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Wilson chamber - an experiment proposal using low cost material for teaching radioactivity

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ABSTRACT

It can be said that the practical class is extremely relevant for science teaching, particularly for Physics teaching, making it easy for students to assimilate content and automatically associate it with everyday life. In addition, carrying out experiments with the use of low-cost materials, in view of the difficulty of finding appropriate laboratories, would help in understanding their content. Thus, this work aims to build a model of a Wilson chamber using low-cost materials for this purpose, in order to show the trajectories of fundamental particles in the classroom. This experiment focuses on the observation of the emission of radiation through the condensation of the vapor existing inside a closed environment. Despite the apparent simplicity of the experiment, as indicated in the bibliographic review, there was a great difficulty to perform it, in addition to the problem in obtaining radioactive sources. However, this work intends to discuss the importance of demonstrating fundamental particles through the Wilson chamber for the teaching of Modern Physics, especially on radioactivity, and on the improvement of practice, with the possibility of using low cost.

Keywords: Wilson's Chamber, Fundamental Particles, Teaching of Radioactivity.

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1. INTRODUCTION

It can be said that the teaching of Physics has been worked in a predominantly theoretical way. Classes are usually expository, despite its empirical aspect, which can lead students to have difficulties in understanding it, in view of the need for abstraction of some concepts. In this sense, the experimental classes have a great didactic value [1].

This is because, in some cases, the structure of educational establishments is an obstacle to experimental practice, due to the fact that they do not have adequate laboratories for the practice of science teaching [1].

In order to make classes more attractive to students there is a need to bring different study objects into the classroom. So, the use of experimentation becomes an important resource in teaching, since the student has the opportunity to observe the physical phenomenon. Experimentation can produce a motivating character for the student, encouraging learning. In this sense, the use of low-cost materials for conducting practical classes becomes a possible instrument to be used in the classroom.

In the case of this work, it is proposed to mount a Wilson chamber, using everyday materials, for the understanding of fundamental particles and radiation in the Modern Physics discipline, worked during high school in schools.

It is worth mentioning, in relation to Modern Physics, that it is present in people's daily lives without them realizing its importance, as for example, in the physical aspects of radioactivity [2].

Thus, in this work the concepts regarding fundamental particles will be presented, a bibliographic review on the assembly of the Wilson chamber and a proposal to build a chamber with the use of low-cost materials to be used in the classroom, and for finally, the conclusions regarding this practice.

2. THEORETICAL FRAMEWORK

2.1. Fundamental particles

They are called fundamental particles as constituent parts of the atom (formerly they were called elementary elements; but, after being detected several times, they can unfold in two or more bands, that is, they are not elements). Currently, eleven fundamental requirements are included, whose presence is definitely proven [3; 4].

In addition, there are several that have been discovered recently and these properties are underused. The following fundamental considerations are: Electrons or Negatron; Proton; Neutron; Positron or Positive Electron; Neutrino; Méson Leve Positivo; Light Negative Meson; Positive Heavy Meson; Negative Heavy Meson; Neutral Heavy Meson; and Photon [4]. Some characteristics are included in Table 1.

Tabel 1: Fundamental particles and their properties [4].

Particle	Symbol	Charge C	Mass Kg
Electron or negatron	ē	$-1{,}602\times10^{-19}$	$9{,}1\times10^{-31}$
Proton	p	+e	$1{,}672\times10^{-27}$
Neutron	n	0	$1{,}674\times10^{-27}$
Positron, Positive Electron	β+ e+	+e	$9{,}1\times10^{-31}$
Neutrine	0η0	0	Insignificant
Photon	γ	0	0
Light Negative Meson	μ	+e	212 times that of the electron
Light Negative Meson	μ	-e	212 times that of the electron
Heavy Positive Meson	π^+	+e	300 times that of the electron
Heavy Negative Meson	π^-	-e	300 times that of the electron
Heavy Neutral Meson	π	Does not have	300 times that of the electron

2.2. Observed traces

When a charged particle passes through Wilson's chamber, traces are observed describing different paths, as shown below in figures 1 to 4. It is worth noting, initially, that these are not cosmic rays. When short and thick trails are observed, it is a sign that one is in front of an atom of atmospheric radon emitting an alpha particle (two protons and two neutrons). Radon is a naturally occurring radioactive element, but it exists in low concentrations in the air [4].

