# A Physical Chemistry Escape Room With 4 Metals

**Michaela Kröppl**
University of Applied Sciences Upper Austria, School of Engineering, Campus Wels, Austria

michaela.kroeppl@fh-wels.at

**Abstract:** Natural sciences such as chemistry are inherently fascinating, but they can also appear complex—often requiring substantial prior knowledge before one can fully understand the phenomena involved. To make scientific topics more accessible and reduce apprehension, game-based approaches have proven highly effective. Problem-solving and experimentation within a gamified environment tend to be intrinsically motivating, encouraging participants to engage actively—often learning without even realizing it. This paper presents a physical chemistry escape room consisting of five task stations. The stations can be played sequentially (1 to 5) or in a parallel rotation format, where four are completed before finishing together at the final station. The thematic focus of the escape room is on metals, with four key metals—aluminium, copper, iron, and zinc—at the centre of each station's learning objectives. At each station (approximately 3–4 m² in size), players are challenged to solve riddles—either clearly visible or hidden (e.g., in envelopes, inside or under books, in newspapers, or on the walls)—by using information provided on surrounding posters and materials. The tasks are designed to convey scientific knowledge related to the four metals, such as properties including mass and magnetism. Activities include crossword puzzles, numeric or pictorial codes, combinatory questions, and hands-on physical experiments. Examples of these experiments include determining the density of metals using various methods or constructing a lemon battery at the final station. The game has been successfully tested with children aged 6 to 12 years. With slight adjustments to pacing, it is expected to be also suitable for older participants—for instance, as a quick and enjoyable way to review previously learned chemistry content. Overall feedback has been very positive, and it appears that all participants leave the game with enhanced knowledge about the four featured metals.

**Keywords**: Chemistry, Escape room, Metals, Gamification

## 1. Introduction

Escape room games are a special kind of gamification. The main objective of escape room games is to solve a series of tasks — either in a set or flexible order — to exit the room or environment where the game is held. In some cases, the goal might also be to discover a hidden treasure.

In the Cambridge dictionary, the following definition for escape rooms can be found: "Escape rooms are a game where people are locked into a room and have to find a way to escape by finding clues (= signs or information that help you to find the answer to a problem or mystery) in it, and solving puzzles, or a special room where this is done."[1]

A subgroup of escape rooms are educational escape rooms. They have emerged as effective tools for increasing engagement and motivation in learning contexts. Solving interconnected challenges in a gamified way can be especially positive for the encouragement of problem solving of abstract or complex topics as for example in science education.[2, 3].

The escape room described in this paper concentrates on the four metals aluminium, copper, iron, and zinc. It was developed to let the participants – originally specifically children - learn interesting things about the metals´ properties. In this sense it should foster curiosity for natural sciences.

## 2. Background and Related Work

Natural sciences like chemistry are incredibly fascinating, but they are often perceived as difficult. To make these topics more accessible and less intimidating, games can be a powerful tool. By embedding problem-solving and experiments in a playful, gamified environment, learning becomes more engaging and enjoyable. Research has shown that gamified learning environments can improve both motivation and learning outcomes.[2] In fact, people often learn without even realizing it and may desire further exploration of a topic.

As escape room games offer structured, goal-oriented environments that combine storytelling, puzzles, and physical interaction [4], they have become increasingly popular in both formal and informal education settings.

The goal behind designing this chemistry escape room with incorporated hands-on experiments on the four metals (aluminium, copper, iron, and zinc), described in more detail below, was to make chemistry more accessible to children by creating tasks that are engaging, interactive, and simple enough for even younger kids to solve - with just a little bit of support.

## 3. Game Design and Structure

### 3.1 Concept and Objectives

In this escape room game four metals (aluminium, copper, iron and zinc) play the main role. They were chosen because of their obviously different properties which makes them distinguishable from each other quite easily. Aluminium is very light, copper has a copper shine, iron is magnetic, and zinc is silvery shining but non-magnetic. Furthermore, these four metals are often familiar from everyday life. In the household, e.g. aluminium foil, copper wires for electricity or iron tools are well-known.

