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Gold mining in the classroom: a lab activity to teach sustainability

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Wondering how to extract gold from mobile phones in a school lab? Explore one of the activities from the project Recycle Your Mobile Phone To Save The Planet.

In the era of so-called 'digital capitalism', it is becoming increasingly vital to raise awareness about the responsible use of smartphones and the necessity of recycling the raw materials they contain.

In this hands-on activity, students will chemically explore the recovery of gold from their smartphones. This resource is part of the multidisciplinary project Recycle Your Mobile Phone To Save The Planet, which is a joint effort between various schools in Italy and the Jane Goodall Institute Italy.[1] You can read more about the project in the accompanying Inspire article.

Suggested age range: 14–19 years old

Students will...

- ...become aware of the valuable resources in their phones, the origins of these resources, as well as the processes and hidden costs behind smartphone production
- ...understand the consequences of overconsumption and be encouraged to adopt responsible behaviour when purchasing, using and disposing of electronic devices;
- ...gain a practical understanding of recovering valuable resources, such as gold, from e-waste, explore the concepts of urban mining and the circular economy, as well as evaluate the opportunities and challenges of WEEE recycling;
- ...understand redox reactions and explore their real-world application.

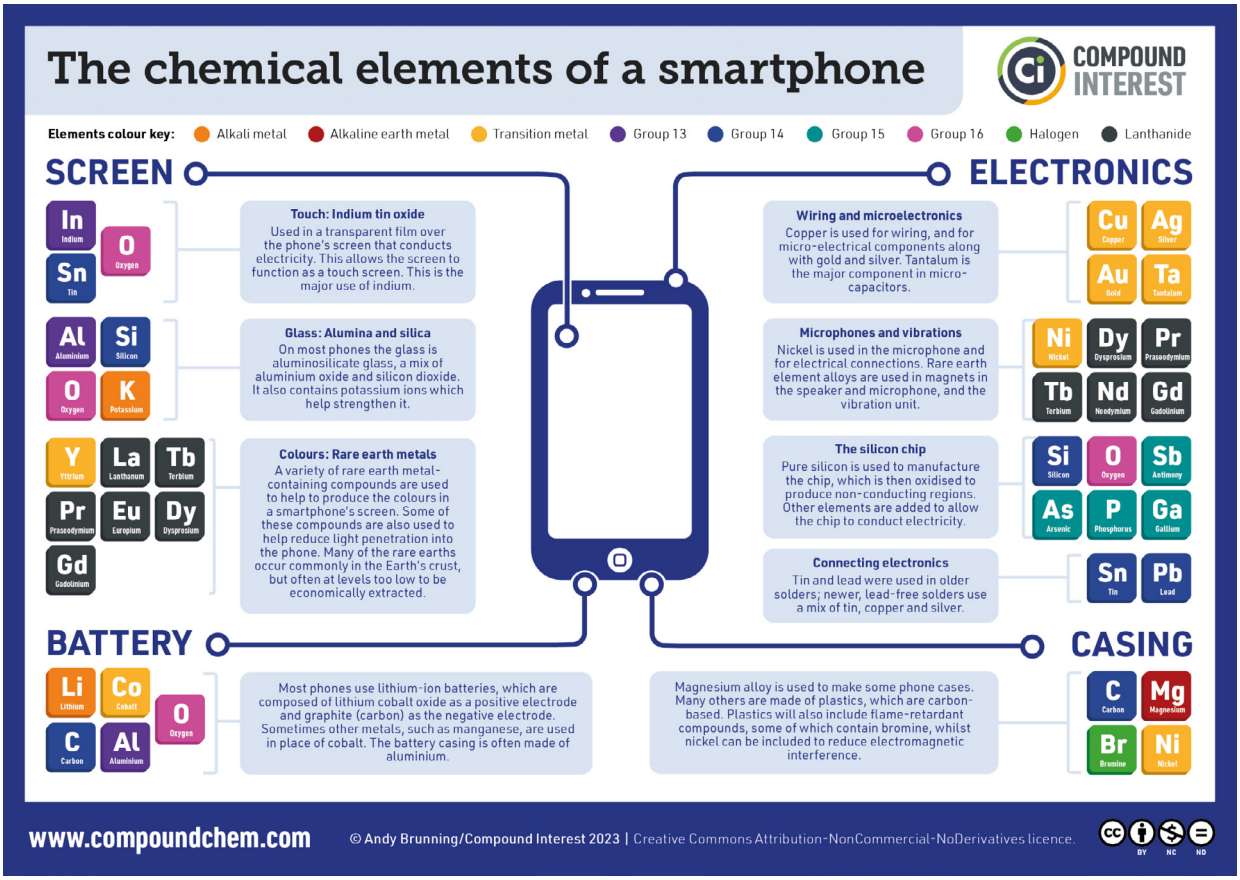


Image: Andy Brunning/Compound Interest, CC BY-NC-ND 4.0

Before you begin: exploring smartphones as an urban mine

Before students dive into the gold extraction experiment, it is a good time to explore certain chemical, environmental and social aspects of the object that almost all students own and love: the smartphone.

There are currently more than 7 billion smartphones in circulation. Yet, when students are asked to estimate how many chemical elements are present inside a smartphone, it turns out that almost all of them are unaware of the number. It is more than 50 elements![2]

