Lecture 2. Chemical, schematic and technological schemes. The essence and methods of compiling material and energy balances.

Chemical production as chemical-technological system

- The **chemical production** is complex chemical-technological system consisting of a large number of devices and of various equipment and connections between them .
- **Chemical-technological system** is the combination of physical and chemical processes and tools to carry out them to obtain the product of specified quality and in required quantity .

- System is divided into
- **1. element** is independent and conditionally indivisible unit;
- **2. subsystem** is a group of elements having a certain continuity and purposefulness.
- In the chemical industry the **element** is said the **apparatus**, in which a generic process proceeds.
- Subsystem is a **group of apparatus**, **technological plant** .

There are different types of bonds between the elements and the subsystem: material, energy and information, which are realized in the form of streams carrying substance and energy.

ChTS has some common features:

- **The overall aim of the operation (chemical production)**
- **The multiplicity of elements and bonds between them,**
- **A large number of parameters characterizing the operation of the system,**
- **High degree of automation processes of production management.**

Classification of bonds (stream)

Streams between the devices are classified according to their content :

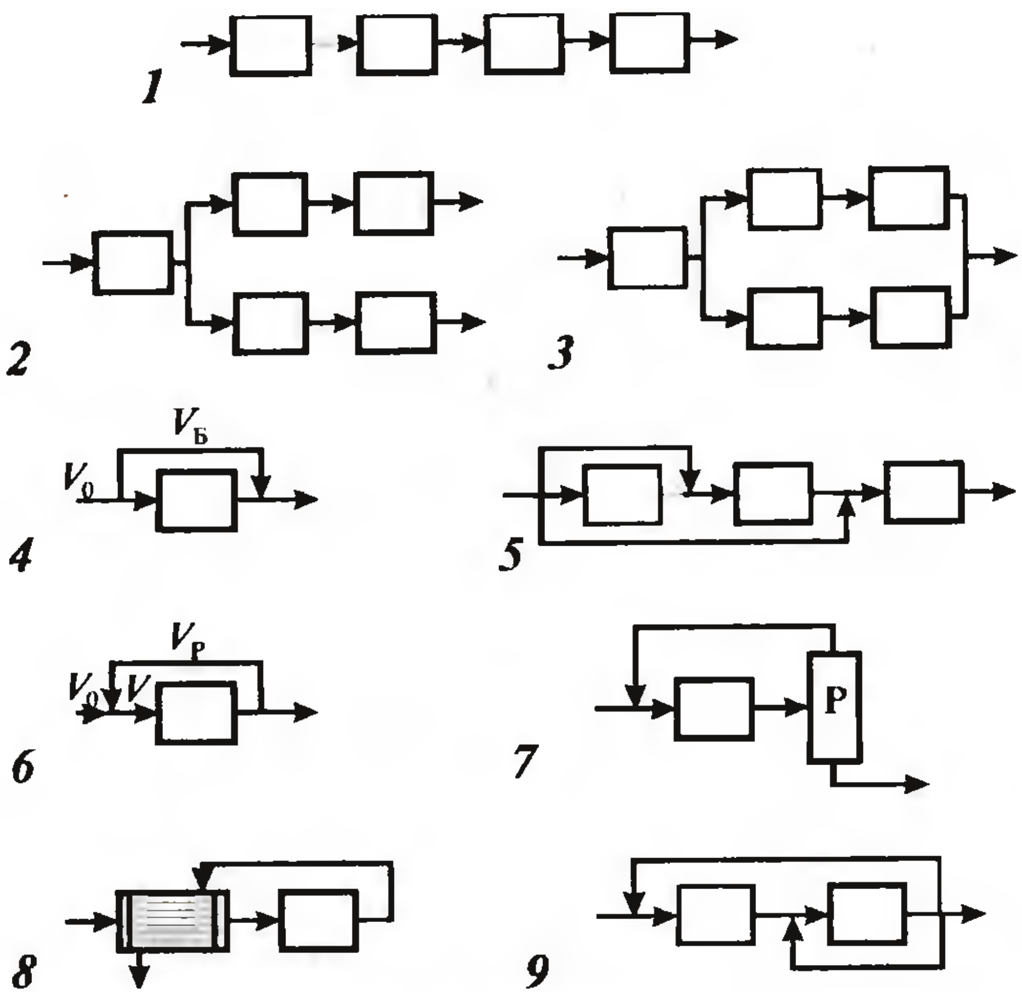
- **Material streams** transfer substances and materials by pipeline, conveyors and other mechanical devices.