In the escape room the players get motivated to identify, investigate, and apply their knowledge from daily life and from additional information slides in the escape room about the four different metals.

By solving the tasks at the different stations, the players can touch, weigh, and test the metals to identify them and to learn more about their properties. This also includes determining volumes (by measuring, calculating and using Archimedes' principle) and masses and then calculate densities with the density formula. The participants can additionally gain information from the information poster slides at each station – which is also very useful for solving the riddles. In the last station, the players should have enough information to construct a functioning battery (the lemon battery) that lights a lamp - hereby completing the “mission”.

The two main learning objectives can be summarized to:

- Introducing the properties of common metals (density, magnetism, colour) and of related alloys
- Encouraging scientific reasoning, mathematical thinking and problem-solving in a playful learning environment

### 3.2 Setup and Logistics

The game is organized into five task stations, each occupying around 3-4 m² - depending on the possibilities in the current playroom. The activity can be run in two formats:

- Sequentially (stations 1 to 5 in order), or
- in parallel (especially for larger groups) with a clockwise rotation from station 1 to 4 and the 5$^{th}$ station with all players.

Each station is supervised by game instructors. Their functions are:

- to help players when they need a hint or have a question to the setup
- to pay attention that the game is played in the right order (some items - like for example envelopes with alchemical symbols or padlocks - can only be opened after having solved a certain riddle or using a decoding mechanism before) or,
- to reset all the puzzles and to reprepare the stations for the next group.

At every station, various tasks are placed - obvious to find or hidden somewhere at the station (e.g. in an envelope, in or under a book, in a newspaper, or on posters).

Additionally, posters with information for the station´s topic (e.g., the periodic table of the elements) can be found in the station area close to the table.

Playing in the parallel mode, players take a break after completing a station until also the other groups have finished their stations, and all stations have been reprepared. After that, all groups move on clockwise to the next station.

Every task station needs around 15 to 30 minutes (depending mostly on the age of the participants) to be completed. In total, the escape room lasts between 2 and 2.5 hours, depending on group size and age. Especially for smaller children, a break of around 15 minutes after two stations (for eating, drinking and relaxing) is often necessary and helpful to recharge their batteries for the next tasks.

Figure 1 depicts the room arrangement for a specific run of the escape room game, with the beamer presentation for the introduction, the task stations with various items and the informational slides visible.

