B3 How does waste separation work? – Separating materials by density and magnetism

The suggested subexperiments are ideal for introducing the basic chemical subject of material separation based on the current topics “environment, waste, and recycling.” Subexperiment 2 would be of particular interest for a physics class. This subexperiment allows students to verify their prior knowledge of electricity and magnetism, using eddy currents and their effects as an example. If students lack this prior knowledge, the teacher should make sure to discuss these subjects before or after the experiment. These experiments can also be used in an interdisciplinary approach, e.g., within the context of an environmental project. The materials supplied allow eight groups of students to conduct the experiments simultaneously.

1 Main question

The constantly growing flood of waste or garbage from households and industry is leading to ever greater pollution and in fact endangers the foundations of human life. One example is plastic waste in the oceans, which is beginning to endanger fish populations in many locations. For this reason, waste prevention and waste recycling are important goals when it comes to protecting the environment. The exploding prices of raw materials and resources that are becoming increasingly scarce require that industry, private companies, public offices, and private households carefully and consciously conserve the valuable resources of our planet. “Recycling all waste materials” is one of the solutions. In many countries, recycling has already become a separate industrial service sector, which is using increasingly sophisticated methods to recover even the smallest amounts recyclable material from waste. In simple experiments, students will become familiar with several basic methods of waste separation in order to use those methods to develop more complicated procedures.

2 Integrating the experiment into the teaching context

2.1 Basic principles

It is preferable, but not absolutely necessary, for students to have prior knowledge of the following:

- Familiarity with density as a material-dependent property
- Buoyancy and weight forces as an explanation for why an object sinks or floats
- Attraction of certain objects to magnetic forces

2.2 Relevance to the curriculum

Age group 12 to 15 years:
In chemistry classes, methods for separating materials are an integral part of every curriculum, particularly sedimentation, decanting, magnetic separation, evaporation, and condensation. The behavior of solids in solutions is also one of the key basic principles.

In physics classes, the mechanics segment covers the density of solids, liquids, and gases (→ air); buoyancy in liquids; floating (suspension), sinking, and rising. The magnetism segment covers the following relevant subjects: ferromagnetic materials, theory of magnetism (→ elementary magnet → Weiss domains), magnetic fields and magnetic field strength, attracting and repelling forces of a bar magnet, magnetic influence, eddy currents (electricity meter principle).

Topics and terms: condense, decant, density, eddy currents, evaporate, industry, interaction, Lenz's law, magnetism, material separation, mixtures, non-ferrous metal, private household, recyclable material, resources, sediment, solid, solutions, solution behavior, waste, waste separation

2.3 Skills

The students will ...

- analyze their own practical experiences and opinions of waste separation.
- recognize that garbage is often a compound of different recyclable materials and that the extraction of pure components often involves considerable effort.
- reflect on the separation of waste types according to categories as they have become common in private households (glass, paper, plastics, biological and residual waste).
- understand that even residual waste conceals many valuable waste materials that can be "rescued" in state-of-the-art waste management facilities.
- become familiar with the basic methods of waste separation in simple experiments.
- understand the rationale behind the recycling of recovered waste materials.
- learn how to use resources responsibly.
- become familiar with the promising development of new energy-saving methods for the recycling cycle.
- expand and promote their responsibility and decision-making skills in this area.

2.4 Explaining the experiment in the teaching context

2.4.1 Subexperiment 1: Separation of a mixture of solids consisting of sand and iron

In this experiment, students will learn how to separate a mixture consisting of sand (in the form of silica sand) and ferrous metals (in the form of iron powder). The separation of these materials is very simple: To separate the iron, you use the magnetic separation method. In other words, ferromagnetic iron components are separated from the mixture of solids using the magnetic attraction of the bar magnet (through its magnetic influence).
Note: The students must use only undamaged, absolutely leakproof plastic bags as the protective covering for the magnet! If the iron powder comes into direct contact with the magnet, it is very difficult to remove completely.
Incidentally, iron and silica sand can also be separated in an aqueous suspension using a special procedure called flotation. This procedure is also used to process ores. The suspension is mixed with tensides, and it then flows through a channel that is aerated from below. The material that is less wettable depending on the detergent used clings to the air bubbles and is carried to the surface, where it is skimmed off. Strictly speaking, this separation is due to differing surface tension, but is also supported by different material densities.

