

**October/November 2016 Teacher's Guide for**

***E-Cycling: Why Recycling Electronics Matters***

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# About the Guide

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Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes Article, Title, and Keyword Indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.

# Student Questions

**E-cycling: Why Recycling Electronics Matters**

* 1. Why was Aidan worried about throwing the old computer in the trash?
  2. Approximately how many computers do U.S residents dispose of each year?
  3. How did Aidan describe the space the discarded computers would fill each year?
  4. List three heavy metals that most electronics contain.
  5. Besides being used in rechargeable batteries where is cadmium found in a typical computer?
  6. List three health effects caused by exposure to lead.
  7. Briefly describe the function of the motherboard and the central processing unit (CPU).
  8. What could happen if the electronic devices end up in a landfill?
  9. The eddy current separator is commonly used in recycling of electronic waste. What does it separate?
  10. In the electrolysis of metals, what happens at the cathode?
  11. The strong acid that will dissolve gold is aqua regia. What does “aqua regia” mean and what is its composition?
  12. Describe what each component of aqua regia does in the presence of gold.
  13. List two ways the article cites to refurbish cell phones*.*

# Answers to Student Questions

**(taken from the article)**

**E-cycling: Why Recycling Electronics Matters**

* + 1. **Why was Aidan worried about throwing the old computer in the trash?**

*Aidan was concerned that they would charge his dad a fine for throwing it in the trash and that it would take up a lot of space in the landfill.*

* + 1. **Approximately how many computers do U.S. residents dispose of each year?**

*Americans dispose of 40–50 million computers each year.*

* + 1. **How did Aidan describe the space the discarded computers would fill each year?**

*Aidan calculated that all of those old computers would be the size of the Great Pyramid of Giza in Egypt.*

* + 1. **List three heavy metals that most electronics contain.**

*Most electronics contain lead, mercury and cadmium.*

* + 1. **Besides being used in rechargeable batteries where is cadmium found in a typical computer?**

*Cadmium is used in circuit boards and semiconductors.*

* + 1. **List three health effects caused by exposure to lead.**

*Exposure to lead can cause:*

1. *Learning disabilities*
2. *Behavioral problems*
3. *Damage to heart, kidneys and bones*
   * 1. **Briefly describe the function of the motherboard and the central processing unit (CPU).**

*“A motherboard allows the computer parts to communicate and receive power, and the CPU is the section that carries out the calculations needed to run a computer.”*

* + 1. **What could happen if the electronic devices end up in a landfill?**

*When electronics end up in a landfill they can contaminate the environment. Hazardous material in the computer can leach into water or enter into the air.*

* + 1. **The eddy current separator is commonly used in recycling of electronic waste. What does it separate?**

*The eddy current separator separates metals (other than iron) from the plastic.*

* + 1. **In the electrolysis of metals, what happens at the cathode?**

*“Electrons that flow through the circuit to the cathode are delivered to the metal ions in solution, reducing them to the solid metal on the cathode.”*

* + 1. **The strong acid that will dissolve gold is aqua regia. What does “aqua regia” mean and what is its composition?**

*“Aqua regia” means “royal water”. This acid is a mixture of three parts concentrated hydrochloric acid and one part concentrated nitric acid.*

* + 1. **Describe what each component of aqua regia does in the presence of gold.**

1. *The gold is oxidized by the nitric acid component of aqua regia.*
2. *The hydrochloric acid in aqua regia provides chloride ions that form a complex ion with the gold (AuCl4–), which then dissolves in solution.*

13**. List two ways the article cites to refurbish cell phones***.*

*The article suggests that cell phones can be refurbished by putting on a new screen or a new case.*

# Anticipation Guide

Anticipation guides help engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

**Directions:**  *Before reading*, in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Residents of the U. S. dispose of fewer than 5 million computers each year. |
|  |  | 1. Most electronics contain heavy metals and precious metals. |
|  |  | 1. Heavy metals can cause severe health effects. |
|  |  | 1. Metals can be reused when computers are recycled. |
|  |  | 1. Metal components of computers can be separated from plastic by magnets. |
|  |  | 1. Precious metals can be recovered by dissolving the metals with a strong acid. |
|  |  | 1. In recovering both silver and gold, the metal ions are reduced through electrolysis. |
|  |  | 1. About half of all states have legislation regarding how to handle electronic waste. |
|  |  | 1. During the past few years, consumers have recycled about the same amount of electronics each year. |
|  |  | 1. Currently, no certified recycling companies exist in the United States. |