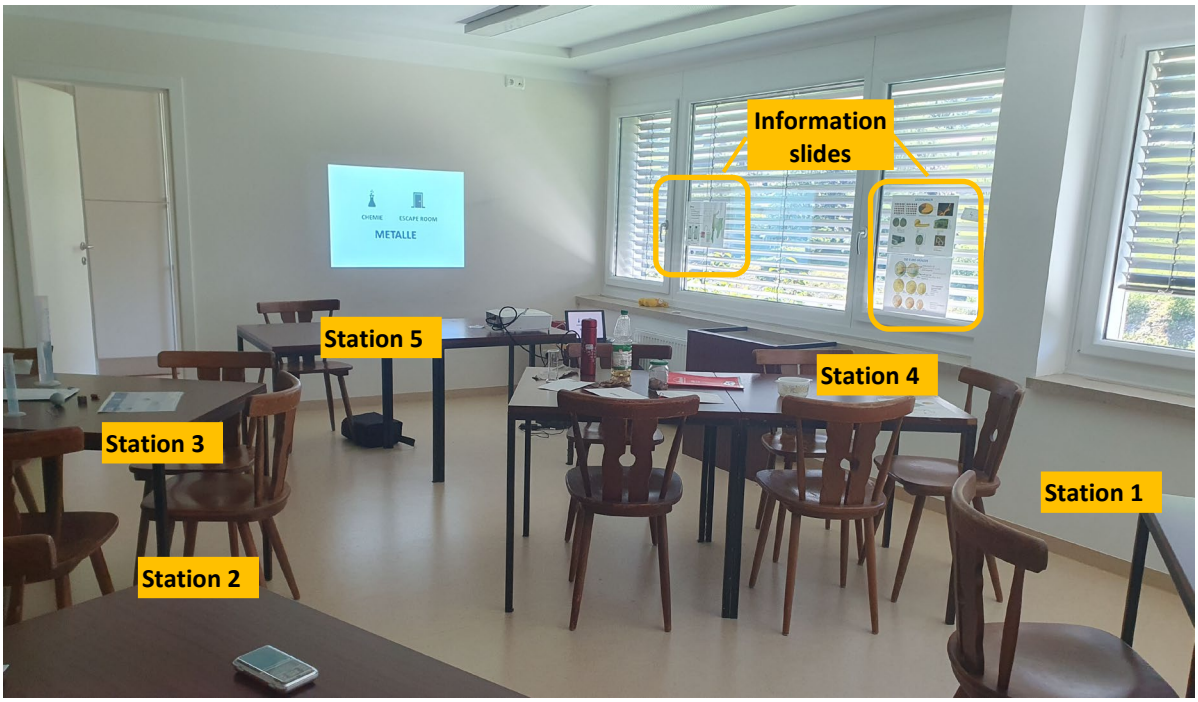



**Figure 1: The set-up of the escape room on one occasion; Photo M. Kröppl**

It must be stated that all materials (poster information slides, work sheets, decoder disc, decoding machine, ….) have been designed and created by the author herself.

## 4. Station Overview and Task Description

The various tasks on the stations should give players things worth knowing about the four metals (e.g. properties like colour, mass, magnetism, usages, positions in the periodic table of the elements, …). They include crossword puzzles, number or picture codes, combination tasks and doing real physical experiments (like for example determining metal densities via different methods or cleaning copper coins with vinegar and salt). The last task is to build a lemon battery with lemons, wires and two different metals and to activate a small lamp.

The following chapters will describe the tasks at the five stations in more detail. For the different riddles, always the solutions will be shown (available also for the game instructors) – in the game, the question fields would be empty for the participants.

### 4.1 Station 1 - Story Introduction

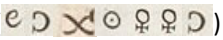
The game begins with a welcome letter inviting the children into an imaginary alchemist's lab and describing the goal of the game – finding a solution to build a battery to activate a small lamp.

It says:

> *"Welcome to my alchemy lab! Nice of you to come visit! Unfortunately, I must dash off quickly. I need to see if I can find a battery. Somehow, I still need to make that little lamp light up today. But feel free to look around the lab already. Who knows, maybe the answer lies in your hands. To make a battery, you need two different metals and an electrolyte. A good combination is one noble metal and one base metal. A few metals lie upon the table. If only I could tell what they are. Could you perhaps help me? Feel free to use anything in the lab and experiment as you wish. I'll be back soon! …*

The table contains:

- metal objects (made of aluminium, copper, iron and zinc)
- a small magnet
- a small lamp
- a chemistry book
- an envelope with a small padlock
- a small key

- an envelope with alchemical symbols (  )
- a newspaper text “Interesting facts about metals”

After the introduction to the game and reading the welcome letter, the players start to play. When they begin to investigate the items on the table, especially the small lamp should catch their interest, as - concerning to the welcome letter – this lamp should later be turned on with a battery. The players might be interested in exploring also other objects on the table - for example the metal objects – and to test them with the small magnet. This allows participants to easily identify iron, as it is the only magnetic metal among the four used in the game. By comparing the weights, they can determine the lightest metal – aluminium. Copper is typically recognized from electrical wires and is distinguished by its noticeably different colour. The remaining metal must therefore be zinc. The participants should now try to memorize the metals carefully as riddles and information to these four metals will appear at every station.

The players may also be curious to read the newspaper article “Interesting facts about metals” which will give them some basic information about metal properties. Participants will realize that, maybe unexpectedly, in most cases, they already know some of these properties — sparking their curiosity about what else they might discover during the game.