- **Energy streams** transfer E in any form: thermal, mechanical, electrical and fuel. The thermal energy and fuel for the power elements usually are transferred by pipelines (steam, hot streams, inflammable gases and liquids), mechanical E - also by pipeline (as gas under pressure). Wires, power cables transmit electrical E.

- **Information streams** are used in control and management of process and production. Electrical wires and thin, capillary tube for pneumatic systems are used.

The structure of bonds

The structure of bonds provides the necessary conditions of work of the system's elements



Bonds in chemical engineering system:

1 – Serial;
2 – Branched;
3 – Parallel;
4, 5 – Bypass: simple (4) and complex (5);
6-9 – Reverse, recycle

Serial bond (Scheme 1). Stream passes the device by turns.

Branched bond (Scheme 2). After an operation the stream is branched and further separate streams are processed by different ways.

Parallel bond (Scheme 3). Stream is branched, the separate parts of it pass through different device, then streams are combined.

Bypass bond (Scheme 4 and 5). Part of the stream not being received to device, “bypasses" it.

Reverse **bond**, or recycle (scheme 6-9). Part of the stream after one of the device returned to the previous one.

Organization of chemical-process

- Development of chemical, principal and technological schemes of process;
- Selection of optimal technological parameters and the establishment of technological mode process;
- Selection of type and construction devises;
- Selection of construction materials for the equipment;
- To establish controlled and adjustable parameters for each stage of the process.

