# Escape Classroom: The Leblanc Process-An Educational ”Escape Game”

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# ESCAPE CLASSROOM: THE LEBLANC PROCESS - AN EDUCATIONAL "ESCAPE GAME"

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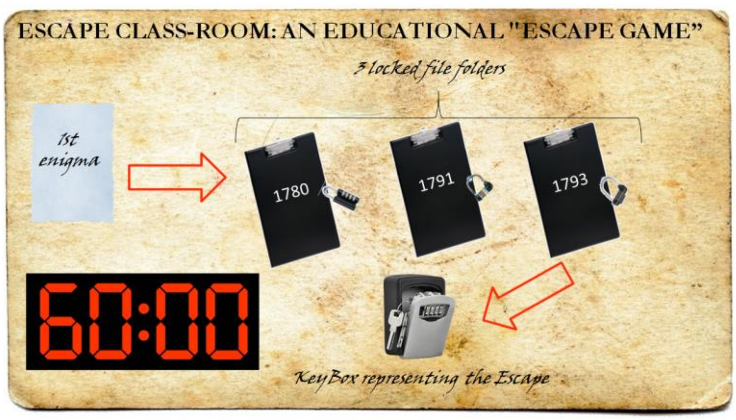
## ABSTRACT

An "escape game" activity is proposed to increase stimulation, team group skills and adaptability in the chemistry classroom. The students follow in the footsteps of Nicolas Leblanc, a young French chemist, who took part in a contest launched by the French Academy of Sciences in 1775 to produce industrial soda ash. By means of scientific puzzles, such as using the periodic table, balancing a reaction, drawing up a flowsheet or performing simple mole calculations, students will access combinations of numbers allowing them to open mechanisms present in the room that give them access to other enigmas. Following a precise sequence (controlled by the teacher present in the room), the students will thus advance in groups by retracing the development of one of the first industrial processes in the world. Escaping from the room is not the end of the activity: a debriefing will highlight the key elements of the construction of this process and will indicate the resources for further research, notably on the environmental consequences of the Leblanc process and the passing of the alkali act, one of the first laws to limit atmospheric pollution in the world. In order to simplify the principle of classical "escape games", a classroom version, based on an easily printable paper sheet and locked file folders, is proposed in this paper.

## GRAPHICAL ABSTRACT




## KEYWORDS

General Public, Chemical Engineering, Collaborative / Cooperative Learning, Communication / Writing, Humor / Puzzles / Games, Reactions /History, Philosophy

## INTRODUCTION

Chemistry is often seen as being difficult to learn and sometimes boring. Consequently, it is often not well appreciated by students. Educators have tried to change this and developed educational games to involve students in interactive and entertaining activities[1]. Games are an excellent method of active learning and many methods have been tested in the past decade: a word game[2], a card game[3,4], a board game[5], computer games[6,7] and a concentration game[8]. In all these activities, gaming is seen as an alternative way of encouraging communication among students, and might allow them to learn in a more entertaining way compared with the traditional lecture format[9,10]. However, most of these games are individual and do not develop team-building and group communication. A game based on the classical “escape game” is proposed here as an alternative educational activity in chemistry classrooms for high-school/college audience.

## THE ESCAPE ROOM

An escape room game is typically a one hour submersion into a scenario built around a specific theme. Participants, working as a group of 5-7 people, are locked in a room and given a set of puzzles and clues that need to be solved in order to escape from the room within one hour. This activity culminates in the discovery of a key or an element that allows "escape from the room”. Escape games are classically performed in a specific room, with locked materials such as lockers, cabinets, closets and advanced mechanisms (secret doors, secret lockers, etc.). As is it expensive to take the students to these escape rooms, or to build a complex escape room in the classroom, or to buy educative escape box systems (like BreakoutEDU) an alternative format is proposed to reproduce the mechanisms and the experience at reduced cost.