Another object catching the player´s interest, could now be the envelope with the small padlock. They surely detect a same-coloured small key on the table and might be curious to try to open the envelope. Inside the envelope, they find a pen and a decoder disc with four circles: the outer circle with numbers from 1 to 26, a circle with letters from A to Z, another circle with alchemical symbols and the inner circle with roman numbers.

With the discovered decoder disc, the “alchemical” symbols on the other envelope can now be deciphered to “METALLE” (metals). Inside this envelope, the players find – as maybe already expected from the deciphered word - a riddle about metals.

When the players look around, they will realize, that additionally to the items on the table, poster information slides are placed at the station. On the posters, information can be found concerning the periodic table (elements, names, atomic number, metals and non-metals) and a basic design of a battery and a galvanic cell made with the metals copper and zinc. The last information is already a hint for the last station of the escape room, where a lemon battery will be the final experiment.

Looking at the posters, the players will find hints for the solutions to the four questions of the “riddle about metals”. The solution code to this riddle then reveals to “1 2 1 1”.

Solving this riddle is not the last task at station 1. On the table, there are still unexamined items – a chemistry book and a newspaper. When browsing through the chemistry book, a hidden word search for precious metals can be found.

Surely, the players might already know some precious metals like gold or silver. But do they also know their chemical symbols? For being able to search the precious metals listed on the riddle, their full names should therefore be known. Here, the periodic table from the poster information slides can help to decipher the chemical language code. Looking then at the yellow highlighted letters, the solution word to this riddle will then turn out to be “METALLE” (metals). The players can thus reach the envelope with the alchemical symbols either by solving the puzzle with the precious metals or by deciphering it using the decoder disc.

Finally, by exploring the newspaper on the table, an “extra tricky chemistry riddle of the week” appears inside. For solving this riddle, the players again need to know something about the chemical symbols (help can again be found in the periodic tables) and some properties of the metals (metal/non-metal, precious/base and magnetic/non-magnetic). Additionally, a mathematical riddle must be solved – with chemical symbols and by using the decoder disc. The solution code for station 1 so turns out to be “4 1 1”.

### 4.2 Station 2 – Density and Mathematics

The aim of Station 2 is to let the players learn more about different properties of the four in this game investigated metals and their usages.

The players find

- a box with four density cubes (aluminium, iron, copper, and a wood cube as control)
- measuring tools (calculator, geometry triangle, small scale)

- a small magnet
- a hexagram puzzle with alchemical signs
- and an envelope with the letters “B D”.

When looking around the station, the poster information slides for the four metals in the game with pictures, usages and properties – and even alchemical symbols - should be an eye catcher.

Looking at the posters, the answers to the hexagram – matching alchemical symbols and metals - can be found with “2 4”. As soon as the players decipher the code “2 4” to “B D”, the envelope can be opened. In the envelope, a worksheet with a table for the calculation of the densities and the identification of the metals can be found.

To determine the densities, the cubes must be weighed and their masses recorded in the table. Their edge lengths (always 2 cm) also need to be measured. With the formula shown on the work sheet, the volume of the cubes can then be calculated as 8 $cm^3$. By applying the density formula, the densities of the four cubes can be determined - and by comparing them with the densities given on the work sheet – their materials can be identified.

To complete the table, the players fill in three columns describing specific properties of the tested materials — whether they are metals or non-metals, magnetic or non-magnetic, and precious or non-precious. A small magnet can help to identify magnetic materials.

By using the first letters of the element names placed correctly in the table and converting them to their positions in the alphabet, the solution code for Station 2 can be generated: “1 6 3 8”.

### 4.3 Station 3 – Density of Irregular Objects (Archimedes’ Principle)

The aim of Station 3 is to let the players learn about the Archimedes´ principle for determining volumes and together with the masses of the investigated irregular objects their densities and to so identify the materials.

At Station 3, the following items can be found on the table:

- four irregular metal objects (a silver sphere, a copper shining cylinder, a darker silvery shining cube and a silver right-angled strip)
- graduated cylinders in different sizes with water
- a mechanical decoder “machine” with moving slits and coded inputs
- measuring instruments (calculator, geometry triangle, small scale)
- a small magnet
- small keys
- and newspapers with different coloured padlocks.

