Oh, Say Can You See CO?

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For the
My Environment, My Health, My Choices project

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Abstract:

The poetry of Edgar Allan Poe is used to introduce the environmental health science issue of carbon monoxide poisoning. It is thought that Poe died of carbon monoxide poisoning from the incomplete combustion of gas lighting prevalent at the time. The symptoms of CO poisoning can be found in his writing. Students match symptoms with quotes from his works using a "Think-Pair-Share" strategy. Student groups research topics including: the physiology of gas transport in blood, CO sources, uses for CO, mitigation of CO, symptoms of CO exposure, physical properties of CO, home deployment of CO detectors, and chemistry of CO detectors. They create and present "poe-sters" that convey information on their topic via a graphic and a poem.

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Teachers, we would appreciate your feedback. Please complete our brief, online Environmental Health Science Activity Evaluation Survey after you implement these lessons in your classroom.
The survey is available online at: www.surveymonkey.com/s.asp?u=502132677711

Name ____ Class ____

1. It most important to place carbon monoxide detectors in
    1. basements
    2. attics
    3. bedroom areas
    4. garages

2. One of the uses of carbon monoxide is to provide
    1. a reducing atmosphere for some chemical reactions
    2. an oxidizing atmosphere for mineral extraction
    3. functional nanoparticles with chromophores
    4. chemicals used to transmutate lead to gold

3. In healthy human red blood cells, oxygen and carbon dioxide are transported by molecules of
    1. hemoglobin
    2. glycerol
    3. carbonic acid
    4. hexane

4. The oxygen carrier molecule has a ring structure. Centered in the middle is an atom of
    1. cobalt
    2. nickel
    3. iron
    4. zinc

5. One of the carbon monoxide detectors uses tin (IV) oxide to monitor CO levels. The molecular formula for tin (IV) oxide is
    1. SnO
    2. SnO2
    3. Sn2O
    4. TiO2

6. The correct chemical equation for the <u>complete</u> combustion of gasoline is
    1. $2\ C_8H_{18} + 25\ O_2 \rightarrow 18\ H_2O + 16\ CO_2$
    2. $C_8H_{18} + 8\ O_2 \rightarrow 9\ H_2O + 8\ CO_2$
    3. $C_6H_{14} + O_2 \rightarrow H_2O + CO_2$
    4. $3\ C_8H_{18} + 6\ O_2 \rightarrow 4\ H_2O + 24\ CO$

7. Which situation is most likely to result in the hazardous accumulation of carbon monoxide that could lead to carbon monoxide poisoning?
    1. An idling car engine sitting in the driveway
    2. A hybrid car left on in the garage
    3. A kerosene heater operating in the living room
    4. Complete combustion of gasoline

8. Treatment for carbon monoxide poisoning typically involves:
    1. Administering high concentrations of oxygen
    2. Replacing carbon monoxide with carbon dioxide
    3. Using medicines that remove carbon monoxide from the blood
    4. Increasing the patient's exercise level

9. The ideal liquid to conduct electricity in an electrochemical carbon monoxide detector is
    1. distilled water
    2. sucrose solution
    3. ethanol
    4. salt solution

10. In the electrochemical cell carbon monoxide detector, the anode
    1. undergoes oxidation and loses electrons
    2. undergoes reduction and loses electrons
    3. undergoes oxidation and gain electrons
    4. undergoes reduction and loses electrons

Teacher Answer Key for Pre/Post Test

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Oh, Say Can You See CO?

Learning Context

Subject Area: Chemistry

Overall Purpose: Examine the environmental health science issue of carbon monoxide (CO) poisoning.

Learning Objectives:
1. Examine physical properties of carbon monoxide.
2. Identify common sources of carbon monoxide poisoning.
3. Recognize the symptoms and consequences of CO poisoning.
4. Differentiate between complete and incomplete combustion.
5. Evaluate the status of CO detectors at home.
6. Compare the underlying chemical processes used in the three basic types of CO detectors.