It is a good practice for students to locate the elements on the periodic table, to classify and learn about the properties of metals and non-metals, as well as to explore their position and function within devices. It is particularly useful to focus on critical materials, such as rare earth elements and the 3TG (tin, tantalum, tungsten, and gold), which are essential for the construction of all the technological devices we use daily. All of them are finite resources and, behind their extraction, lie stories of exploited young workers, habitat destruction and pollution of local lands.[3]

It is estimated that, in Europe alone, demand for critical minerals used in green technology and advanced electronics is forecast to quadruple by 2040.[4]
Moreover, WEEE (waste from electrical and electronic equipment) is the fastest-growing waste stream in the world. As you can see in the image below, a record 62 million tonnes of e-waste was produced in 2022, and it is on track to rise another 32%, by 2030.[5] As a natural consequence of this, we need to shift the focus onto recovering and reusing these raw materials.

However, less than one quarter (22.3%) of the year 2022's e-waste mass was documented as having been properly collected and recycled. The rest ends up in illegal landfills, where the materials are often burned or informally recycled, which leads to water, air and soil pollution, as well as bearing health risks for local populations and workers.
We have prepared an information sheet for students (see supplementary materials) covering the most important points of the topic.

Alongside the student information sheet, a teacher guide for optional activities on these points is provided, which helps students to grasps the importance of smartphone recycling.

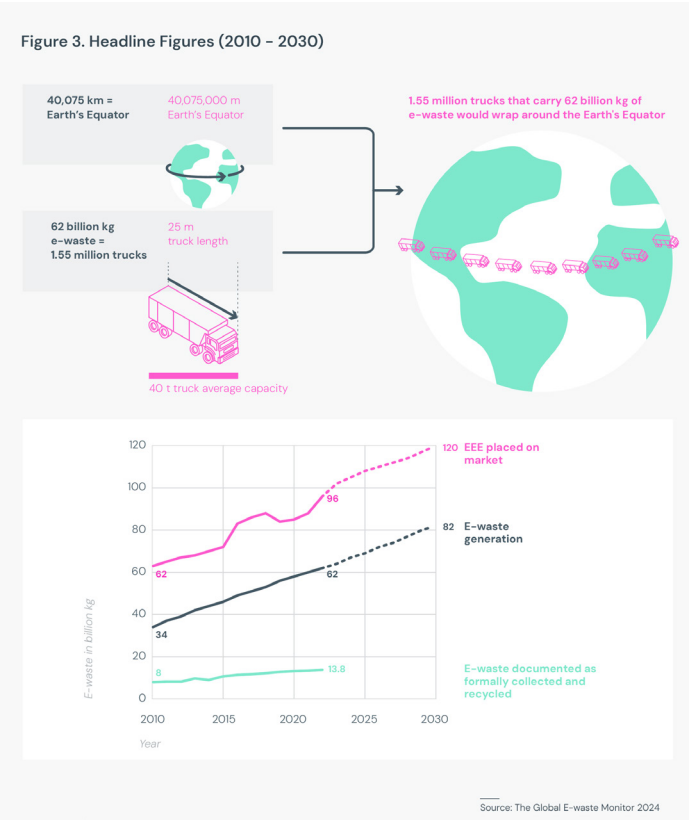


Image courtesy of the Global E-waste Monitor 2024

Activity 1: Gold recovery from smartphones

In this activity, we use a method for recovering gold from obsolete mobile phones through a process of oxidation followed by reduction, striving to use substances with the lowest possible environmental impact.