Additionally, in the station area there are posters on the Archimedes’ principle and geometric solids.

At first glance, there appears to be no task to be solved on the table. Therefore (and maybe with the hint of an instructor), the players investigate the poster information slides. And there - on one of them - is a riddle. The question of the riddle is the following: “When a man – in this case Archimedes – enters a bathtub, will the water level in the bathtub change and when yes, how?” By looking at the poster information about the Archimedes´ principle or maybe even doing a small experiment by placing a metal object in a graduated cylinder at the table and looking at the change of the water level, the right answer “The water is overflowing.” can be found. Next to the answer the players see a blue key sign.

As the answer to the question with Archimedes and the bathtub is the blue key, the players can now conclude that the newspaper with the blue padlock can be opened. Inside, they find a work sheet with a table to fill in masses of metals, volumes and a column to calculate the densities of the metals.

Since the metal objects are only roughly geometric solids, measuring and calculating their volumes with the mathematical formulas shown on an information slide will only yield approximate results. Therefore, a better method is applied at this station using the Archimedes´ principle. By following the table on the worksheet, the players see that they need to measure the masses of the metals (using a scale, as in station 2) and determine their volumes — this time by placing the metal objects in graduated cylinders filled with water, reading the water levels before and after insertion, and calculating the difference.

After calculating the densities and concluding which metals the four objects are made of, the results can be entered in the mechanical decoder machine screen with the four slits. By first decoding the symbols of the table headers, the stripes with the shapes of the four metal objects can be placed in the right positions.

The solution code for station 3 can so be found to “1 2 4 3”.

### 4.4 Station 4 – Alloys and Coins

This station introduces the concept of metal alloys and their everyday applications, using both real and toy Euro coins as learning tools.

Materials on the table include:

- Euro coins (1c, 2c, 5c) (real coins and play coins as decoration for the topic)
- a bottle of vinegar
- table salt
- a small graduated cylinder
- a scale
- a small magnet
- a wire
- a red folder with a red padlock
- a newspaper article about “Nitinol - a shape-memory alloy”
- two envelopes with puzzles and a battery setup diagram
- a note paper with a scheme for the set-up of a lemon battery
- some notes
- a newspaper article about how to clean copper coins
- an envelope with a paper clip symbol
- an envelope with alchemical symbols  )

Additional information slides give information about alloys with some examples from the daily life and descriptions of the Euro coins (sizes, weight and especially interesting the metals used for the coins).

To start the game at station 4, a game instructor (for safety reasons) starts with a small experiment. He takes the wire from the table and requests the participants to attentively watch the following experiment. When the wire is put in a small bowl with hot water (practically taken from a thermos flask), the wire immediately forms a paper clip. This is nice wow effect for all players! In a self-designed paper article the players can then find out that the paper clip consists of a so called memory alloy called “Nitinol”.

After this amazing experiment, the envelope with the paper clip symbol can be opened. Inside, a crossword puzzle for alloys can be found. All answers can be found on the information slide about alloys and in the newspaper article about nitinol. In both cases, the hidden word — formed by arranging the red-circled letters — is “EURO”.

By looking at the items on the table and combining them cleverly, the word “EURO” from the crossword puzzle should lead to the envelope with the alchemical symbols. By using the decoder disc, the symbols can be deciphered to “EURO” which allows this envelope to be opened – a quiz about EURO coins emerges. All answers to this “extra difficult” riddle can be found on the information slide about the Euro coins.

After having solved all questions, the players will realize that in the quiz always the red key marked the correct solution. This understanding leads the players to the red map with the small red padlock. In there, another quiz about Euro coins can be found. The second quiz can be solved by weighing 5-cent Euro coins and measuring their volume using Archimedes' principle (which was the experimental topic of the previous station), followed by calculating their density. Comparing the result with the metal densities given at the quiz work sheet the players realize that the cent coins only have a copper coating but consist mainly of iron making them therefore magnetic. This leads to the solution code “1 1 3 1”.