# Reading Strategies

These graphic organizers are provided to help students locate and analyze information from the articles. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the articles. The use of bullets helps them do this. If you use these reading strategies to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

***Teaching Strategies (for entire October/November 2016 issue):***

* Links to **Common Core Standards for Reading**:
  + ELA-Literacy.RST.9-10.1:Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
  + ELA-Literacy.RST.9-10.5: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
  + ELA-Literacy.RST.11-12.1:Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
  + ELA-Literacy.RST.11-12.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
* Links to **Common Core Standards for Writing**:
  + ELA-Literacy.WHST.9-10.2F: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
  + ELA-Literacy.WHST.11-12.1E: Provide a concluding statement or section that follows from or supports the argument presented.
* **Vocabulary** and **concepts** that are reinforced in this issue:
  + Forensic science
  + Molecular structures
  + Polar and nonpolar molecules
  + Wavelengths of light
  + Chemical reactions
  + Personal and community health
  + Heavy metals
  + Conservation of matter
  + Consumer choices
* Some of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them make informed choices as consumers.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles. The Background Information in the *ChemMatters* Teachers Guide has suggestions for further research and activities.
* In addition to the writing standards above, consider asking students to debate issues addressed in some of the articles. Standards addressed:
  + **WHST.9-10.1B** Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and **counterclaims** in a discipline-appropriate form and in a manner that anticipates the audience’s knowledge level and concerns.
  + **WHST.11-12.1.A** Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

**Directions**: As you read the article, complete the graphic organizer below to describe what you learned about recycling electronics.

|  |  |  |
| --- | --- | --- |
| 3 | **Reasons to recycle electronic waste** |  |
| 2 | **New things you learned about chemistry through reading the article** |  |
| 1 | **Question you have about recycling electronic waste** |  |
| Contact! | **What one thing would you like to tell your friends about recycling electronic waste?** |  |

# Connections to Chemistry Concepts

**(for correlation to course curriculum)**

1. **Physical and chemical properties**—Descriptions of a variety of metals including lead, mercury, cadmium, silver and gold, aid in understanding the properties of these elements and how their properties make them useful in the everyday world.
2. **Separation of mixtures**—The description of how electronic waste is recycled provides an excellent real world example of how mixtures are separated into their components using the chemical and physical properties of each component.
3. **Oxidation and reduction**—The process of recovering silver and gold are described using oxidation and reduction reactions. These serve as excellent examples of the importance of redox reactions.
4. **Electrolysis**—The article briefly describes the process of electrolysis used to purify the silver and gold from electronic waste.
5. **Heavy metals**—E-waste is loaded with toxic or heavy metals. The article does define the terms, as well as introducing some of the hazards with these elements.
6. **Periodicity**—The article discusses several metals. It can be pointed out that several of the metals are in the same family (cadmium and mercury, silver and gold) with similar properties, and most are considered transition elements.
7. **Toxicity**—The hazards of lead, mercury and cadmium are described in this article. It also mentions the dangers to the environment when these elements are placed in a landfill.
8. **Sustainability**—Recycling e-waste preserves natural, valuable and precious resources that are scarce and limited in their availability.