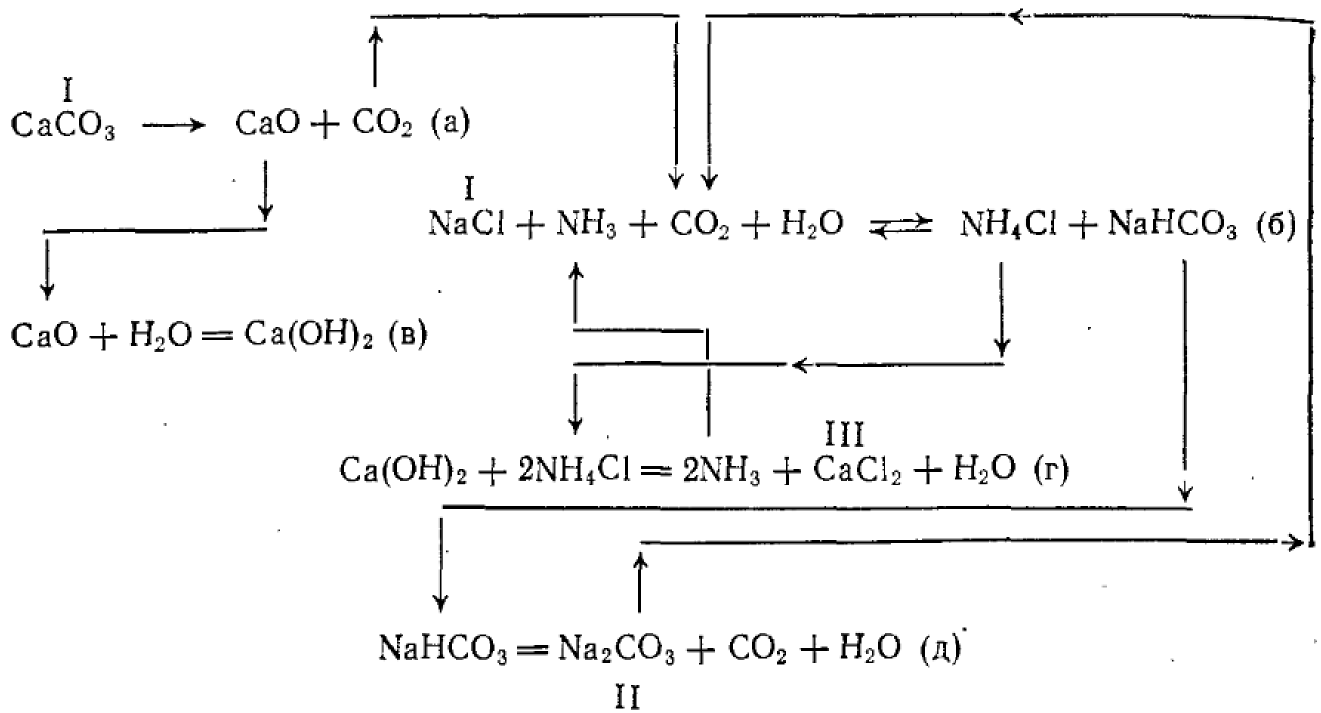
Chemical schemes

Chemical schemes are chemical reaction occurring to obtain the desired product from given raw materials .

$$Ca_5(PO_4)_3F + 5H_2SO_4 = 3H_3PO_4 + 5CaSO_4 + HF$$

$$Ca_5(PO_4)_3F + 10HCl = 3H_3PO_4 + 5CaCl_2 + HF$$

$$Ca_5(PO_4)_3F + 10HNO_3 = 3H_3PO_4 + 5Ca(NO_3)_2 + HF$$



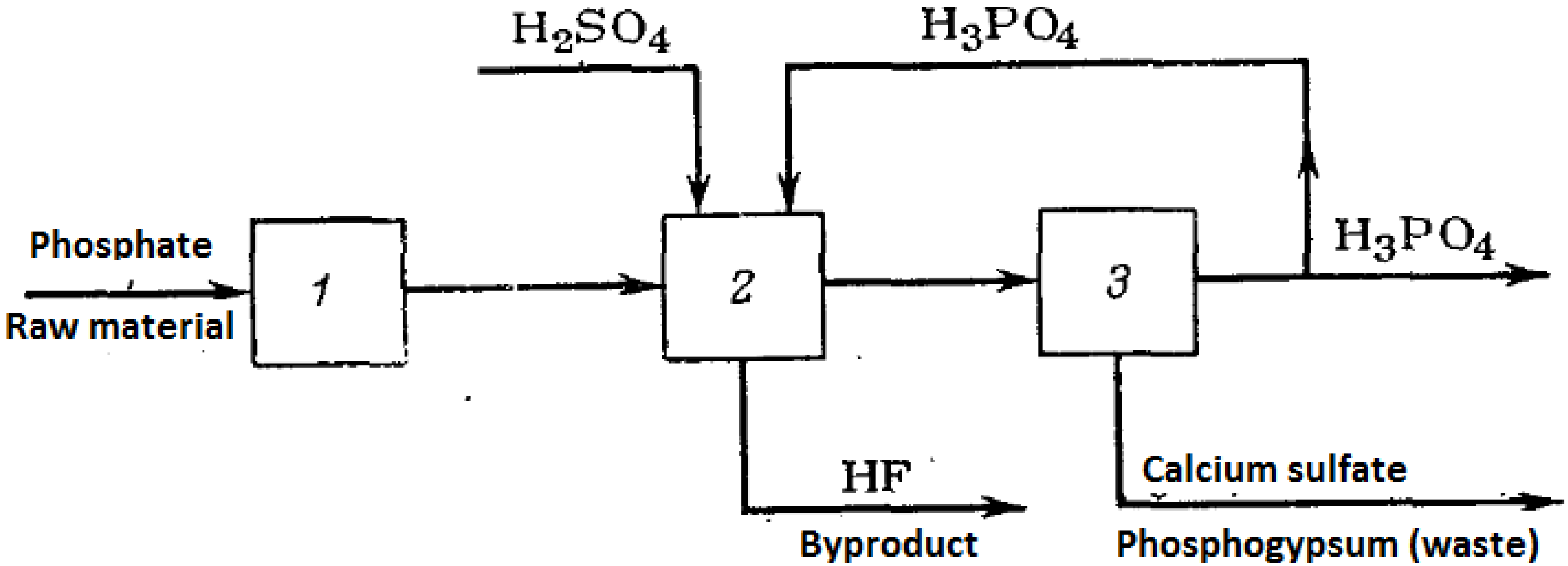
Principal schemes - Block Flow Diagram (BFD)