After solving the quizzes about the Euro coins, there is still something to be done at station 4. On the table, a paper note provides interesting information about how to set up a lemon battery, a newspaper clipping explains how to clean copper coins, and there are also some additional notes.

The final step at Station 4 is to carry out a chemical experiment. Each group cleans one copper coin (resulting in a total of four cleaned coins for Station 5 if four groups are playing), following the method described in the

newspaper article. This experiment is fascinating for the players — like magic, dull copper coins are quickly transformed into shiny ones by swirling them in salty vinegar

### 4.5 Station 5 – Lemon Battery and Treasure

The fifth station marks the grand finale. The goal here is for players to combine all the knowledge they have gained about the investigated metals from the previous stations to assemble a battery and power a small lamp.

From the very beginning, the story's objective was to build a battery using a noble and a base metal to light the small lamp (or, in a variation, to power a small clock). Now, the participants apply their knowledge to construct a functioning lemon battery — as demonstrated in Station 4, this is indeed possible. A scheme how to set up a lemon battery with the metals copper and zinc is shown on the poster information slide.

On the table, the players find:

- lemons
- copper coins (cleaned in Station 4)
- zinc nails or platelets
- wires with crocodile clips
- a small lamp (from Station 1) and maybe additionally a small clock
- an envelope with a lightbulb symbol
- and a treasure chest with a number lock.

By using the cleaned copper coin from station 4 and some zinc nails or platelets, inserting them in the lemons as shown on the scheme on the poster and connecting them in the right manner together with the small red lamp, which had already been on the table at the first station, the lamp can successfully be powered by lemons! (see Fig. 2)

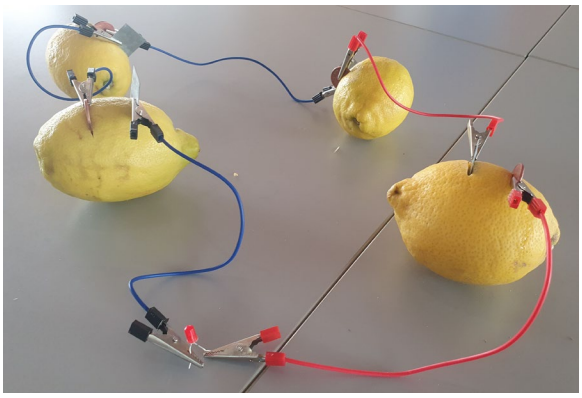


**Figure 2: Lemon battery with shining lamp; Photo M. Kröppl**

## 5. Results and Discussion

The "Chemistry escape room" was tested in over 15 workshops in 2023 and 2024 at "KinderUni" events. Participants were children aged 6 to 12 years, with varying group sizes (mostly 16 to 20 participants).

Although no formal pre/post testing was conducted, the following insights emerged through informal observations and anecdotal feedback:

- Most children really enjoyed solving the puzzles, were engaged and eager to participate.
- Particularly well received was that the children learned interesting facts about the metals and carried out practical experiments.
- Many participants left with some additional knowledge about the four metals addressed in the game and featured at all four stations.
- Teams of four to five often showed improved collaboration and communication over time when solving tasks at the different stations.
- The organizers from the "KinderUni" reported that the overall feedback to this escape room was very positive. So, even additional workshops were organized as there were so many children on the waiting list.

These observations suggest that the escape room not only increases motivation but also promotes long-term memory formation through active participation and storytelling. Structured evaluation tools (e.g., short quizzes or reflection forms) will be introduced in future implementations.

## 6. Conclusion and Future Work

This project demonstrates how gamified, narrative-driven formats can significantly enrich chemistry education for young learners. This escape room encourages the players – and it this special setup already children - to try out things with hands-on experimentation and playful exploration. It brings science closer to the participants and also enhances their curiosity.

Planned future developments include:

- Adaptations for secondary school level with more complex chemical content
- Implementation of quantitative assessment tools for measuring learning outcomes

This model introduces a scalable and dynamic framework that integrates scientific content with creativity and enjoyment, enhancing both accessibility and long-term retention.

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