The procedure described here – from the selection of the circuit boards to melting the gold and recovering the final product – takes approximately three days of work given that some reactions last up to 12 hours. It would be best to conduct the experiments over three consecutive days.

Safety notes



Given the hazardous nature of some reagents, the experiment must be conducted exclusively by the teacher in a suitably equipped chemistry laboratory.

Acidic solutions and chemical reagents must be handled safely using appropriate personal protective equipment (PPE), including acid-resistant gloves, heat-resistant gloves, an acid-resistant lab coat and safety goggles. Furthermore, fume hoods must be used during a significant portion of the experiment to minimize exposure to hazardous substances.

Great care must be taken when handling hydrogen peroxide, concentrated acid and potassium permanganate, due to their high reactivity.

Many reactions (e.g., the preparation of an acid–hydrogen peroxide mixture, the addition of potassium permanganate or, alternatively, manganese dioxide) can be highly exothermic. As a precaution, cool the reaction environment using an ice-water bath. If you want to increase the cooling effect of the water-ice bath you can add sodium chloride (NaCl) to decrease its temperature a few degrees.

Below, you can find a short description of the procedure. A more detailed procedure is given in the teacher guide in the supplementary materials.

Materials

For 1 g of recovered circuitry, the following are required:

- 1 ml of a 1:1 mixture of 37% hydrochloric acid (HCl) (or 20% sulfuric acid (H_2SO_4)) and 30% hydrogen peroxide (H_2O_2)
- a few spatula-tips of potassium permanganate ($KMnO_4$) or alternatively, a 10% solution of sodium hydroxide (NaOH) and a spatula manganese dioxide (MnO_2).
- diluted HCl solution for rinsing: obtained by diluting 37% HCl 1:10 with distilled water
  Note: always add the acid to the water, never the other way around!
- distilled water
- 2 g of urea
- 2 g of sodium metabisulfite ($Na_2S_2O_5$)
- filter papers: Thickness (0.17 mm) Particle retention (5–8 µm)
- fume hood
- beaker
- flasks
- spatulas
- muffle furnace or alternatively a Bunsen burner
- magnetic stirrer with stir bar
- funnels
- conical flasks (100 ml and 500 ml, if using 10 g of selected circuits)
- ceramic crucible
- to retrieve the circuits from the smartphone, pliers and screwdrivers are needed
- an ice-water bath, or an ice-water bath with NaCl

