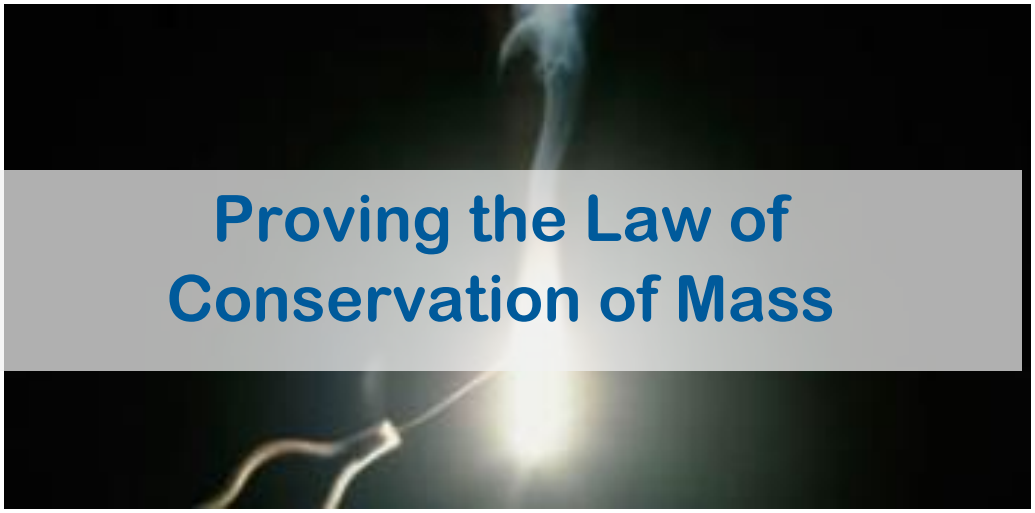
Teacher's Card



Proving the Law of Conservation of Mass

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General Introduction

The aim of this lesson is to draw attention to the law of conservation of mass and test it experimentally. The reaction used in this experiment is deliberately chosen so that the students cannot prove the law of conservation of mass, thus raising the issue of resource circulation, the conditions in which production processes take place, side reactions and other aspects.

This lab exercise is designed for students aged 16 and above, who know how to write redox equations, safely conduct experiments that produce a large amount of heat and a bright flame, perform calculations based on chemical equations as well as use critical thinking to search for and use information.

Keywords:

Magnesium, redox reactions, circular economy, conservation of mass

Additional Background Information

Every process is based on the laws of conservation of mass and energy. The law of conservation of mass states that if a system is not exposed to any external influence, its total mass does not change over time; that is, mass can neither be destroyed nor created from nothing, it is an integral part of matter. In the context of chemical reactions, it means that in any course of a reaction, no atoms of any of the chemical elements disappear or appear. The number of atoms of the element remains the same before and after the chemical reaction. Hence, the mass of the reacting substances is equal to the mass of the resulting substances. Similar principles are seemingly applied to different processes on Earth, including various production processes, and it is rare that attention is paid to losses and side processes (in this case, other side reactions) which in reality are typical components of these processes.

Learning Outcomes

Upon completion of this activity, the students will be able to:

- apply the principles of redox reactions;
- observe various types of chemical reactions and correlate the observations with these reactions;
- observe the signs of a chemical reaction and assess how the conditions of the experiment affect the end products of the reaction;
- analyse the composition of the air and the reactive substances contained therein.

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Key Competences within the European Framework

Literacy competence
S1. Ability to understand and interpret concepts, feelings, facts or opinions in oral and written form.
S4. Ability to interact in an appropriate and creative way in any situation.
Multilingual competence
S1. Ability to understand and interpret concepts, feelings, facts or opinions in oral and written form.
S4. Ability to interact in an appropriate and creative way in any situation.
S5. Knowledge of vocabulary, grammar and language.
Mathematical competence and competence in science, technology and engineering
S1. Ability to use constructive thinking in order to solve a problem in every situation.
S5. Capacity for quantitative thinking.
S6. Ability to extract qualitative information from quantitative data.
S7. Ability to formulate problems mathematically and in symbolic form to facilitate their analysis and solution.
S8. Ability to design experimental and observational studies and analyse data resulting from them.
S9. Ability to formulate complex problems of optimisation and decision-making and to interpret the solutions in the original contexts of the problems.
Digital competence
S1. Critical use of information technology for work.
Personal, social and learning to learn competence
S1. Ability to pursue and persist in different kinds of learning.
S2. Identifying available opportunities.
Citizen competence
S1. Ability to effectively interact with other people.
S3. Ability to work effectively and collaborate with other team members.
Cultural awareness and expression competence
S3. Ability to plan and manage tasks.

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United Nations' Sustainable Development Goals

The Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including those related to poverty, inequality, climate change, environmental degradation, peace and justice.