Thus, the alpha particles emitted by radon atoms are bulky and of low energy, describing these trails (Figure 1). Muons are the heaviest "cousins" of electrons and are produced when a cosmic ray is released from an atmospheric molecule in the stratosphere. They are massive and when they pass through the steam, they leave straight lines (Figure 2).

When zigzag curves are observed, one is looking at an electron or positron (electron antiparticle). Electrons and positrons are created when a cosmic ray interacts with atmospheric molecules. Electrons and positrons are light particles and jump when they reach air molecules, leaving zigzags and curved tracks (Figure 3). If the trail splits (forked), it is a sign that there was a decay of a particle (cosmic rays or muons). Many particles are unstable and disintegrate into more stable, fork-like particles (Figure 4).

Figure 1: *Observed traces for the emission of alpha particles* [5]

Figure 2: *Observed traces for muon emission.* [6]

Figure 3: Traços *Observed traces for poitron emission*. [7]

Figure 4: Observed traces for cosmic ray emission. [8]

3. MATERIALS AND METHODS

This work aims to build a Wilson chamber using low-cost materials to be used in experimental classes of Physics, more specifically, Modern Physics. Thus, it is intended to visualize the traces produced when charged particles and ionizing radiation cross the environment of Wilson's chamber.

For this, a bibliographic review was initially carried out, through articles, videos and internet pages regarding the construction of Wilson's chamber and its use in the classroom. After this search, low-cost materials were used to build a model to be used in practical classes. be used in practical classes.

The results referring to the bibliographic review in relation to the models found in the literature and the results on the models proposed for this work will now be presented.

3.1. Bibliographic review - construction of Wilson's chamber using low-cost materials

Some models of Wilson's camera can be found in articles, dissertations, websites and videos on YouTube [9; 10; 11].

On the assembly for the verification of radioactive emissions, an electronic camera was found, inspired by the Fog chamber and the Langsdorf chamber [12]. In this model, instead of using solid carbon dioxide (dry ice) to form a temperature gradient in the chamber, he applied the concept of electronic solid state cooling with thermoelectric modules (Peltier effect), using alpha and beta sources sold on the internet (Americium 241 from smoke detectors, uranium from ceramics and radio from the end of a clock).

Another model also used an alpha source of Americium 241 from a smoke detector, in an electrical circuit [13]. It was also possible to build a chamber using a thermic source of radioactive Thorium 232 [14] and using an electrical circuit to demonstrate cosmic rays [15].

Some internet pages also demonstrate the construction of the fog chamber, either for cosmic rays or for visualization of radioactive traces. For example, in an article published by Scientific American Brazil [16], entitled “Build the simplest particle detector in the world”, it demonstrates the use of low-cost materials, a model that approaches the proposal of this work in producing a experiment that can be used inside a classroom, where students themselves can assemble and build the Fog chamber.

The chamber model suggested by “Seara da Ciência”, from the Federal University of Ceará [17], uses as a chamber a large glass jelly jar with a lid, preferably that this lid is metallic, when its base (lid) is cooled alcohol inside the glass cools a lot, remaining in a supersaturated state, in which state any disturbance can condense the vaporized alcohol. The difference of this chamber from the others above is the use of anhydrous alcohol and not isopropyl alcohol for the production of the cooled steam inside the chamber. It also uses a radioactive source as an emitter and the procedures for obtaining the path of the particles are the same as already mentioned.

It was also proposed to build a chamber using a jar of peanut butter or a container of delicatessen, only this container the lid is not threaded but pressure, in addition to the dry ice at the base uses a bowl with warm water placed on top the plastic container that will act as a chamber [18]. This device heats the isopropyl alcohol making the chamber fill with steam more quickly. On the Science Friday page [19] it is possible to find a model using low-cost materials.

Finally, the Department of Physics at the University of Oxford, proposed a simpler fog chamber than the ones presented above. Use a one-liter cup or glass of clear cinema popcorn as a camera. In order to avoid the leakage of steam in the chamber, modeling clay was used around the rim of the glass with the metal plate [20].

3.2. Proposed camera model using low-cost materials and methods

Wilson's chamber, proposed in this work, consists of a watertight container (Figure 5) that can be made of glass or plastic (A). Inside this container it contains a mixture of air with isopropyl alcohol vapor, which is supported on a metal plate (B), which at the bottom has dry ice (C). This structure is placed inside a tray (D). At the top of the chamber, a felt saturated with isopropryl alcohol (E) is placed, and at the bottom, a metal plate or cover of the chamber, a black fabric or paper to work as a contrast when condensation forms (F).