## THE MATERIAL

In order to reproduce the mechanism experience, several locks are needed. From 2 to 4 locks are necessary (depending on the duration of the escape game, which is typically from 30 to 60 minutes). These can be found at a variety of stores and can range in price from $5.00 to $10.00 each. Different mechanisms can be chosen for a better experience: key, number combination, word combination or directional lock. Multiple sets of locks can be purchased in order to run multiple groups at one time in the same classroom. In this case, locks can be chosen in different color for each group. The closets are replaced by file holders, mounted with a lock, and containing a step of the puzzle sequence. The ultimate step is escape from the room, and a keybox, a toolbox, or an ammunition box is ideal for this. This box will be where the solution, prize, treasure, or escape key will be found. An invisible ink marker and backlight, a flash drive, a fake book or a fake clock can also be used in order to add hints in the classroom. Finally, the game budget starts at 30$ for a 4 step, one hour escape game. The last item necessary for starting the game is a scenario with a historical background, an objective to complete in our hour and a chemistry environment. For this purpose, a scenario based on the invention of the Leblanc processes during French revolution is proposed.

## THE LEBLANC PROCESS

The Leblanc process, named after its inventor, Nicolas Leblanc [11], was an early industrial process for the production of soda ash (sodium carbonate) and was used throughout the 19th century. It involved two stages: production of sodium sulfate from sodium chloride (Equation 1), followed by reaction of the sodium sulfate with coal and calcium carbonate to produce sodium carbonate (equation 2) as follows:

$$2\ NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2\ HCl \qquad (1)$$

$$Na_2SO_4 + CaCO_3 + 2\ C \rightarrow Na_2CO_3 + CaS + 2\ CO_2 \qquad (2)$$

Leblanc's contribution was the second reaction, in which salt cake was mixed with *calcium* carbonate and coal, and fired to obtain sodium carbonate and calcium sulfide (*black ash*). The soda ash was separated from the black ash by washing with water. The wash water was then evaporated to yield solid sodium carbonate (lixiviation). Leblanc set up the first Leblanc process plant in 1791 in Saint-Denis near Paris. However, French Revolutionaries took the plant and made Leblanc's secrets public. He got the plant back in 1801, but without the funds, nor his contest prize, to repair it, and competed against other soda works that had been established in the meantime. Leblanc committed suicide in 1806 [12]. At the beginning of the 19th century, French soda ash producers were making between 10,000 and 15,000 tons annually, but it was in Britain that the Leblanc process became most widely used. By 1850, British annual soda production had reached 140,000 tons and reached 200,000 tons annually in the 1870s, more than that of all other nations in the world combined [13]. The process gradually became obsolete after the development of the Solvay process in 1857 [14].

## THE SCENARIO

The class is divided into groups of 5-7 students. The game starts with an introduction to the historical background by the teacher: "*In 1775, the French Academy of Sciences offered a prize of 2400 livres for the development of a process whereby soda ash could be produced from salt. The French Academy wanted to promote the production of much-needed sodium carbonate from inexpensive sodium chloride. In 1780 Nicolas Leblanc, a young French scientist, accepted a position of private physician to the household of Louis Philip II, Duke of Orléans. You are entering his office, in order to find the secret of his discoveries. You have one hour to escape and solve the game".* The timer is started for 60 minutes and each group receives a first enigma sheet (supplementary elements) and the three locked file folders: 1780, 1791 and 1793.

The first enigma is an easy puzzle based on the periodic table of Mendeleev [15,16]. The objective of this game is to make students use the table and imagine how it could help them to open the first lock. As a first hint, the educator can point them towards the line number which is indicated on the left of the table. As a second hint, the educator can say that personal passwords are usually based on the names of people. Note that hints can be given orally by the teacher or printed on the paper. The solution of this first enigma is the first name of Nicolas Leblanc, spelled in elements: Ni, Co, La and S. With the line number of each element, it is then possible to access the first 4 number combination necessary to open the first locked file "1780". This first step represents the education of Nicolas Leblanc and his need to learn science, and chemistry in particular, that would help him to become a chemist. It is possible, as a variation, to change the code for another name compatible with the periodic table, like a high school or university name, a city name or even famous character, such as *MoNaLiSa, AmErICa, BaNaNa, CoPErNiCuS, DyNAmITe, IReLaNd, SiNGaPoRe, BaZiNGa etc.* It is also possible to color the elements boxes with a UV marking pen and give a black light.