- *At an early stage*
- *Provide an overview of a complex process or plant*
- *Blocks that represent individual processes or groups of operations*

Properties

1. Operations shown by blocks
2. Major flow lines shown with arrows giving direction of flow
3. Flow goes from left to right whenever possible
4. Light stream (gases) toward top with heavy stream (liquids and solids) toward bottom
5. Critical information unique to process supplied
6. If lines cross, then the horizontal line is continuous and the vertical line is broken.
7. Simplified material balance provided

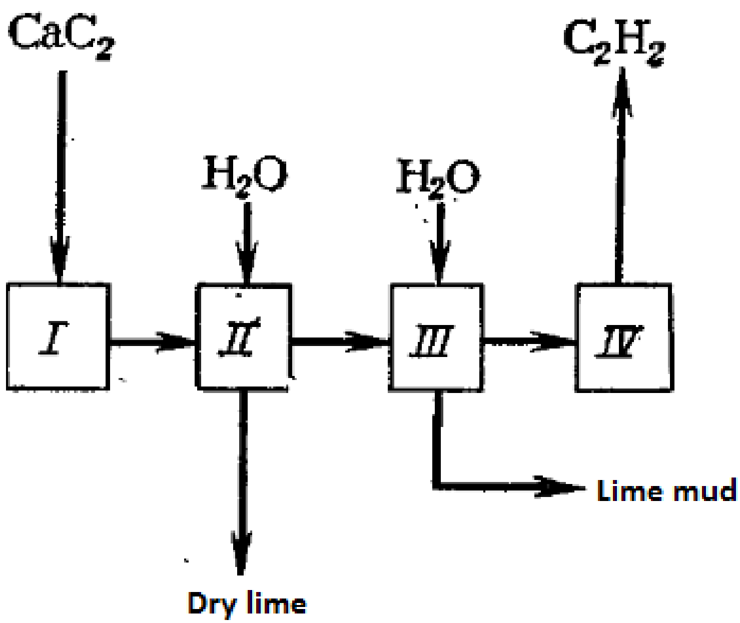
Principal schemes



Technological schemes - Process Flow Diagram (PFD)

- Shows material and energy balances
- Shows major equipments of the plant. They include all vessels, such as reactors, separators, and drums; special processing equipment; heat exchangers; pumps; and so on.