# Possible Student Misconceptions

**(to aid teacher in addressing misconceptions)**

1. **“I thought I could throw anything in the trash.”** *The regulations for what is allowed in a landfill are suggested by the Environmental Protection Agency (EPA), but are actually written and passed by each state. The EPA has defined universal wastes as a category of hazardous waste that is commonly generated. The federal universal waste regulations apply to four types of waste: batteries, pesticides, mercury-containing equipment, and mercury lamps. Each state can decide what they will regulate as universal wastes, so it is important to know what your state will allow in a landfill. To determine what your state considers universal waste, banned from landfills, go to this site:* [*https://www.epa.gov/hw/us-state-universal-waste-programs*](https://www.epa.gov/hw/us-state-universal-waste-programs)*. Items that are considered toxic and should not be placed in the trash include motor oil, electronics, oil-based paint, batteries, fluorescent light bulbs, smoke detectors and mercury thermometers.*
2. **“Electrolysis of metals is the same as electrolysis of hair.”** *The only similarity between the two is that they both use a source of electricity. In the electrolysis of metals, a current is passed through the solution to cause an oxidation-reduction reaction to occur. In the electrolysis of hair a needle is place into an individual hair follicle. A low-level electrical energy pulse is sent into the follicle to destroy it.*
3. **“The only reason to recycle e-waste is to prevent contamination of the soil and water with toxic metals.”** *Recycling of e-waste does remove toxic metals from the environment, which is important, but it also has many other advantages. By recycling electronics we are recovering and conserving many natural resources such as silver, gold, mercury, platinum, copper and iron. They are considered precious and valuable because they are limited in supply and are used in a wide variety of materials. Recycling electronics saves approximately 70% of the energy needed to mine and produce these materials. In addition recycling e-waste saves landfill space.*
4. **“If gold and silver are components of e-waste, I should be able to make lots of money by recycling it, right?”** *Although there is gold and silver in computers and cell phones, the amount in a single item would not be profitable for an individual to recycle. For example, a typical cell phone contains 0.034 g of gold worth about $1.82 and 0.35 g of silver worth $0.36. More significantly, the materials required to extract these metals from the e-waste are highly toxic, hazardous and would require special safety equipment to insure your safety.*

# Anticipating Student Questions

**(answers to questions students might ask in class)**

1. **“Is my old television a hazardous waste?”** *Old televisions (like many old computer monitors) were cathode ray tube (CRT) devices. CRTs are generally considered hazardous waste under the Resource Conservation and Recovery Act. A CRT contains 5–7 pounds of lead in the glass. They also contain cadmium, silver, gold as well as other heavy metals and toxic materials. Most landfills will not take CRTs for that reason.*
2. **“Why does the glass in CRTs have so much lead?”** *There are two reasons lead was added to glass for CRTs. By adding lead to glass the optical quality of the glass is improved, making the image sharper. It also acts as a shield against radiation created by the electron beam inside the CRT, keeping it from penetrating the glass and exposing the viewer to radiation.*
3. **“Isn’t leaded added to glass to make ‘crystal’?”** *According to Sheffield Assay Office:*

*Lead crystal glass is one of the four main categories of glass primarily used for decorative purposes. It becomes ‘lead’ glass when lead oxide is added during the manufacturing stage to replace calcium oxide. The lead is added as it reduces the temperature of the molten material to allow for increased ‘work time’ with the glass. The addition of lead also provides an improved look to the finished product through increasing the refractive index and density of the glass, making it a clearer, less flawed substance. The term ‘crystal’ is misleading as there is no crystal structure within the glass as it is an amorphous solid, meaning that the arrangement of the elements in glass is variable and held together by tight chemical bonds.*

*(*[*http://www.assayoffice.co.uk/latest-news-and-press/lead-crystal-glass-factsheet*](http://www.assayoffice.co.uk/latest-news-and-press/lead-crystal-glass-factsheet)*)*

1. **“Do all recycling businesses handle electronic wastes responsibly?”** *Not every electronic recycler is actually recycling your electronics. It is estimated that 70–80% of the electronic waste that is reportedly recycled is sent to developing countries such as Ghana, India and China. In these countries the workers, who are often children, take apart the waste without any protective equipment or safety measures. As a result they breathe in toxic materials to recover the silver, gold and other precious metals. Make sure you find a certified recycler. In the United States there are two certification groups: e-Stewards and Responsible Recycling (R2). (*[*http://e-stewards.org/*](http://e-stewards.org/) *and* [*http://www.responsiblerecycling.org/*](http://www.responsiblerecycling.org/)*)*
2. **“Our family has several old computers. How do we find a reliable place to recycle them?”** *The first thing you need to do is to make sure you erase all your data from the hard drive. This takes more than just deleting files. To cleanse your hard drive you can use software that overwrites your data. There are some that are available as free downloads. Once that is done you can find a reliable recycler near you by going to this website:* [*http://e-stewards.org/find-a-recycler/*](http://e-stewards.org/find-a-recycler/)*.*
3. **“Can we recycle e-waste in class as a laboratory activity?”** *It would be fascinating to be able to actually recycle e-waste in a laboratory activity. Unfortunately there are too many hazardous materials in electronic waste that we are not equipped to handle. It also requires the use of concentrated strong acids that are too dangerous for a laboratory activity. The best we can do is to watch a video that shows the entire process, or find a local recycling operation that handles e-waste and see if a field trip could be arranged.*