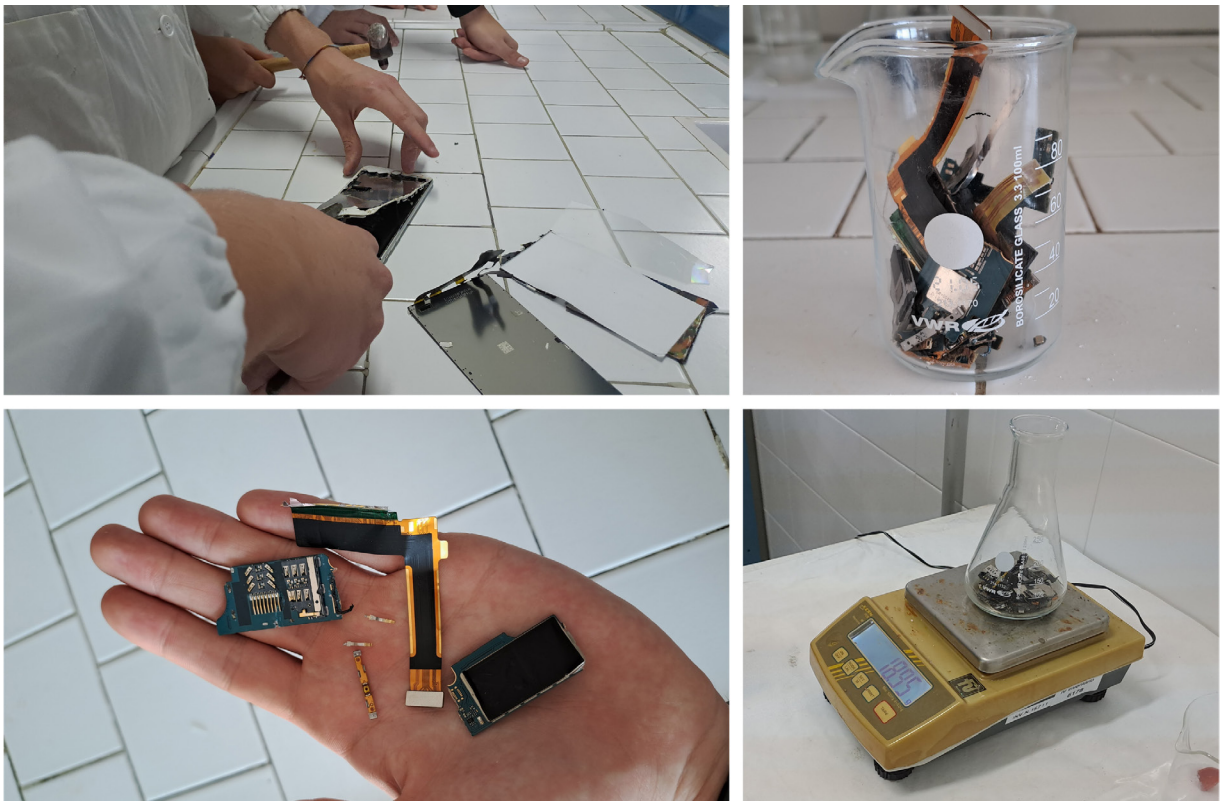


Image courtesy of the authors

Reagents for alternative routes:

- alternative to HCl: 20% H_2SO_4
- alternative to KMnO4: 10% NaOH and MnO_2

Procedure

1. Preparation: Disassemble the discarded cell phones, separate the circuit boards and select the components which are known or suspected to contain gold.[6]

Info box:

Obtain circuit boards only from smartphones that have already been assessed as irreparable. You may also obtain unusable circuit boards from electronics repair shops, workplace or school IT departments, or second-hand online marketplaces.

2. Acid Digestion: Gradually add a 1:1 mixture of 37% hydrochloric acid (HCl) and 30% hydrogen peroxide (H_2O_2) to a beaker containing the selected components.
3. Oxidation reaction: Stir the mixture at room temperature for approximately 12 hours using a magnetic stirrer and stir bar. Subsequently, the reaction mixture is separated from the rest by filtration.
4. Excess Peroxide Elimination: Solid potassium permanganate ($KMnO_4$) is added to destroy most of the hydrogen peroxide.
5. Precipitation: Add urea, heat gently, add sodium metabisulfite ($Na_2S_2O_5$), and allow the reaction to proceed until a dark brown or black precipitate forms (this may take several hours, depending on the circuits chosen).
6. Filtration and Collection: Filter the precipitate and wash it with a dilute hydrochloric acid solution.
7. Calcination and Melting: Place the dried filter paper containing the residual precipitate into a suitable crucible and proceed to calcine the paper to eliminate it. Melt the residual gold-bearing powder inside the crucible using a Bunsen burner or a muffle furnace, so as to fuse the powder particles into a single, compact block.

For the detailed procedure, please refer to the teacher guide.



Image courtesy of the authors

Results

The final product consists of small gold nuggets or a black/brown powder.[7] The yield of the two reactions depends on the amount of gold present in the selected printed circuit boards and is therefore highly variable, making it impossible to determine an exact value beforehand. Consequently, careful selection of the printed circuit boards is crucial for effective gold recovery.[8]

Discussion

To round up the experiment, a discussion can be initiated by dividing the class into groups to address the following topics. Example answers to the questions can be found in the supplementary materials.

- Where should recycling appear in the hierarchy of possible actions? Rank the following actions from most to least preferable and explain your ranking: recycling, repair, reuse, resale, refurbish
- What might prevent people from returning their old phones for reuse or recycling?
- What could encourage more people to return their phones?
- What are possible bottlenecks of recycling smartphones?
- Gold recovery from circuit boards still requires energy, equipment and chemicals. Why can it nevertheless be environmentally preferable to mining new gold?
- What information would a recycling company need before deciding whether recovering metals from smartphones is economically viable?
- The experiment focuses on gold, but what other components or materials might be reused or recovered from a smartphone?