2.4.2 Subexperiment 2: Can we separate a mixture consisting of sand, plastic, water, and salt?

The snippets of polyethylene plastic are separated from the sand by taking advantage of the different density properties of the materials compared to that of the water being used as a separation medium. Materials with a greater density than water sink, while materials with a lesser density than water float to the top. A rake (or a spoon in the experiment) can be used to skim off the plastic snippets. Afterwards, the silica sand and the snippets of polyethylene plastic can be air-dried (on newspaper or filter paper) and then reused.

Industrial processes often use airflow instead of water as a separation technique. This method also separates materials according to density: Less dense materials fly further and collect at a different site compared to more dense materials. Even more cutting-edge procedures use optical and spectroscopic methods. A laser scans a conveyor belt under which a large number of tiny compressed air jets are installed. Depending on the spectral range a particle absorbs, it is blown off the conveyor belt by an air jet. This technique can be used not only to separate paper from plastic, but also to separate different types of plastic from each other, with a 95% success rate.
Adding table salt to the sand and polyethylene plastic snippets results in a mixture when dry.
Yet be careful not to draw false conclusions: If you add water to the mixture, the table salt dissolves in the water. This forms a true solution, in other words a mixture of the smallest particles (in this case sodium and chloride ions and water molecules). True solutions cannot be separated using mechanical methods such as sedimentation, centrifugation, or filtration. With solutions, you need to use methods that also function at the level of the smallest particles, such as reverse osmosis or distillation.

2.4.3 Subexperiment 3: Principle of the separation of aluminum from other non-ferrous metals

This subexperiment will demonstrate how difficult it is to separate non-magnetic non-ferrous metals from ferrous metals and other materials. In this experiment, separation liquids have a limited scope of use. The densities of non-magnetic metals such as copper, brass, zinc, tin, and aluminum range between 9 and 2.7 g/cm^3. Compared to glass and sand on one hand and paper and plastic on the other, the difference in density is too low to obtain good separation based on density. The fact that the folded aluminum foil floats on the surface of the water in our experiment, contrary to what students expect, is due to the air trapped between the layers.

The fact that even aluminum can be moved by a strong magnet is an observable effect based on the eddy current effect produced in the experiment. When the magnet is moved, the magnetic flow through the conductive aluminum object changes, causing eddy currents. Eddy currents then generate a magnetic field opposite to that generated by the magnet. The interactions with the magnet's field repel non-ferrous metals in accordance with Lenz's law; in other words, the aluminum moves.
Note: In the experiment, students fold the aluminum foil into an octagon. The reason for this is that the effect is especially pronounced on surfaces that are nearly circular.

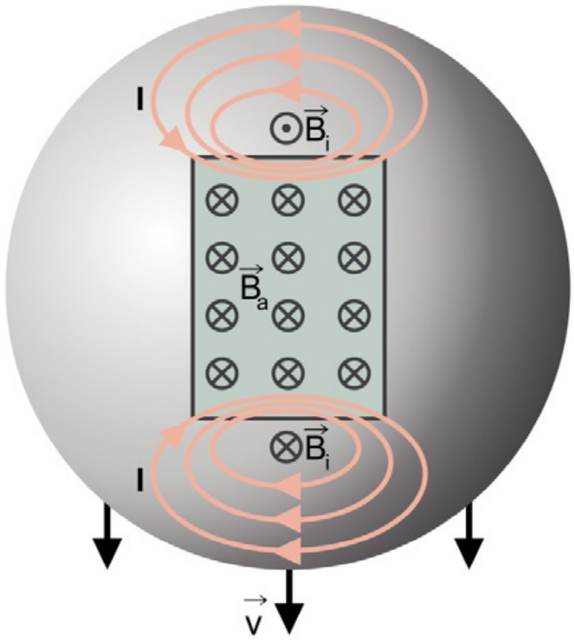

Fig. 2: Eddy currents in metal objects.