	Enable access to basic services		Equal access to global expertise
	Safe medical devices		Sustainable urbanization
✓	Access to education	✓	Responsible consumption and production
	Less hardship, more opportunities		Strengthen resilience, reduce disaster impact
	Safe and affordable water		Reduce marine pollution
	Energy – the golden thread	✓	Sustainable use of terrestrial ecosystems
	Safety of workers and economic growth		Promote peaceful and inclusive societies
	Resilient infrastructure and sustainable industrialization		Better access to technology and innovation

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Contents – Theoretical Principles

It is best to demonstrate the law of conservation of mass if the reaction is explicit under the given conditions, meaning that there are no reagents in the surrounding system that could interfere with the reaction, and none of the resulting products are volatile (or the system is fully closed).

During the combustion of magnesium, the temperature may exceed 500 ^{o}C and a bright flame occurs. Burning magnesium produces white smoke, namely magnesium oxide. This is the first reason why the law of conservation of mass cannot be proven with this experiment – since the system is not closed, students cannot determine the loss of magnesium oxide mass.

This experiment is carried out in the air atmosphere. It contains many reactive substances (not just oxygen), such as carbon dioxide, water and nitrogen. Since a large amount of heat is released during the combustion process, it can act as an activation energy for other reactions, such as:

$Mg + H_2O \rightarrow Mg(OH)_2 + H_2$

$MgO + H_2O \rightarrow Mg(OH)_2$

$MgO + CO_2 \rightarrow MgCO_3$

$3Mg + N_2 \rightarrow Mg_3N_2$

$Mg + CO_2 \rightarrow MgO + C$

Magnesium hydroxide, magnesium oxide and magnesium carbonate are all white substances, however, they have different molar masses. It is impossible to distinguish based solely on visual observations whether there is only one of these products in the crucible. In all the experiments carried out so far, the students have also obtained carbon, which looks like a black powder alongside the white mixture of magnesium-containing products. Depending on how long the students burn the sample, magnesium nitride may also occur, which is olive-green in colour. So, the students shall deduce based on visual observations that other reactions must have also taken place because there are several visually different products.

The last aspect that must be taken into account in this experiment is the "initiator" of the process, namely the gas burner. For the pieces of magnesium ribbon to ignite, it is necessary to supply heat. It is achieved by burning butane (usually). However, it is worth noting that the combustion of butane is a chemical reaction in and of itself producing various products. Any organic matter can either burn completely (producing carbon dioxide and water) or partly (generating water and carbon monoxide or just carbon). So, in fact, there are two reactions in this system of magnesium combustion taking place, each of them subject to the law of conservation of mass.

This simple reaction mimics real processes that we encounter in manufacturing and other areas. It encourages us to pay closer attention to the processes of circulation and realise how complex they are.

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Lab Procedure

The purpose of this lab exercise is to experimentally test the law of conservation of mass. The reaction used in this experiment is deliberately chosen so that the students are unable to prove the law of conservation of mass, thus raising the issue of resource circulation, the conditions in which production processes take place, side reactions and other aspects.
Resources on this topic:

Module 1 – Burning Magnesium

Learning Pathway

Step 1 – 10 min. – the teacher reminds students of the specific safety rules pertaining to this lab exercise, especially the fire safety principles and the use of personal protective equipment.
Step 2 – 40 min. – students are divided into groups of 3 people each. Each group receives its own metal crucible and carries out the experiment based on the prepared lab procedure outline.
Step 3 – 50 min. – students work in groups to fill out the remaining protocol, answer the questions, search for information, discuss the obtained results, etc.

Evaluation

The lab protocols submitted by students can be evaluated according to the following criteria:

1. *Registration of data in the table* – 1 point. Pay attention to the number of digits behind the decimal point, which depends on how accurate the balances are.
2. *Describe the contents of the crucible (purple liquid, red powdery substance, etc.). Using available literature and previous knowledge, identify the chemical formulas of the potential products! Write at least 3 chemical equations representing the transformations that could have occurred during the experiment!* – 5 points. 2 points for a correct description of the observed substances and their chemical formulas. 1 point for each logical, correctly written chemical equation, a total of 3 points.

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3. *What did you observe during the experiment? Assess whether, by conducting such an experiment, it is possible to prove the law of conservation of mass! Substantiate your answer! Write at least 2 suggestions on how this experiment could be improved to prove the law of conservation of mass more successfully!* – 5 points. 1 point for correct observations (bright flame, white smoke, heat). Assessment of the experiment and justification of the answer – 2 points (explanation based on the comparison of the theoretical and experimentally determined mass, and visual appearance of the products). 1 point for each reasonable recommendation, a total of 2 points (Examples: capture MgO smoke to determine its mass; conduct an experiment in an atmosphere of pure oxygen; use another heat source for burning, etc.)

Description of Student's Cards

Student's Card 1 – Burning Magnesium

Sources

https://www.youtube.com/watch?v=IqOrCiOquRI
https://www.angelo.edu/faculty/kboudrea/demos/burning_magnesium/burning_magnesium.htm
https://chem.libretexts.org/Ancillary_Materials/Demos_Techniques_and_Experiments/Lecture_Demonstrations/Burning_Magnesium
https://www.nature.com/scitable/knowledge/library/the-conservation-of-mass-17395478/

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