Prerequisite knowledge and skills:
- Understand the role that red blood cells and hemoglobin play in the transport of oxygen and carbon dioxide in the human body.
- Understand the role of catalysts in chemical reactions.
- Determine oxidation numbers in a chemical reaction
- Identify redox reactions based on electron loss or gain
- Differentiate between anode and cathode.
- Helpful: studied the poem “The Raven” by Edgar Allan Poe

Classroom Timeline: Four forty minute class periods.

Class 1:
- Conduct the pre-test.
- Introduce the module with a puzzle.
- Involve students in a Think-Pair-Share learning activity to engage their interest using quotes from the writings of Edgar Allan Poe.
- Start Power Point and introduce the Poe poem called “The Raven” and give a short biographical sketch about Poe.

Class 2:
- Continue the PowerPoint and lesson provided.
- Given research materials, prepare posters on aspects of CO that include a graphic and a poem to convey information.

Class 3:
- Students continue work on their posters.
- Students present their “Poe-sters” to their classmates.

Class 4:
- Finish presentations.
- Review with Power Point on topics covered.

- Share a summary of homework about CO deployment at home.
- Wrap up with reading of last stanza of “The Raven” and a “modified” version of the last stanza.
- Conduct the post-test.

Equipment and Supplies:

- Technology to display a PowerPoint presentation.
- Poster paper
- Coloring Pencils

Student Handouts:

For each student:

- Optional: Copy of Poem “The Raven”
- Quotes from the Writings of Edgar Allan Poe
- Symptoms of Carbon Monoxide Poisoning
- Oh, Say Can You See CO? Homework Assignment

For student research pair:

Each pair of students should receive a folder labeled with their assigned topic that contains two copies of the research materials relevant to their topic. Label the appropriate number of folders with the following topics, and then insert two copies of the relevant research information into each folder:

- Physical properties of CO
- Symptoms and treatment of CO poisoning
- Physiology of oxygen transport
- Sources of CO Poisoning
- Detection and Chemistry of CO detectors
- Recommendations on CO detectors in the home
- Uses of CO

Introduction:

Scientific Method

Good theories
are those capable
of being disproved, Karl
Popper says. Like
that if I come
next week,
at the same time, sit
over my coffee
just exactly
there
where I looked up
and observed
you,
looking at me,
that I will find you,
again,
there,
and this time
have the courage
to smile.

–Roald Hoffman, author and Nobel laureate

Who would think you could write a poem about the "Scientific Method". That is the title of the above poem by Roald Hoffman, chemist and Nobel laureate. I never really went into this project trying to connect chemistry curriculum and poetry, but it jumped out at me: The picture of Edgar Allan Poe a reflection of carbon monoxide poisoning? His dream-like writings the product of a poisonous haze brought on by the gas lamp of his hotel room in Maryland? Everyone loves a mystery, what better way to intersect chemistry and poetry and science.

Teacher Guide

Class 1:

1. Administer pre-test. (5 min)

2. Start the Slide # 1 of Power Point-Student Version

3. Introduce the puzzle (Slide #2) to find the common denominator of seemingly random words. Be sure to stop with the last clue, “quoth the raven”. The answer will be provided in Slide #3, which shows a picture of Edgar Allan Poe. (10 min)

4. Slides # 4 through #7 - Have a student volunteer to read the first three stanzas of the “The Raven.” Some students may be familiar with the poem from their English classes. Note: A copy of the poem is provided if you choose to use it. This is an optional handout It is not critical that students read or have copies the entire poem.