Conclusion

Extracting gold from discarded smartphones is an essential educational tool that addresses critical global challenges.

In a world rapidly approaching the depletion point of raw materials, raising awareness on this topic becomes essential: without a circular management of resources, even the future availability of the smartphones we use every day could be at risk.

This educational activity fits perfectly into the framework of the UN Sustainable Development Goals (SDGs), particularly SDG 10 (Reduced Inequalities) and SDG 12 (Responsible Consumption and Production), by allowing students to link mining and consumption directly to global ecological and socio-economic impacts.

Furthermore, holding a physical piece of recovered gold provides students with a vivid and memorable image of the valuable resources in a phone, thereby highlighting the importance of recycling. «

References

[1] The Jane Goodall Institute's mobile phone collection campaign: https://www.janegoodall.it/index.php/azione/cellulari/

[2] Critical minerals powering your smartphone: https://www.sfa-oxford.com/knowledge-and-insights/critical-minerals-in-low-carbon-and-future-technologies/critical-minerals-in-electronics/critical-minerals-in-smartphones/

[3] The EU conflict minerals regulation: https://policy.trade.ec.europa.eu/development-and-sustainability/conflict-minerals-regulation/regulation-explained_en

[4] Europe's electronic waste crisis: https://www.reuters.com/sustainability/society-equity/europes-electronic-waste-crisis-holds-key-supply-security-if-we-act-it--ecmii-2026-08-24/

[5] The global E-waste Monitor 2024: https://ewastemonitor.info/the-global-e-waste-monitor-2024/

[6] How much gold is in a cell phone: https://learn.apmex.com/learning-guide/science/how-much-gold-is-in-a-cell-phone/

[7] What causes the colours of metals like gold: https://www.webexhibits.org/causesofcolor/9.html

[8] Gold recovery efficiency: https://www.thesilvermountain.nl/en/gold/how-much-gold-is-in-a-phone

Resources

- Watch parts of the extraction procedure in this video performed by the author Alberto Marchetti.
- Explore the wider smartphone recycling project behind this teaching resource: Cavaliere C (2026) Turning e-waste into hope: a student project on phone recycling. *Science in School* **80**.
- Check out which chemical elements are found in a smartphone.
- Learn about the WEEE forum.
- Find out more about critical minerals in smartphones.
- Watch this video to get a clearer sense of the vast scale of the dumb site in Agbogbloshie, Ghana, and its environmental and health impacts.
- Take a deep dive into innovative strategies for sustainable recycling and the integration of a circular economy in the context of our e-waste crisis.

- Learn how some of the elements used in modern technology are scarce and finite resources: Furze J, Harrison T (2021) Elements in danger! *Science in School* **54.**
- Bring circular economy concepts to your classroom with Girls Go Circular: Calavita N, Lager A (2025) Girls Go Circular: your key to engaging STEM Education. *Science in School* **73**.
- Extract keratin from wool and learn about its use as a raw material for biobased products: Zambrotta M (2024) Extract value from wool waste: keratin and the circular economy. *Science in School* **69**.
- Analyse coffee grounds to determine their suitability as a soil enhancer, while teaching about the concepts of the circular economy: Messori G (2025) Chemistry in a coffee cup: does coffee waste contain key elements for plant growth? *Science in School* **73**.

AUTHOR BIOGRAPHY

Chiara Cavaliere teaches natural sciences at a high school in Pavia, northern Italy, working within both the applied sciences and computer science curricula. With a degree in medical and pharmaceutical biotechnology, she has pursued her lifelong dream of teaching, merging it with a passion for biology that she first developed in high school.

Alberto Marchetti obtained a PhD in chemical sciences at the University of Pavia, where he worked as an organic chemistry research fellow until 2010. After a brief period in the private sector, he transitioned to education in 2014 and currently works as a high school chemistry teacher.

Chiara and Alberto met in 2024, when they worked at the same school, the I.T.I.S. Cardano in Pavia.

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