Opening the first file holder will release the second enigma sheet, depicted in Figure 1. The solution of this puzzle is necessary to unlock the 1791 file holder with its colored lock. The second sheet refers to a citation of Lavoisier, one of the 'fathers of modern chemistry' [17], in whose laboratory Nicolas Leblanc carried out his research. According to the Lavoisier citation, the objective is to balance the reaction and link the number obtained to the color combination of the second lock. As a first hint, the educator can explain the global method for balancing a reaction on the blackboard. As a second hint, the educator can give the first or first two steps of the balance procedure. This second enigma represents the work done by Lavoisier to find a way, and a chemical reaction, to create soda ash from basic compounds. This discovery was to enable him to propose a complete process in 1791 – represented by the second file holder. In order to increase the level of this enigma, supplementary equations could be given such as the first equation (Equation 1) of the process. This three equation system would take more time for the students to balance and would need three four-digit combinations to open three locks. In this variation, a master lock or a lockout hasp (with multiple locks) could be necessary.

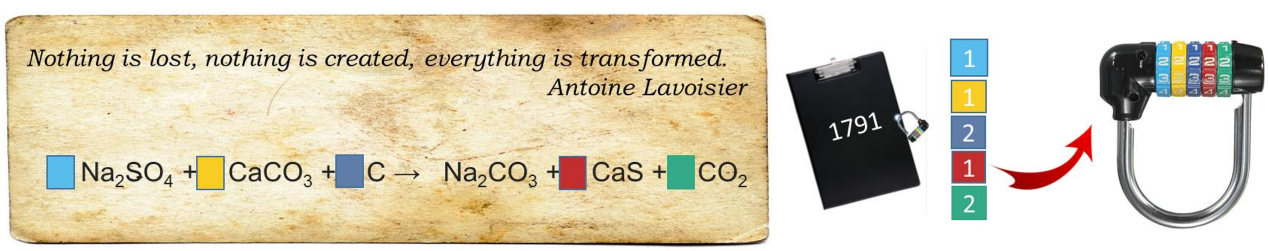



Figure 1. Second enigma sheet, present in the '1780' file holder, and its solution.

After opening the second locked file holder, the students have access to the third enigma sheet, represented in Figure 2. This puzzle consists of finding a five-letter combination corresponding to the 5 steps of the process patented by Leblanc in 1791. In order to increase the difficulty, only the four main steps are described: production of sodium sulfate, production of sodium carbonate (both high temperature reactions as indicated on figure 2), water washing and evaporation. As the first two reactions take place at high temperature, and as the third step uses liquid water, a cooler operation is needed between steps 2 and 3. The combination of the five unit operations unlocks the final word-lock of the "1793" file. A hint about this step could be given after a few minutes. The properties of the compounds, such as boiling and melting points, could be given directly or a chemical handbook could be present in the classroom.