5. Slide #8 through #12 - Go through the short biographical sketch on Poe and the theories on his death. There are many theories for what caused Poe’s death. This learning experience focuses on the theory that Poe died of carbon monoxide poisoning due to the gas-lighting in his Maryland hotel environment The symptoms of CO poisoning can be found in the writings of Poe. (5 min)

6. Slide #13 through #15 - Hand out the student sheet of “symptoms” and “quotes” from Poe and ask students to read the instructions that ask them to Write in the symptoms that seem to match with the contents of each quote. Model how students should do this activity using quote provided on this slide. Leave slide #15 on the screen as students work.

7. Ask the students to work individually, then pair with one other person to share their answers and check their work.

8. Slide #16 - Ask the students to post their results around the room and carousel around the room to compare their answers with those of other groups. (20 min)

Class 2:

1. Show slide #17 that shows the topics for “Poe-sters.” Ask students to continue to work in pairs from the previous day

2. Distribute folders with the following topics on the front cover to each pair of students. Make doubles (or triples) of some to suit class size (5 min)
    - Physical properties of CO
    - Symptoms and treatment of CO poisoning
    - Physiology of oxygen transport
    - Sources of CO Poisoning
    - Detection and Chemistry of CO detectors
    - Recommendations on CO detectors in the home
    - Uses of CO

3. Show Slides #18 and 19. Explain that the folders contain research materials relevant to their topics. Ask student pairs to use the research materials in their folder to create

one group "Poe-ster" each with their names, topic, graphic and poem. This will take the period. Show Power Point example of poem by Roald Hoffman (35 min)

4. Handout **Oh, Say Can You See CO?** homework assignment to survey CO detector use at home

5. Optional: Collect folders at the end of class so that the contents may be used for other classes.

Class 3:

1. Collect homework assignment.

2. Provide half a period to continue work and finalize posters. (20 min) Explain that each pair of students will have a maximum of 5 minutes to display their "poe-ster" and interpret for their classmates what it is all about.

3. Show Slide # 20 and begin student "Poe-ster" presentations (20 min) Inform students that they will be taking a post-test that has questions based on their classmates presentations

Class 4:

1. Show slide #20. Allow time for remaining students present their "Poe-sters." Remind them that the post-test has questions based on their classmates presentations (20 min)

2. OPTIONAL: You may choose to show slides #21 through # 41 that review topic research. If so allow at least an additional 20 minutes.

3. Share summarized results of homework assignment.

4. Finish learning experience with the slides #42 through #44. These include a poem written by Roald Hoffman (Nobel laureate Chemistry) the last stanza of poem and a "modified" version of last stanza. (5 min)

5. Administer post-test.

The Raven

by Edgar Allan Poe (1845)

Once upon a midnight dreary, while I pondered, weak and weary,
Over many a quaint and curious volume of forgotten lore,
While I nodded, nearly napping, suddenly there came a tapping,
As of someone gently rapping, rapping at my chamber door.
" 'Tis some visitor," I muttered, "tapping at my chamber door;
Only this, and nothing more."

Ah, distinctly I remember, it was in the bleak December,
And each separate dying ember wrought its ghost upon the floor.
Eagerly I wished the morrow; vainly I had sought to borrow
From my books surcease of sorrow, sorrow for the lost Lenore,.
For the rare and radiant maiden whom the angels name Lenore,
Nameless here forevermore.

And the silken sad uncertain rustling of each purple curtain
Thrilled me---filled me with fantastic terrors never felt before;
So that now, to still the beating of my heart, I stood repeating,
" 'Tis some visitor entreating entrance at my chamber door,
Some late visitor entreating entrance at my chamber door.
This it is, and nothing more."

Presently my soul grew stronger; hesitating then no longer,
"Sir," said I, "or madam, truly your forgiveness I implore;
But the fact is, I was napping, and so gently you came rapping,
And so faintly you came tapping, tapping at my chamber door,
That I scarce was sure I heard you." Here I opened wide the door;---
Darkness there, and nothing more.

Deep into the darkness peering, long I stood there, wondering, fearing
Doubting, dreaming dreams no mortals ever dared to dream before;
But the silence was unbroken, and the stillness gave no token,
And the only word there spoken was the whispered word,
Lenore?, This I whispered, and an echo murmured back the word,
"Lenore!" Merely this, and nothing more.