2.5 Experimental variations

- Students can work in teams of two for subexperiments 1 and 2.
- The two subexperiments can also be conducted simultaneously in two or more groups. This allows the individual teams to share their expert knowledge from the subexperiments with the other group(s) and compare and discuss their findings in the remaining class time.
- All subexperiments can be conducted with each of the age groups mentioned. Teachers can differentiate the lesson by varying the depth of the analysis and follow-up questions.

3 Additional information on the experiment

You will find additional media for preparing or for further study of this experiment on the Siemens Stiftung Media Portal:
https://medienportal.siemens-stiftung.org

4 Notes on conducting the subexperiments

4.1 Facilities

No special facilities are necessary.

4.2 Time required

	Preparation	Execution	Analysis	Discussion
Subexperiment 1	5 min.	15 min.	10 min.	Depending on the depth
Subexperiment 2	5 min.	5 min.	10 min.	Depending on the depth
Subexperiment 3	5 min.	5 min.	10 min.	Depending on the depth

4.3 Safety aspects

The students may conduct the experiments only in the presence and under the supervision of the teacher.
The teacher is to point out to the students that the provided materials may be used only according to the respective instructions.
Make sure that no damage can occur to water-sensitive materials and apparatus.

4.4 Apparatus and materials

Required materials that are not supplied:

- A strong neodymium magnet needs to be acquired for the last subexperiment. Due to safety regulations governing their transportation, this magnet could not be included in the kit. (For possible sources of magnets in German-speaking areas, please refer to the section entitled “Additional information on the experiment.”)
- Large sheets of filter paper or newspaper
- Paper towels for drying cups (optional)
- Ruler, set square
- Water (about 2 liters)

Supplied:

The apparatus and materials supplied are sufficient to allow **eight** groups of students to conduct the experiments simultaneously.

Depending on the students' level of knowledge, teachers should explain proper wiring and the proper use of multimeters, LEDs, and motors in advance, demonstrating if necessary.

The following materials included in the kit are needed for **one** group of students:

Material	Quantity
Aluminum foil, roll	1x
Bowl, plastic	1x
Digital multimeter	1x
Iron powder, can	1x for entire class
Magnet (permanent), rectangular	1x
Measuring cable assembly, banana plug to alligator clip, red and black for each	1x
Nail (steel, “iron”)	2x
Plastic bag 3 l (polyethylene)	1x
Plastic cup (clear), 500 ml	3x
Plastic cup, 100 ml	2x
Scissors	1x
Silica sand (“filter sand”)	1x
Table salt, box	1x for entire class
Teaspoon	1x

Fig. 2: Apparatus and materials supplied for one group of students

4.5 Cleanup, disposal, and recycling

All apparatus and nearly all materials from the kit can be reused. Therefore, after the students have completed the respective experiment, they should put the apparatus and materials back in the appropriate boxes and return them to the kit. This practice will ensure that you and your colleagues will find everything again quickly the next time the kit is used.
Apparatus that become dirty during the experiment, such as cups, bowls, spoons, and test tubes, should be cleaned before being returned to the kit. We recommend that you have the students do this immediately after they have completed the experiment.
Also make sure that the apparatus are in working order for the next time. For example, recharge used accumulators immediately (It makes sense to charge the accumulators even if they will not be used for an extended period.).
Materials that cannot be reused, such as used pH test strips and filter paper, should be disposed of properly.
The waste that accumulates during this experiment can be disposed of in the regular trash or poured down the sink.