# Activities

**Labs and Demos**

1. **Wet lab—simple electrolysis of potassium iodide:** Students can investigate the electrolysis reaction, using an electrolytic cell consisting of a 9-volt battery as the energy source, a petri dish as the reaction vessel and pencil leads as the electrodes. An excellent description of the lab can be found at this Flinn Scientific site: <https://www.flinnsci.com/media/620463/91208.pdf>.
2. **Electroplating a brass key with copper:** Students can further study electrolysis by electroplating a common object such as a nail, key or coin. In this electrolysis process, the electrodes not only conduct the current; one electrode is coated with the metal of the other electrode. There are many such labs described on the Internet. This site serves as a good example of such a lab: <http://www.hometrainingtools.com/a/electroplating-science-project>.
3. **Laboratory experiment for electroplating on a small scale:** A small scale electroplating lab can be done in a well plate using pencil leads to minimize the amount of chemicals required. This site provides such a laboratory experiment: <http://www.flinnsci.com/media/621156/91454.pdf>.
4. **A laboratory investigating the metal reactivity series:** Using several metals and the solutions of the metal salts, students can investigate their relative reactivity. There is a variety of these investigations available. At the following site a small scale procedure for such a lab is available: <http://dwb5.unl.edu/CHEM/SmallScale/SmallScale-024.html>

**Simulations**

1. **Electrolysis of aqueous solutions:** This simulation shows, on both a macroscale and a molecular scale, what happens when a solution of sodium sulfate undergoes electrolysis. (<http://www.factmonster.com/chemistry/simlab/electrolpt1.html>)
2. **Interactive video:** This interactive video explains electrolysis using molecular view drawings and clever analogies. It also explains the uses of electrolysis to purify copper. (<http://www.bbc.co.uk/education/guides/zk96fg8/activity>)

**Media**

1. **The process of recycling computers:** The *How It Works* video “Computer Recycling” (5:55) shows the actual process of recycling computers, with a detailed explanation of each step of the process. It is filmed in an actual recycling plant and explains the chemistry of each process. (<https://www.youtube.com/watch?v=zU62hh3DBfg>)
2. **The recycling of E-waste:** This short video, “How to Recycle Electronics” (2:40), is a commercial video prepared by Sims Recycling Solutions. It not only shows video of their recycling operations but also shows an animation of how the material is chopped, the iron and steel are separated, and the remaining metals are separated from the plastic. This animation demonstrates how the eddy current separator operates. (<http://www.simsrecycling.com/newsroom/video/electronics-recycling>)
3. **A series of videos on the process of refining precious metals:** Through a series of videos produced by the International Precious Metal Institute (IPMI), the chemistry of the separation and purification of the precious metals silver and gold are explained. Each video is relatively short and is packed with chemistry that high school students can understand and appreciate. These are excellent in relating chemistry to the real world.

“How to Refine Precious Metals—Hydrometallurgy: Part 1 Leaching” (3:46) (<https://www.youtube.com/watch?v=4J4nLdmcZzw>)

“How to Refine Precious Metals—Hydrometallurgy: Part 2 Concentration and Purification” (4:18)

(<https://www.youtube.com/watch?v=EFzBAT6N338>)

“How to Refine Precious Metals—Precipitation: Hydrometallurgy Part 3” (4:47)

(<https://www.youtube.com/watch?v=0lfTtP6llT8>)

“How to Refine Precious Metals—Electrolysis: Hydrometallurgy Part 4” (5:23)

(<https://www.youtube.com/watch?v=hAkWMdrLXmo>)

1. **Electrorefining:** This BC Learning Network video, “Electrorefining” (9:31), explains graphically the chemistry involved in electrorefining. It describes the chemistry using molecular drawings and animations along with redox equations. The explanation incorporates a reduction potential table to explain which ions are oxidized and reduced. (<https://www.youtube.com/watch?v=wwN8lwpQVLk>)