Back into the chamber turning, all my soul within me burning,
Soon again I heard a tapping, something louder than before,
"Surely," said I, "surely, that is something at my window lattice.

Let me see, then, what thereat is, and this mystery explore.
Let my heart be still a moment, and this mystery explore.
" 'Tis the wind, and nothing more."

Open here I flung the shutter, when, with many a flirt and flutter,
In there stepped a stately raven, of the saintly days of yore.
Not the least obeisance made he; not a minute stopped or stayed he;
But with mien of lord or lady, perched above my chamber door.
Perched upon a bust of Pallas, just above my chamber door,
Perched, and sat, and nothing more.

Then this ebony bird beguiling my sad fancy into smiling,
By the grave and stern decorum of the countenance it wore,
"Though thy crest be shorn and shaven thou," I said, "art sure no craven,
Ghastly, grim, and ancient raven, wandering from the nightly shore.
Tell me what the lordly name is on the Night's Plutonian shore."
Quoth the raven, "Nevermore."

Much I marveled this ungainly fowl to hear discourse so plainly,
Though its answer little meaning, little relevancy bore;
For we cannot help agreeing that no living human being
Ever yet was blessed with seeing bird above his chamber door,
Bird or beast upon the sculptured bust above his chamber door,
With such name as "Nevermore."

But the raven, sitting lonely on that placid bust, spoke only
That one word, as if his soul in that one word he did outpour.
Nothing further then he uttered; not a feather then he fluttered;
Till I scarcely more than muttered, "Other friends have flown before;
On the morrow he will leave me, as my hopes have flown before."
Then the bird said, "Nevermore."

Startled at the stillness broken by reply so aptly spoken,
"Doubtless," said I, "what it utters is its only stock and store,
Caught from some unhappy master, whom unmerciful disaster
Followed fast and followed faster, till his songs one burden bore,---
Till the dirges of his hope that melancholy burden bore
Of "Never---nevermore."

But the raven still beguiling all my sad soul into smiling,
Straight I wheeled a cushioned seat in front of bird, and bust and door;
Then, upon the velvet sinking, I betook myself to linking

Fancy unto fancy, thinking what this ominous bird of yore --
What this grim, ungainly, ghastly, gaunt and ominous bird of yore
Meant in croaking "Nevermore."

Thus I sat engaged in guessing, but no syllable expressing
To the fowl, whose fiery eyes now burned into my bosom's core;
This and more I sat divining, with my head at ease reclining
On the cushion's velvet lining that the lamplight gloated o'er,
But whose velvet violet lining with the lamplight gloating o'er
She shall press, ah, nevermore!

Then, methought, the air grew denser, perfumed from an unseen censer
Swung by seraphim whose footfalls tinkled on the tufted floor.
"Wretch," I cried, "thy God hath lent thee -- by these angels he hath
Sent thee respite---respite and nepenthe from thy memories of Lenore!
Quaff, O quaff this kind nepenthe, and forget this lost Lenore!"
Quoth the raven, "Nevermore!"

"Prophet!" said I, "thing of evil!--prophet still, if bird or devil!
Whether tempter sent, or whether tempest tossed thee here ashore,
Desolate, yet all undaunted, on this desert land enchanted--
On this home by horror haunted--tell me truly, I implore:
Is there--is there balm in Gilead?--tell me--tell me I implore!"
Quoth the raven, "Nevermore."

"Prophet!" said I, "thing of evil--prophet still, if bird or devil!
By that heaven that bends above us--by that God we both adore--
Tell this soul with sorrow laden, if, within the distant Aidenn,
It shall clasp a sainted maiden, whom the angels name Lenore---
Clasp a rare and radiant maiden, whom the angels name Lenore?
Quoth the raven, "Nevermore."

