

Chapter 3

Principles of Thermodynamics and the First Law of thermodynamics

6.1 Applications of Enthalpy in Renewable Energy Systems

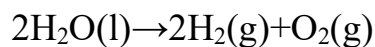
Enthalpy change (ΔH), which represents the amount of heat absorbed or released during a chemical reaction or physical change at constant pressure.

- If ΔH is positive (endothermic), it means the system absorbs energy from its surroundings.
- If ΔH is negative (exothermic), it means the system releases energy to its surroundings.

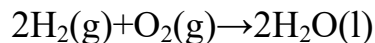
Understanding enthalpy is essential for designing renewable energy systems because they rely on converting energy from one form to another, often involving chemical or physical reactions.

1. Green Hydrogen Systems and Fuel Cells

Green hydrogen is produced through the electrolysis of water, a chemical reaction. Knowing the enthalpy change for this reaction (ΔH) helps us determine the amount of energy required to convert water into hydrogen and oxygen. This reaction is endothermic (requires energy).



In a fuel cell, the opposite happens: hydrogen and oxygen react to produce water, and this reaction is exothermic. Knowing enthalpy helps us calculate the amount of energy that can be generated.



The importance of enthalpy: It helps us calculate the thermal efficiency of these systems—that is, the amount of heat lost and how it can be utilized.

2. Thermal Energy Storage

These systems rely on materials that store energy in the form of heat, such as phase change materials (PCMs). These materials change state (for example, from solid to liquid) at a certain temperature and absorb a large amount of energy in the form of latent heat, which is a type of enthalpy change.

For example, these materials are used in buildings to store the sun's heat during the day and slowly release it at night to heat the home. Knowing the enthalpy of fusion of these materials (the amount of energy required to convert them from solid to liquid) helps engineers choose the most appropriate material for the application.

3. Concentrated Solar Power (CSP) Systems

These systems use mirrors to concentrate sunlight to heat a liquid (such as molten salt), which in turn heats water to produce steam that drives turbines to generate electricity.

The Importance of Enthalpy:

1- Calculating Energy Gain: It helps us determine the amount of thermal energy absorbed by a fluid from sunlight.

2- Cycle Efficiency Analysis: We can use enthalpy at various stages of the cycle (heating, evaporation, cooling) to calculate the overall efficiency of the system and identify heat losses.

In short, enthalpy gives us a quantitative perspective on the energy flowing through our systems, enabling us to design more efficient and sustainable renewable energy systems.

6.2 Applying the first law of thermodynamics to renewable energy systems.

The first law of thermodynamics, also known as the law of conservation of energy, states that energy cannot be created or destroyed, but only transformed from one form to another.

This law is fundamental to analyzing the efficiency of renewable energy systems, such as solar cells and fuel cells, because it helps us track energy flows and understand where energy is gained and lost.

1- Analysis of solar cell efficiency

A solar cell is an open thermodynamic system because it exchanges energy and matter with its surroundings. A solar cell converts light energy (photons) from the sun directly into electrical energy.

- Energy gained:

Incident light energy (Q_{in}): This is the amount of solar energy that falls on the surface of the cell. It is usually calculated using the solar radiation intensity (W/m^2) and the cell area.

- Energy lost:

Heat loss (Q_{loss}): When photons from the sun strike the cell, some of them are not used to generate electricity but are converted into heat, raising the temperature of the cell. This loss is one of the main reasons for the low efficiency of solar cells.

- Reflection loss: Part of the sunlight is reflected off the surface of the cell and is not absorbed.

- Bandgap loss: Solar cells made of certain materials (such as silicon) can only absorb photons with a certain energy. Photons with very low energy pass through the cell, while the excess energy of high-energy photons is converted into heat.

Efficiency calculation:

The first law defines efficiency (η) as the ratio between the energy produced (electrical energy) and the energy absorbed (incident light energy).

$$\eta = (\text{electrical energy produced}) / (\text{incident light energy})$$

- **Example:** If 1000 watts of solar energy falls on a 1 m² cell and 200 watts of electricity is generated, the efficiency of the cell is 20%. The remaining 800 watts is energy lost in the form of heat and reflections.

2-Analysis of fuel cell efficiency

A fuel cell is an electromechanical device that converts the chemical energy of fuel (such as hydrogen) and oxidant (oxygen) directly into electrical energy.

- Energy gained:

o Chemical energy of fuel (Q_{chem}): This is the energy stored in the hydrogen and oxygen bonds.

- Energy lost:

Heat loss (Q_{loss}): Although fuel cells are not subject to the Carnot cycle limitations, they still lose part of their energy in the form of heat. This loss arises mainly from the internal resistance of the cell and voltage losses.

- Ohmic loss: This occurs due to the electrical resistance of the internal materials.

- Activation loss: The energy required to activate electrochemical reactions.

- Concentration loss: This occurs due to the difficulty of the reactants reaching the reaction sites.

Efficiency calculation:

The first law is used to determine efficiency by comparing the electrical energy produced with the total chemical energy of the fuel.

$$\eta = (\text{electrical energy produced}) / (\text{chemical energy of the fuel})$$

- **Example:** If a quantity of hydrogen containing 1000 joules of chemical energy reacts and the fuel cell produces 500 joules of electrical energy, its efficiency is 50%. The remaining 500 joules are lost as heat energy.

3. Comparison between the two systems

• **Solar cells:**

- Input energy: solar radiation (light energy).
- Output energy: electricity + heat.
- Efficiency: Highly affected by temperature. High cell temperatures significantly reduce efficiency.

• **Fuel cells:**

- Input energy: Chemical energy.
- Output energy: Electricity + heat.

Summary:

The first law of thermodynamics is a fundamental tool for evaluating the performance of renewable energy systems. It states that energy does not disappear, but rather transforms from one form to another, highlighting the importance of reducing thermal and mechanical losses to maximize the efficiency of these systems.

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