AM-03.07

Water electrolysis — make oxygen without creating matter

Version PDF de travail - contenu du cours HTML canonique

Course compass

Guiding question : How can electricity split water into hydrogen and oxygen, and where does every atom go?

Essential answer

Water electrolysis — make oxygen without creating matter. The question to solve is: How can electricity split water into hydrogen and oxygen, and where does every atom go? Electrolysis supplies electrical energy to drive a reaction that does not proceed spontaneously at the required rate. Atoms must be conserved: the left side has 4 H and 2 O; the right side has 4 H in 2 H_2 and 2 O in O_2. The rest of the course turns that idea into an auditable line of reasoning: explicit units, stated assumptions, reproducible calculations, order-of-magnitude checks and interpretation limits. A result is useful only when the reader can explain what it measures, where every input came from and which engineering decision it can support.

Starting synthesis: derivations, examples, limitations and sources are developed in the course body.

Key terms before you start

mole · molar mass · efficiency · unit · assumption

1 — The physical question

How can electricity split water into hydrogen and oxygen, and where does every atom go?

2 — Symbols, reading and units

H_2O — water; H_2 — hydrogen; O_2 — oxygen; arrow — chemical transformation; coefficients 2,2,1 — stoichiometric proportions.

3 — Where does the relation come from?

Electrolysis supplies electrical energy to drive a reaction that does not proceed spontaneously at the required rate. Atoms must be conserved: the left side has 4 H and 2 O; the right side has 4 H in 2 H_2 and 2 O in O_2.

4 — A — Count molecules

2 water molecules correspond to 2 H_2 molecules and 1 O_2 molecule in the stoichiometric equation.

5 — B — Work in moles

2 mol H_2O 2 mol H_2 + 1 mol O_2. Coefficients become direct ratios of amount of substance.

6 — C — Work in masses

Using classroom rounded molar masses: 36 g water corresponds to 4 g H_2 + 32 g O_2. 4+32=36 g: total mass is conserved.

7 — Go deeper

Electricity supplies energy, not atoms

Electrical current does not turn into oxygen. It enables the chemical bonds of existing water molecules to be rearranged.

Why the ISS is a useful example

The ISS Oxygen Generating Assembly uses polymer-electrolyte-membrane electrolysis to split water. Oxygen goes to the cabin atmosphere while hydrogen can feed a carbon-dioxide reduction system.

Energy efficiency becomes an engineering question

The chemical equation alone does not tell us required electricity, cooling, maintenance or cell replacement. A Mars settlement must separate theoretical chemistry from real industrial performance.

The overall equation hides two half-reactions

An electrochemical cell separates transformations occurring at two electrodes. Half-reactions let us track where electrons are produced or consumed and which ions cross the electrolyte. This course stays conceptual: the goal is to understand material accounting before studying detailed design of a real electrolyzer.

Current is connected to production rate

Electric current is a rate of charge flow. Over a time t, total charge is $Q=I\times t$. Faraday's laws then connect charge to moles transformed. This explains why raising current can raise production rate while also increasing losses, heating and hardware stress.

Real cell voltage exceeds the thermodynamic minimum

A reaction has a thermodynamic energy requirement, but a real cell also has overpotentials, electrical resistance and transport losses. The practical applied voltage must therefore exceed the theoretical minimum. The difference appears as heat or electrochemical loss — another application of asking where the energy went.

Gas separation is part of the system

Producing H_2 and O_2 is not enough: a system must prevent hazardous mixing and manage pressure, humidity, purity, sensing and venting. A membrane or cell architecture contributes to this separation. Chemical performance must therefore be evaluated together with safety and product quality.

Electrolysis belongs to a resource chain

In life support, water can feed oxygen generation while hydrogen can participate in CO_2 reduction. On Mars the same chemistry can also become part of an ISRU chain. Sizing then depends on daily demand, buffer storage, electric power and the chosen level of redundancy.

8 — Exercises and answers

Challenge 1

A — Count molecules: repeat the reasoning with the stated values, then explain the physical meaning of the result.

Challenge 2

B — Work in moles: repeat the reasoning with the stated values, then explain the physical meaning of the result.

Challenge 3

C — Work in masses: repeat the reasoning with the stated values, then explain the physical meaning of the result.

9 — Primary and technical sources

• NASA — Environmental Control and Life Support Systems

• NASA NTRS — Electrochemical Solutions for Advanced Life Support

• NASA — Water recovery milestone on ISS