"Be that word our sign of parting, bird or fiend!" I shrieked, upstarting--
"Get thee back into the tempest and the Night's Plutonian shore!
Leave no black plume as a token of that lie thy soul hath spoken!
Leave my loneliness unbroken! -- quit the bust above my door!
Take thy beak from out my heart, and take thy form from off my door!"
Quoth the raven, "Nevermore."

And the raven, never flitting, still is sitting, still is sitting
On the pallid bust of Pallas just above my chamber door;
And his eyes have all the seeming of a demon's that is dreaming.
And the lamplight o'er him streaming throws his shadow on the floor;
And my soul from out that shadow that lies floating on the floor
Shall be lifted---nevermore!

Quotes from the Writings of Edgar Allan Poe

Below each quote, write the symptom that you think best matches with the content of the quote. Note: You do not need to use all of the symptoms and a symptom may be used more than once.

1834: Loss of Breath

"I will endeavor to depict my sensations upon the gallows. … Every writer should confine himself to matters of experience… I heard my heart beating with violence—the veins in my hands and wrists swelled to nearly bursting—and I felt that my eyes were starting from their sockets."

Symptom: ____

1839: The Conversation of Eiros and Charmion

"The first sense of pain lay in a rigorous constriction of the breast and lungs, and an insufferable dryness of the skin…We gasped in the rapid modification of the air. The red blood bounded tumultuously through its strict channels. A furious delirium possessed all men…"

Symptom: ____

1839: The Fall of the House of Usher

"ghastly pallor of the skin... a cadaverousness of complexion"

Symptom: ____

"nervous agitation"

Symptom: ____

"insipid food was alone endurable"

Symptom: ____

"gazing upon vacancy for long hours, in an attitude of the profoundest attention, as if listening to some imaginary sound"

Symptom: ____

"hysteria in his whole demeanor"

Symptom: ____

"irrepressible tremor gradually pervaded my frame"

Symptom: ____

1840: The Philosophy of Furniture

"We are violently enamored of gas [gas lighting of the time that often produced CO] and of glass. The former is totally inadmissible within doors. Its harsh and unsteady light is positively offensive. No man having both brains and eyes will use it."

Symptom: ____

1844: The Premature Burial

"Sometimes, without any apparent cause, I sank, little by little, into a condition of hemi-syncope, or half swoon; and, in this condition, without pain, without ability to stir, or strictly speaking, to think, but with a dull lethargic consciousness of life and of those who surrounded my bed, I remained, until the crisis of the disease restored me, suddenly, to perfect sensation. At other times I was quickly and impetuously smitten. I grew sick, and numb, and chilly, and dizzy, and so fell prostrate at once."

Symptom: ____

Symptoms of Carbon Monoxide Poisoning

Match these symptoms with the quotes from Poe by writing the symptom below the quote:

- Headache
- Shortness of breath
- Difficulty breathing
- Vision changes
- Rapid pulse
- Dizziness
- Weakness
- Drowsiness
- Emotional changes
- Confusion
- Poor judgment
- Clumsiness
- Fainting
- Nausea and vomiting
- Diarrhea
- Chest pain
- Bluish discoloration of the skin and nails
- Rarely, a cherry red appearance to skin and lips
- Coma, loss of consciousness

Name: ______________________

"Oh, Say Can you see CO?" Homework Assignment

1. In my home there is at least one potential source of carbon monoxide. Check one. ____ Yes ____ No

2. There is a carbon monoxide detector on every level of my home where people work, sleep, or play? Check one. ____ Yes ____ No

3. I tested the carbon monoxide detectors in my home to be sure they were all working. Check one. ____ Yes ____ No

4. There is/are ______ carbon monoxide detectors in my home.

Answer these as true (T) or false (F):

__5. If I detect smoke or the CO detector goes off, I should call 911 then leave the house.

__6. If the power goes out, it is okay to heat the house with a space heater that uses bottled gas.

__7. It is okay to operate a gas-powered motor in the basement of my house.

__8. If my compact disk player loses power, it is okay to borrow the batteries from the CO detector.

__9. Heating systems and chimney should be checked every two years.

__10. One question that I have about CO (carbon monoxide) is........

Research Materials for Folders
Used in Developing “Poe-sters”

Topic: Sources of Carbon Monoxide

Where does carbon monoxide come from?

