Popcorn Neutrinos

At a glance

By measuring popcorn before and after popping, students will investigate the concepts behind beta decay, neutrinos and the South Pole IceCube Project which is searching for neutrino sources in the universe.

Background

The first law of thermodynamics, also known as the law of conservation of energy, states that energy can neither be created nor destroyed. This lab models a reaction in which there was an apparent loss of energy, which led to the discovery of a particle called a neutrino.

In 1931, study of nuclear reactions showed that when a neutron changed into a proton in a process called 'beta decay', it released an electron which is called a beta particle. However, careful measurements showed that the proton and the beta particle together had slightly less energy than the original neutron.

This led Wolfgang Pauli, an Austrian theoretical physicist, to propose that another particle was released during beta decay, which carried the missing energy. Since the particle would have to have a neutral charge and small mass, it was called a neutrino (which means 'little neutral one'). It wasn't until 1956 that scientists first experimentally detected a particle fitting these characteristics.

Time

Preparation: ~1 hour
Class time: Two 50 minute class periods

Materials

Per class

- 2 types of popcorn (such as two different brands or varieties white, yellow, black)

Per group of students

- Popcorn popper (Air poppers are easiest to use because they do not need oil)
- Popcorn (~40-100 grams per team, depending upon the popcorn popper)
- Container for kernels and container for popped corn
- Data recording sheet, student notebook, or computers with spreadsheet software
- Balance (sensitive enough to measure to at least 0.1 g, and preferably to 0.01 g)

Advanced Preparation

Before the lab:

1. Get the popcorn, the popcorn poppers (poppers may be either purchased – e.g., at thrift stores, or brought in by the students), and the balances.
2. Try the experiment in advance to become familiar with it.
3. Test the circuits to make sure there is enough wattage for all popcorn poppers simultaneously.

Directions

1. Ask the students if they think popcorn weighs the same, more, or less after it is popped. Have them make a prediction and explain their reasoning.
2. Ask them how they could test their predictions. What equipment will they need? How will they control the variables?
3. Remind them of the safety precautions and discuss the importance of accurate data collection and recording. (Don't eat the popcorn before measurements are complete!)
4. Review the proper use of the balances and the popcorn poppers, then divide the students into teams and give each team 40-100 grams of popcorn (depending on the type of popper being used), and a balance. Give half of the teams one kind of popcorn, and half the other kind.

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5. Have the students count out and weigh 100 kernels.
6. Each group should pop all their corn and weigh 100 pieces of popped popcorn.
7. While the students are doing the experiment, circulate among the teams and ask them guiding questions such as:
   - Why not pop just one kernel?
   - According to the data, is your hypothesis correct? Did the mass of the kernels increase, decrease, or stay the same?
   - What are the variables in this experiment?
   - What difficulties did you encounter? How were you able to overcome them?
8. After all the groups are done with the experiment, bring the whole class together to discuss the results. Have them calculate the average mass of one kernel before and after popping, and the average mass change.
9. Tell the students about the discovery of neutrinos and ask them how the experiment they just conducted relates to this discovery.
10. Discuss how neutrinos are being used to 'map' part of the universe and why Antarctic is the ideal place for this kind of study.

Caution

If you are going to allow the students to eat the popcorn, take special precautions to wash lab tables, have clean containers, wash hands, and stress that students not eat the popcorn until after all the measurements are taken.

Discussion

1. How many teams found a gain in mass? A loss? The same mass? Why might teams get different results? (Get beyond 'bad measurements' – some possibilities are: Variations in popcorn, popcorn popper temperature, or speed of popping, and what the group decided to count, e.g. what to do in terms of data and calculations with unpopped or partially popped corn.)
2. What variables affected the results of this experiment? Would it matter if new or old corn was used? Why?
3. According to the Law of Conservation of Mass, can mass be lost? If mass was lost, where did it go? (The students should figure out that the 'lost' mass is due to the water contained in the kernel escaping as steam.)
4. How is this experiment an analogy for the beta decay process?
5. It took scientists a long time between proposing the neutrino as a hypothetical particle and collecting evidence which proved its existence. Are there other outstanding open questions in physics or science, where a theoretical answer is in place, but the evidence needed to prove the theory is lacking?

Extensions

- Use a video camera to record individual corns popping (probably from a flat pan, beware of spattering oil. Use a motion analysis software (LoggerPro by Vernier Software) to make quantitative measurements of energy. Many individual energy estimates can be combined to produce an energy spectrum for the popped corn. This work should produce a data set suitable for statistical analysis.
- Calculate the initial pressure inside the kernel, based on available quantitative measurements and reasonable quantitative assumptions.
- Develop a method to collect, condense, and weigh the water vapor released by the popping corn. Re-examine the earlier conclusions about conservation of mass vs. mass loss with this new information.
- Prepare popcorn kernels with different moisture levels (using different times in a drying chamber or low temperature oven) and compare mass loss and/or popping energy spectra.
- Invent a way to damage the seed coats of the popcorn, and examine the effect of this damage on popping. Challenges include being able to quantify both the extent of the damage, and the effect on popping.
- Use an infrared camera to collect pictures of the popped kernels. What new kinds of analysis are possible with this new way to look at this phenomenon?

Links

IceCube Neutrino detector website: www.icecube.wisc.edu
IceCube Education & Outreach site: www.icecube.wisc.edu/outreach/
YouTube Movie about the detector: www.youtube.com/watch?v=nx5wphtHBZQ
Popcorn popping in super-slow motion: www.youtube.com/watch?v=CXDstfD9eJ0

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