Technological schemes



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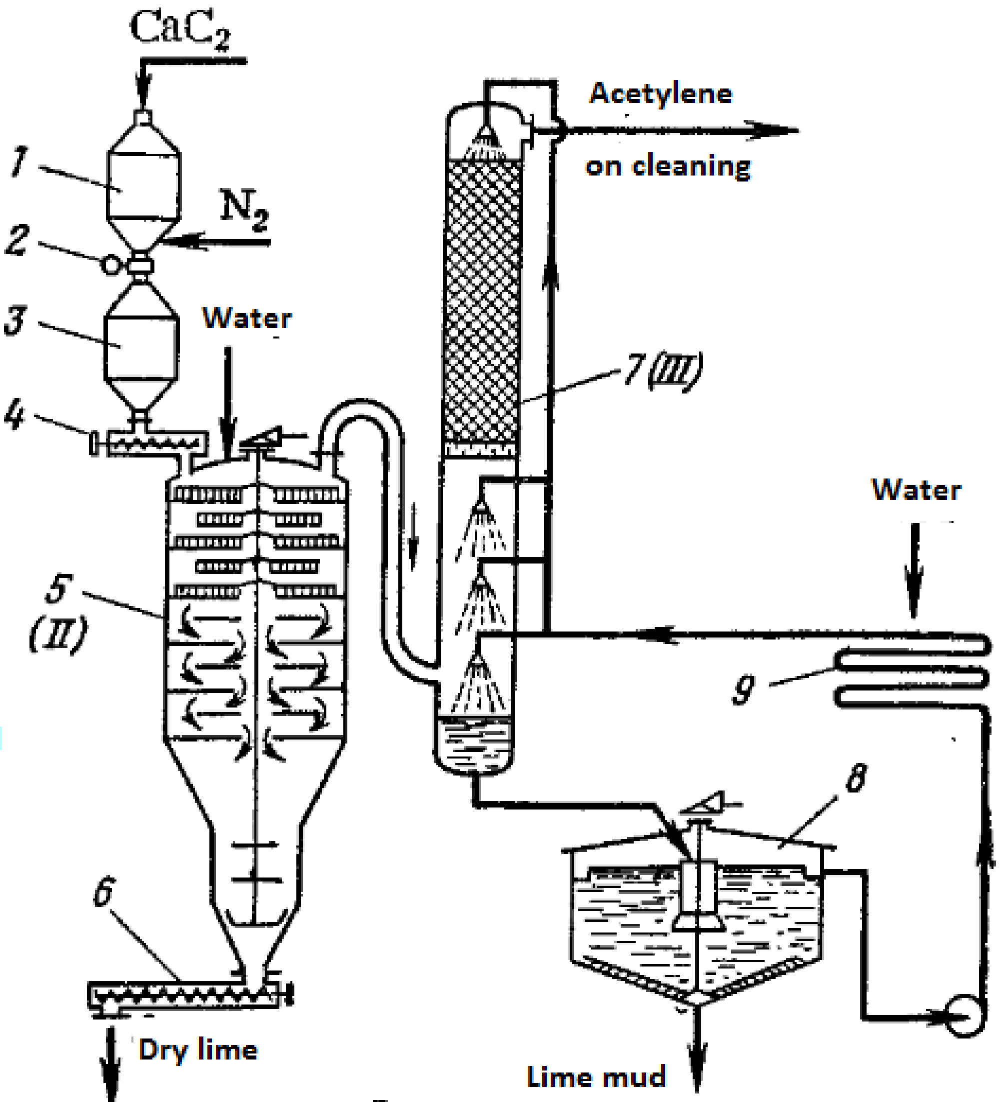

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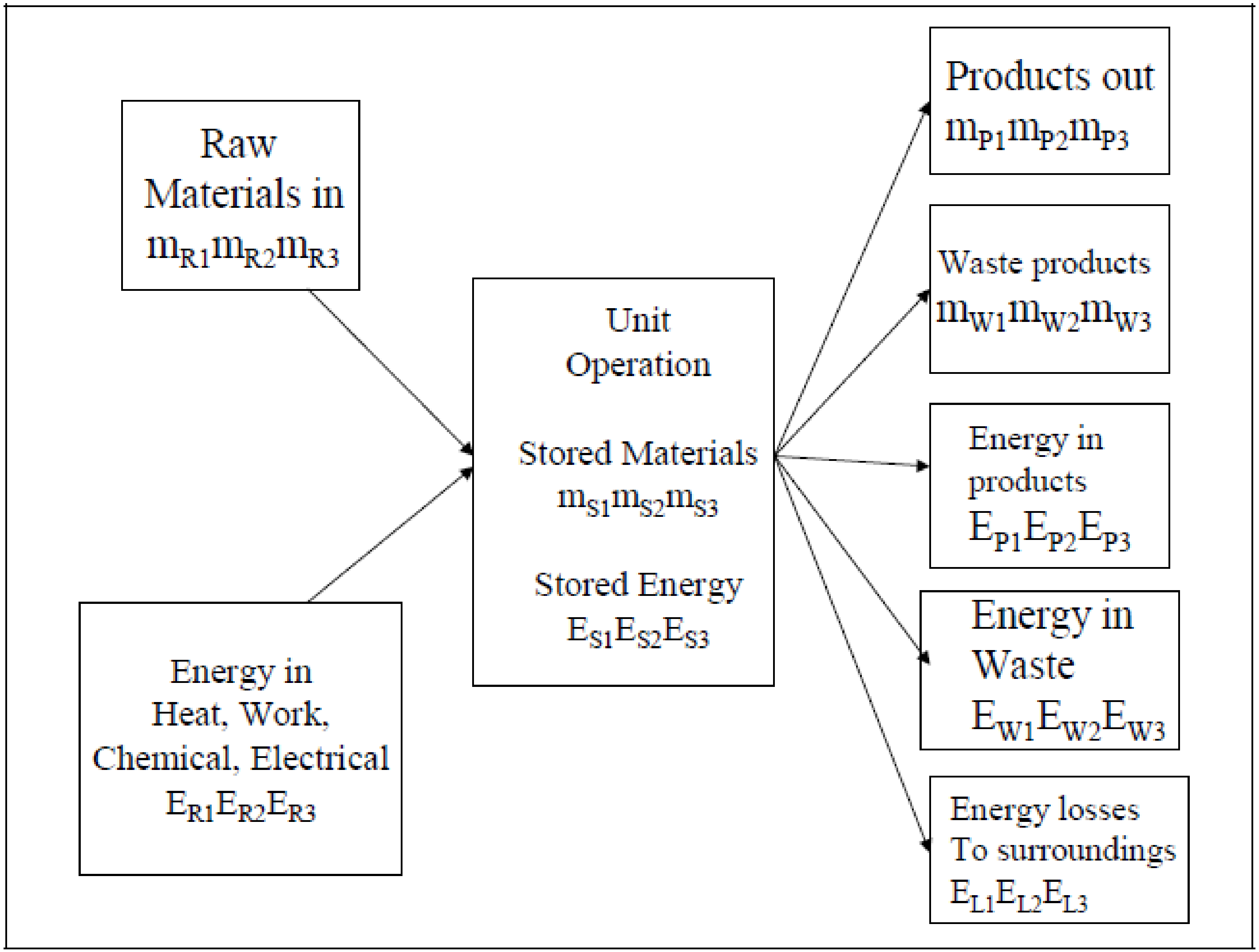
Material and energy balances