**Lessons and Lesson Plans**

1. **Investigating e-waste:** This lesson plan, called “E-cycling for Environmental Justice”, is designed for high school students to investigate e-waste and incorporates science, social studies and civics. It includes: relationships to national standards; background information; resources; an activity on the life cycle of an electronic device; a study of the environmental injustice in Guiyu, China; a writing activity to create solutions to e-waste dumping; and suggestions for a discussion. (<http://www.earthday.org/sites/default/files/E-Cycle%20for%20Environmental%20Justice_Lesson%20Plan.pdf>)
2. **Recycling:** This lesson, “Garbage Dreams”, is produced by PBS and includes a video and a game geared to understanding the importance of recycling. It is designed for middle school but could easily be used for higher grades as well. (<http://www-tc.pbs.org/independentlens/garbage-dreams/classroom/04_garbagedreams_lesson.pdf>)
3. **Electrolysis:** “Lesson Plan for Electrolysis of Water‐Splitting: High School Level” is designed for high school chemistry. It includes objectives, background information, a student laboratory procedure, student analysis and advanced questions, and an instructor’s guide which includes extension questions and answers to all the questions. (<http://sunlight.caltech.edu/mrose/Lesson-Plan_H2-from-H2O_WaterSplitting_CP_120310.pdf>)

**Projects and Extension Activities**

1. **A debate about exporting electronic waste:** Students could research and debate the pros and cons of exporting electronic waste. There are many articles written on the subject. Here are a few of the articles that could be used to introduce the project: “E-waste-The Great E-waste Recycling Debate” (<http://www.grida.no/publications/vg/waste/page/2868.aspx>; “Used Electronic: Opportunity or Toxic Waste?” (<http://www.usatoday.com/story/money/business/2013/09/26/e-waste-empire-middlebury-vermont-discarded-electronics/2880359/>)
2. **Student research project on local e-waste recycling:** Students could investigate the recycling of e-waste in their area or state. They could also investigate the legislation that governs their electronic waste.
3. ***Khan Academy* video on electrolysis:** Students can be assigned to watch the Khan Academy video (6:54) “Introduction to Electrolysis” at home. By viewing this video, the students will review oxidation-reduction reactions and the voltaic cell. It then explains the operation of an electrolysis cell. Advanced students can be assigned to also watch the “Quantitative Electrolysis” video (6:59). This video works through a calculation to determine the amount of zinc deposited on the electrode, given the time and the amps used in the reaction. This video would prepare them for a variety of electrolysis calculations. Both videos can be found at <https://www.khanacademy.org/science/chemistry/oxidation-reduction/electrolytic-cell/v/quantitative-electrolysis>.

# References

**(non-Web-based information sources)**

**The references below can be found on the   
*ChemMatters* 30-year DVD, which includes all articles   
published from the magazine’s inception in October 1983 through April 2013, all available Teacher’s Guides, beginning February 1990, and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab directly under the *ChemMattersonline* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen).**

**Selected articles and the complete set of   
Teacher’s Guides for all issues from the past three   
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMattersonline”*.**



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An article about the recycling of aluminum that describes the electrolysis of aluminum can be found here: Husband, T. Recycling Aluminum: A Way of Life or A Lifestyle? *ChemMatters*, 2012, *30* (2), pp 15–17.

The Teacher’s Guide for the April 2012 article above contains additional information on oxidation-reduction reactions and the electrolysis of alumina, using redox reactions to explain the process.

Author Withgott describes heavy metal poisoning from lead in this article. (Withgott, J. Lead—Beethoven’s Heavy Metal Ailment. *ChemMatters*, 2001, *19* (4), pp 14–15)

This article describes the environmental problem and the bioaccumulation of mercury. (Agner, M. Frozen Fish Stick Blues. *ChemMatters*, 2016, *34* (2), pp12–13)

The Teacher’s Guide for the April 2016 article above is loaded with information about the heavy metal mercury and its effects on our health. It also includes several activities that investigate mercury in our environment.