As the felt is soaked with alcohol, the alcohol contained in it evaporates and diffuses through the air from the top to the bottom of the chamber, occupying the entire environment of the chamber. The vapor closest to the base of the chamber cools, due to contact with dry ice, at about -80ºC. With cooling, the vapor density increases, resulting in a strong vertical temperature gradient. A layer of supersaturated alcohol vapor, an unstable layer, forms near the base. As the vapor is supersaturated, a charged particle passing through the supersaturated alcohol vapor will ionize the molecules that are in its path. When ionizing, condensation of alcohol vapor will occur, which will form a trace that can be observed when illuminated by a high intensity lamp (G). The duration of this stroke is a few seconds.

Initially, cut a piece of felt with a circular shape equal to the bottom of the pot and fix it to the bottom with adhesive tape or another fixer, also cut a black cardboard or blotting paper in a circular shape like the lid of the pot, in the felt and blotter soak with isopropyl alcohol leaving them saturated. After this step, the pot is closed with the lid and the watertight chamber is there. Take the water retaining plate from the plant pot and place dry ice inside and then the closed chamber on top of the dry ice. Wait approximately ten minutes until the room inside the chamber is completely filled with alcohol and air vapor. After this step, you have to be patient and wait for charged particles to condense the alcohol vapor, thus describing traces in the chamber.

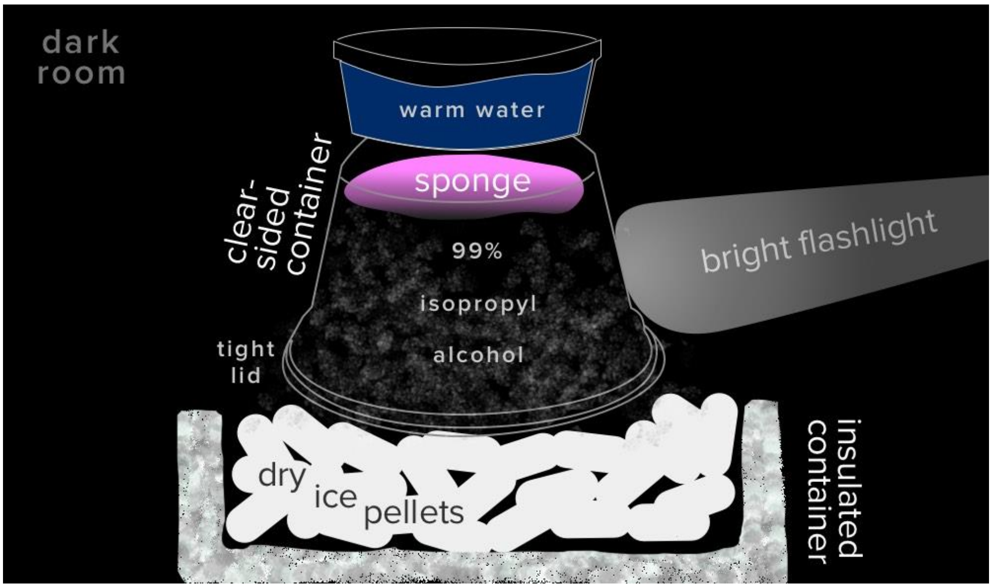


Figure 5: Proposed Standard Model. [21]

4. RESULTS AND DISCUSSION

4.1. Model 1

In this model (Figure 6) the upper chamber and the 9 cm high candy jar were used, with a circular shape bottom with a diameter of 16.5 cm and a pressure cap with a 19 cm diameter called the lower chamber; 18cm diameter plant pot water retention plate; white felt of circular shape with a diameter of 16cm; black felt of circular shape with a diameter of 16.5 cm; alcohol-resistant adhesive tape; LED flashlight; Isopropyl Alcohol; and dry ice.

Two sources of Cesium 137, gamma emitter, with energy of 0.662MeV and half-life of 30 years were tested. The assembly of the chamber was carried out in a refrigerated place to maintain the characteristics of the materials stored there. The fact that the place was chilled interfered positively, and the dry ice had a dual function, that of dissipating the heat from the table and the chamber. The dashes appeared quickly after a few minutes.

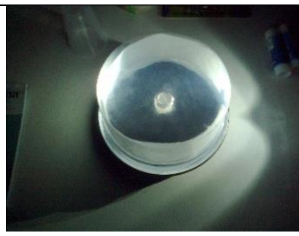
	Cesium 137 test source		Up chamber with source of Cesium 137
	Low chamber with Cesium source 137		Low chamber with Cesium source 137
	Low chamber with Cesium 137 test source		dry ice

Figure 6: Model 1- The sources used are indicated, as well as the process of construction of the Chamber.