- Material balances are important first step when designing a new process or analyzing an existing one. They are almost always prerequisite to all other calculations in the solution of process engineering problems.
- Material balances are nothing more than the application of the law of conservation of mass, which states that mass can neither be created nor destroyed. Thus, you cannot, for example, specify an input to a reactor of one ton of naphtha and an output of two tons of gasoline or gases or anything else. One ton of total material input will only give one ton of total output, i.e. total mass of input = total mass of output.



Mass and Energy Balance

- The law of conservation of mass leads to what is called a mass or a material balance.
  - Mass In = Mass Out + Mass Stored
  - Raw Materials = Products + Wastes + Stored Materials.
  - $\Sigma m^R = \Sigma m^P + \Sigma m^W + \Sigma m^S$
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- $\Sigma m^R = \Sigma m^{R1} + \Sigma m^{R2} + \Sigma m^{R3}$ = Total Raw Materials
- $\Sigma m^P = \Sigma m^{P1} + \Sigma m^{P2} + \Sigma m^{P3}$ = Total Products.
- $\Sigma m^W = \Sigma m^{W1} + \Sigma m^{W2} + \Sigma m^{W3}$ = Total Waste Products
- $\Sigma m^S = \Sigma m^{S1} + \Sigma m^{S2} + \Sigma m^{S3}$ = Total Stored Products.

- The energy coming into a unit operation can be balanced with the energy coming out and the energy stored.
- Energy In = Energy Out + Energy Stored
  - $\Sigma E^R = \Sigma E^P + \Sigma E^W + \Sigma E^L + \Sigma E^S$

- $\Sigma E^R = E^{R1} + E^{R2} + E^{R3} + \ldots\ldots$ = Total Energy Entering
- $\Sigma E^p = E^{P1} + E^{P2} + E^{P3} + \ldots\ldots$ = Total Energy Leaving with Products
- $\Sigma E^W = E^{W1} + E^{W2} + E^{W3} + \ldots$ = Total Energy Leaving with Waste Materials
- $\Sigma E^L = E^{L1} + E^{L2} + E^{L3} + \ldots\ldots$ = Total Energy Lost to Surroundings
- $\Sigma E^S = E^{S1} + E^{S2} + E^{S3} + \ldots\ldots$ = Total Energy Stored
- Energy balances are often complicated because forms of energy can be interconverted, for example mechanical energy to heat energy, but overall the quantities must balance.