# Web Sites for Additional Information

**(Web-based information sources)**

**E-waste—basic information**

Basic information about e-waste is given at this site. It is short but provides clear and concise information. [(https://planetgreenrecycle.com/fundraising/e-waste-problem](file:///C:\Users\Bill\Downloads\(https:\planetgreenrecycle.com\fundraising\e-waste-problem))

This article, “Facts and Figures on E-Waste and Recycling,” provides detailed information on the facts and data about electronic waste and its recycling. It is loaded with data in tables and graphs. (<http://www.electronicstakeback.com/wp-content/uploads/Facts_and_Figures_on_EWaste_and_Recycling.pdf>)

These two sites list interesting facts about electronic waste that students would find interesting and amazing. (<http://earth911.com/eco-tech/20-e-waste-facts/> and (<https://www.dosomething.org/us/facts/11-facts-about-e-waste>)

This site provides a stepwise explanation of what to do when you are ready to recycle an old computer. (<http://www.digitaltrends.com/computing/how-to-recycle-your-old-computer/>)

This site provides a table of hazardous materials found in e-waste and where they occur. It also gives a brief description of some of the hazardous materials. (<http://ewasteguide.info/hazardous-substances>)

An interactive map of the United States that provides information by state of the legislation governing electronic waste can be found here: <http://www.ecycleclearinghouse.org/content.aspx?pageid=10>.

**E-waste—problems with e-waste**

This site provides an overview of the problems with e-waste. It highlights the major problems and provides links for additional information. (<http://www.electronicstakeback.com/resources/problem-overview/>)

Through pictures and graphics, the problems of electronic waste are presented at this site. These would make good pictures and graphics for a presentation. (<http://ifixit.org/ewaste>)

**E-waste—recycling**

At this site a step by step process of recycling electronic waste is given. It also suggests uses for the recycled material. (<http://www.conserve-energy-future.com/e-waste-recycling-process.php>)

“Printed Circuit Board Recycling Methods” is a detailed paper on the recycling of printed circuit boards and can be found at this site. It includes information about printed circuit boards, characterizes their waste, and details the commercial recycling process, including some of the chemistry. (<https://www.epa.gov/sites/production/files/2014-05/documents/handout-10-circuitboards.pdf>)

This site describes the theory behind the eddy current separator, as well as describing how it works. It includes graphics that aid in the explanation. (<http://www3.uninsubria.it/uninsubria/allegati/pagine/6484/Ed.pdf>)

**Electrolysis**

This site provides extensive information on electrolysis. It includes basic information on electrolysis, the electrolysis of molten salts and ionic solutions, redox half reactions, instructions on how to do basic quantitative calculations, purification of copper and electroplating. It also contains a link to an interactive video (mentioned in the simulations section above) and a short quiz that can be used to test a students’ understanding. (<http://www.bbc.co.uk/education/guides/zk96fg8/revision>)

Another site that describes electrolysis, compares electrolytic cells to voltaic cells, and describes applications of electrolysis can be found here: <http://chemwiki.ucdavis.edu/Core/Analytical_Chemistry/Electrochemistry/Electrolytic_Cells/Electrolysis>.

This site not only explains electrolysis, but also provides a little history of its use and provides sample calculations. It also has short concise explanations and graphics that describe the chloro-alkali process for the production of chlorine gas and the electrolytic refining of aluminum. (<http://www.chem1.com/acad/webtext/elchem/ec8.html#IN>)

**Heavy metals**

This article, “Heavy Metals”—A Meaningless Term? (IUPAC Technical Report), extensively describes the problem with the term “heavy metal”. It also describes the numerous ways that are used to classify metals. It discusses factors to be considered when classifying metals for toxicity and other possible ways to classify metallic elements as a basis for their toxicity assessment. (<http://iupac.org/publications/pac/pdf/2002/pdf/7405x0793.pdf>)

At this site a brief overview of heavy metals is given. Brief statements about several toxic metals are provided and each has a link that provides more detailed information about each one. (<https://www.osha.gov/SLTC/metalsheavy/>)

Another site that provides information about heavy metals and their effects on the environment can be found here: <http://www.lenntech.com/processes/heavy/heavy-metals/heavy-metals.htm>.

“Chelation: Harnessing and Enhancing Heavy Metal Detoxification—A Review” is an extensive article dealing with chelation therapy for the treatment of toxic metal poisoning. It describes background information, describes various chelating agents, including natural and pharmaceutical ones, as well as the benefits of using chelation therapy. (<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3654245/>)

At this site chelation therapy is described. It describes several different substances used as chelators and the element or elements for which they work best. (<http://www.lifeextension.com/Protocols/Health-Concerns/Heavy-Metal-Detoxification/Page-08>)