel cells) is produced
  - > high energy efficiency.
- ☆ 题意 electrolyte 为 acidic / alkaline medium
  - > acidic: OH^- 为 H^+
  - > alkaline: H^+ 为 OH^-
  - > carbonate (CO_3^{2-}): 转做 acidic medium (OH^- 为 H^+), 再为 CO_3^{2-} ($2H^+ + CO_3^{2-} \rightarrow CO_2 + H_2O$) (Acid-base)

2 Examples

HYDROGEN FUEL CELLS, ACIDIC MEDIUM



A: $H_2 \rightarrow 2H^+ + 2e^-$ (∵ acidic medium ∴ 不用变)

C: $4H^+ + O_2 + 2H_2O + 4e^- \rightarrow 4OH^- + 4H^+$ (∵ acidic medium ∴ OH^- 为 H^+)

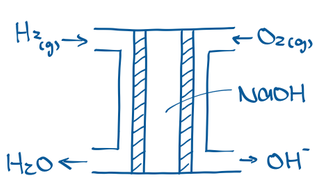
↳ $4e^- + 4H^+ + O_2 \rightarrow 2H_2O$

$\Rightarrow$ $2H_2 + O_2 \rightarrow 2H_2O$

↳ +ve: environmentally friendly as water is produced

-ve: explosive (∵ H_2)

HYDROGEN FUEL CELLS, ALKALINE MEDIUM



A: $2OH^- + H_2 \rightarrow 2H^+ + 2e^- + 2OH^-$ (∵ alkaline medium: H^+ 为 OH^-)

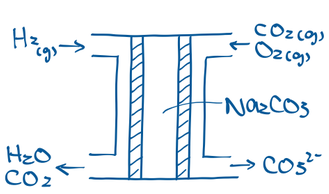
↳ $2OH^- + H_2 \rightarrow 2H_2O + 2e^-$

C: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ (∵ alkaline medium ∴ 不用变)

$\Rightarrow$ $2H_2 + O_2 \rightarrow 2H_2O$

↳ +ve/-ve same as acidic medium cell

HYDROGEN FUEL CELLS, CARBONATE MEDIUM



A: $CO_3^{2-} + H_2 \rightarrow 2H^+ + 2e^- + CO_3^{2-}$

↳ $CO_3^{2-} + H_2 \rightarrow CO_2 + H_2O + 2e^-$

C: $4H^+ + O_2 + 2H_2O + 4e^- \rightarrow 4OH^- + 4H^+$ (先变成 acidic medium)

↳ $2CO_3^{2-} + O_2 + 4H^+ + 4e^- \rightarrow 2H_2O + 2CO_3^{2-}$ (H^+ 为 CO_3^{2-})

↳ $O_2 + 2CO_2 + 2H_2O + 4e^- \rightarrow 2H_2O + 2CO_3^{2-}$

↳ $O_2 + 2CO_2 + 4e^- \rightarrow 2CO_3^{2-}$

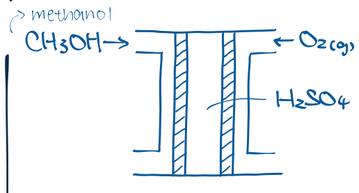
$\Rightarrow$ $2H_2 + 2O_2 \rightarrow 2H_2O$

↳ +ve/-ve same as acidic medium cell

For hydrogen fuel cells

- overall eqn.
  - > 无论如何也是 $2H_2 + O_2 \rightarrow 2H_2O$
- Acidic medium
  - > Anode: H^+, Cathode: H_2O
- Alkaline medium
  - > Anode: H_2O, Cathode: OH^-

OTHER FUEL CELLS



C: $4H^+ + O_2 + 2H_2O + 4e^- \rightarrow 4OH^- + 4H^+$

↳ $4e^- + 4H^+ + O_2 \rightarrow 2H_2O$

A: $H_2O + CH_3OH \rightarrow CO_2 + 6H^+ + 6e^-$ (1×C ⟹ 1×C)

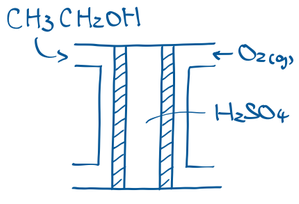
full eqn: $CH_3OH + O_2 \rightarrow H_2O + CO_2$ (combustion of hydrocarbon → CO_2 & H_2O)

↳ if O_2 reduces to H_2O, then CH_3OH must oxidise to CO_2

$\Rightarrow$ $12 \times [4e^- + 4H^+ + O_2 \rightarrow 2H_2O]$

$+) 3 \times [H_2O + CH_3OH \rightarrow CO_2 + 6H^+ + 6e^-]$

$2CH_3OH + 3O_2 \rightarrow 4H_2O + 2CO_2$



C: $4H^+ + O_2 + 2H_2O + 4e^- \rightarrow 4OH^- + 4H^+$

↳ $4e^- + 4H^+ + O_2 \rightarrow 2H_2O$

A: $3H_2O + CH_3CH_2OH \rightarrow 2CO_2 + 12H^+ + 12e^-$ (2×C ⟹ 2×C)

$\Rightarrow$ $12 \times [4e^- + 4H^+ + O_2 \rightarrow 2H_2O]$

$+) 3 \times [3H_2O + CH_3CH_2OH \rightarrow 2CO_2 + 12H^+ + 12e^-]$

$CH_3CH_2OH + 3O_2 \rightarrow 3H_2O + 2CO_2$