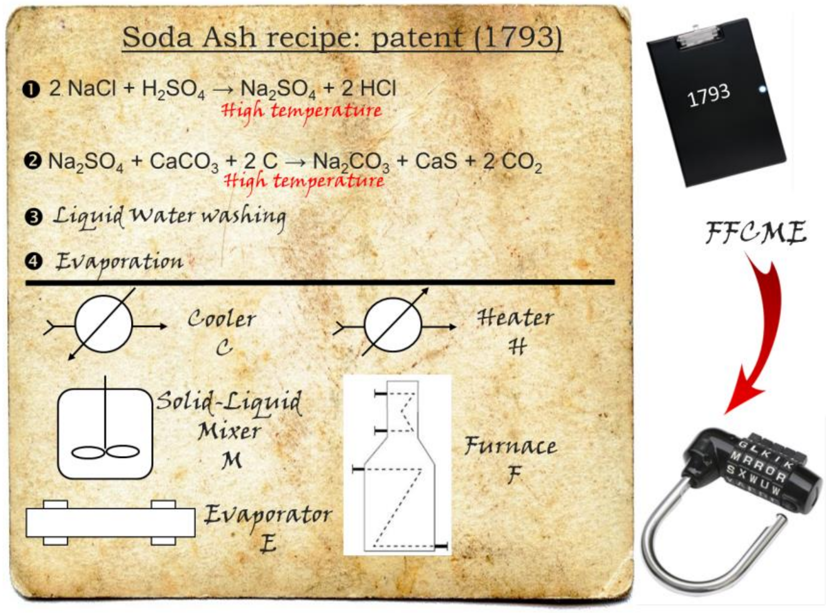



Figure 2. Third enigma sheet, present in the 1791 locked file holder, and its solution

Finally the students have access to the last enigma sheet, available in the supplementary section. In this enigma sheet, the global equation of the process is given, and a calculation of the daily production capacity of hydrogen chloride is requested. This step represents the application area of the process and its impact on the environment. Molar weights could be given to the students as a hint, or they could use the periodic table given in the first puzzle or a chemical handbook. The answer to this enigma is the four digit combination necessary to unlock the last box. Opening the last box will release the final key of the room or a winning/congratulation message. Finally, when all groups have finished the sequence of enigmas, a debriefing will highlight the key elements of the chemistry necessary for the construction of this process and the educator will indicate the resources for further investigation after the class, particularly on the environmental consequences of the Leblanc process due to hydrogen chloride production and the passing of the alkali act [18,19], one of the first laws to limit atmospheric pollution in the world.

## RESPONSES TO THE GAME AND DISCUSSION

A classroom escape game stimulates students to discover scientific concepts in a team and in a playful way, and gives them the opportunity to develop the adaptive and responsive skills that are expected of each student. Instead of listening to lectures or completing assigned reading and writing tasks, students are immersed in a story and given an opportunity to accomplish a fictional objective within a given time limit. It is also a chance for them to compete with, and against, their classmates, show off their individual skills, interact with each other, and experience moments of discovery and wins. This game do not replace classical lectures, but it is a complementary tool, that must be done punctually and following the specific classes to take a break and to escape monotony in classroom. The game has been tested on 40 students and volunteers, and four teachers from university and high-school. A survey form was completed in french by students and teachers and showed that 96% of the survey panel thought the game was suitable to develop team-building, and was a good tool for increasing motivation (93%) and students communication (90%). 67% of the panel thought the game helped the students to be more active than in a traditional classroom and 62% of the panel who had already tested a classical escape game, felt a similar sensation in the game presented here. Finally, 80% of the panel enjoyed the experience and recommended this activity for use in the classroom. Moreover, this game could be applied, not only for students, but also for professional development and for teachers or technical and other kinds of personnel in order to work on team-building. Once the material has been purchased, it can be re-used for many subjects and fields of chemistry, such as other famous processes like Solvay or Haber-Bosh, and famous chemists in history: *Curie, Pasteur, Dalton, Faraday, Nobel, Boyle, Lavoisier, Mendeleev, Molina, Caninizzaro, etc.*

## CONCLUSION

An adaptive and original learning and practicing tool is proposed in this paper, based on the classical escape games. A flexible and inexpensive adaptation is detailed in order to apply the escape room concept in a chemistry classroom. The game provides a complementary teaching method and helps the students to associate the basic concepts of chemistry (periodic table, balancing equations, moles calculation) with simple access enigmas in an immersive and entertaining environment. After getting to know the basic background of the scenario, students are involved in a time battle to crack a sequence of several enigmas (from 2 to 4 for a 30 minute to 60 minute game), and can actually practice chemistry knowledge for this purpose. Students are more active than in a traditional classroom, and apply and learn chemistry with pleasure and motivation. The game can be used as a refreshing tool to increase motivation and team-building in the classroom but also as a method for discovering a specific chemist, the basics of chemical engineering and its consequences on pollution. Organizing this escape classroom takes a certain time (material and scenarios) but the benefits of this technique are really stimulating.

## ASSOCIATED CONTENT

### Supporting Information

Detailed enigma sheets for printing (PPT)

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Note: The author declares no competing financial interest.

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