4.2. Model 2

In this experiment (Figure 7) the upper and lower chamber with black felt of circular shape, with diameter according to each chamber, alcohol-resistant adhesive tape, led flashlight, isopropyl alcohol; dry ice and the source of thorium 230, series 11766, 35.4α / s / 2π and the source of thorium 230, series 11761, 354000cpm / 2π, alpha emitters were used.

The experiment was carried out in an aerosol room. The aerosol room is not a dark room like the refrigerated room. In this room, to make it dark, aluminum foil was placed on the windows. The scattered light was reflected by the aluminum foil and also by the white walls, making the room a little clear.

In this experiment, a wooden plank was used to isolate the table chamber to avoid what happened in the previous experiment, where dry ice dissipated the heat from the table and chamber. The dashes appeared quickly after a few minutes.

Wilson's chamber is an elaborate project that requires a good deal of manual skill, patience and creativity. Sometimes the camera may not work for several reasons. If the amount of steam is excessive, the chamber is cloudy and opaque. You must wait for several minutes until it clears. One reason for the camera to malfunction is a cover that does not make it watertight. It is essential that the pot is hermetically sealed. On the other hand, the lid must be metallic or thin if it is made of another material, if it is very thick and of thermally insulating material, the dry ice will not be able to cool the alcohol and will not cool the alcohol vapor, if there is no cooling there will be no condensation. The ideal would be to use thin metal covers or, if necessary, sand the one you have until you leave it very thin.

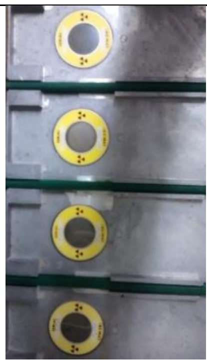
	Source of Thorium 230 35.4α / s / 2π 11/04/05 11766 Series		Sources of Thorium 230 11761 Series 354000cpm / 2 π 11760 Series 101000cpm / 2π 11759 Series 12200cpm / 2π 11758 Series 11100cpm / 2π
	Sources of Thorium 230 11761 Series 354000cpm / 2π		Sources of Thorium 230 11761 Series 35400cpm / 2π
	Source of Thorium 230 35.4α / s / 2π 11/04/05 11766 Series		Source of Thorium 230 35.4α / s / 2π 11/04/05 11766 Series
	Source of Thorium 230 35.4α / s / 2π 11/04/05 11766 Series		Sources of Thorium 230 11761 Series 35400cpm / 2π
	The two sources in the low-height chamber		The two sources in the low-height chamber
	The two sources in the low-height chamber		

Figure 7: Model 2. The sources used are indicated, as well as the process of construction of the Chamber.

5. CONCLUSIONS

The construction of Wilson's chamber was a great challenge. Its assembly requires patience to obtain the results. Its relevance is due to the fact that it was an experiment that contributed to the study and discoveries of atomic particles, being an experiment that requires patience for those who are operating, since when the lines appear for a few seconds.

The chambers presented by some articles and works have large dimensions, such as aquariums, which make it difficult for the student to handle in the classroom, although most can be performed in a demonstration laboratory. There are also camera models presented that use low-cost materials in part of their assembly; however, they use compressed air for cooling and not dry ice, a material that would increase the cost of the experiment.

Other cameras use electronic components as emitters, which have a higher cost and require assembly by a professional who understands the subject, staying away from the proposal of this work, which is a simple experiment to be applied in the classroom.

It was observed that the chamber must be mounted on a table or bench that is not conductive of heat, otherwise it will interact, and the internal environment of the chamber will not be cooled.

The ideal environment would be a dark room with black interior paint, the rooms where the chambers were mounted are rooms whose walls reflected the scattered light, making the room a little clear.

The literature indicates the application of beta radiation, mainly those from americium, uranium or thorium. In the case of this work, gamma (Cesium 137) and alpha (Thorium 230) emitters were used. The result was positive for both sources.

This paper argues that experimental activities can contribute to students' teaching and learning. The importance of these experimental activities helps to understand and explain the contents transmitted in the classroom, so Wilson's chamber can contribute to the understanding of particle physics in modern high school physical discipline.

Finally, it is understood that there are two types of Chamber: of Fog and Wilson. The difference is that in fog, cosmic rays are detected, while Wilson's elementary particles, due to the use of radioactive sources.

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