Carbon monoxide is produced by the incomplete combustion of carbon-containing fuels, such as gas (domestic or bottled), coal, oil, coke and wood. Gas stoves, fires, heating boilers, gas-powered water heaters, paraffin heaters, and solid fuel-powered water heaters are all potential sources of carbon monoxide. The problem arises when such appliances are poorly maintained, not serviced and housed in poorly ventilated areas.

When the waste products of combustion are not effectively removed, for example because of blocked flues and chimneys, then poisonous gas mixtures may re-enter the room. This problem is not just associated with older or poorer homes; it can also affect the occupants of newer homes with gas central heating. Exhaust fumes from cars is another obvious source.

Domestic sources of carbon monoxide include:

- domestic heating systems
- blocked flues/chimneys
- inadequate ventilation in living areas
- inadequate ventilation in adjoining car garages
- leakage from faulty appliances and chimneys/flues.

How is carbon monoxide formed?

When any fire burns, in an enclosed room, the amount of oxygen available gradually decreases. At the same time the amount of carbon dioxide increases. As the amounts of these two gases change, this increasingly causes the combustion process to alter from one of complete combustion to one of incomplete combustion. This results in the release of increasing amounts of CO.

This highlights an important issue. Even with perfectly designed and maintained heating appliances (or any kind of combustion device), they too will eventually begin producing dangerous amounts of CO if used in confined and poorly ventilated areas. Having poorly operating appliances, only makes the problem worse more quickly. Maintaining appliances and ensuring sufficient fresh air is available are two easy ways of avoiding potentially lethal scenarios.

Topic: Physical Properties of Carbon Monoxide

Preparation of Carbon Monoxide

Carbon monoxide, CO, is prepared in the laboratory either:

1. by dehydrating formic acid with concentrated sulfuric acid.

$$HCOOH \implies H_2O + CO$$

2. by passing carbon dioxide over heated carbon.

$$CO_2 + C \xrightarrow{\text{heat}} 2\,CO$$

Industrially, carbon monoxide is prepared by the incomplete oxidation of natural gas, which consists primarily of methane or by the water gas reaction.

Properties of Carbon Monoxide

The physical properties of carbon monoxide are that it:

- is a colorless, odorless, neutral, gaseous oxide, which is highly poisonous,
- is sparingly soluble in water, but is soluble in ethanol and in benzene.
- Melting Point: -199 degC
- Boiling Point: -91.5 degC
- Relative density: 1.25

The chemical properties of carbon monoxide are that it:

- is a flammable and highly toxic gas,
- is a neutral oxide which burns in air to give carbon dioxide
- is a good reducing agent, and is used for that purpose in industry

$$CuO + CO \implies Cu + CO_2$$

- is an important industrial gas, which is widely used as a fuel
- is also an important reducing agent in the chemical industry

Uses of Carbon Monoxide

Carbon monoxide is an important industrial gas, which is widely used as a fuel. It is also an important reducing agent in the chemical industry.

http://www.ucc.ie/academic/chem/dolchem/html/comp/co.html

Topic: Detection and Chemistry of CO Detectors

The three most common CO detection technologies available today are:

- Chem-optical,
- Electro-chemical
- Semiconductor

CHEM-OPTICAL (GEL CELL) TECHNOLOGY

Chem-optical technology alarms are also known as gel cell or biomimetic technology alarms. These alarms utilize a type of sensor that simulates hemoglobin in the blood.

Biomimetic sensors utilize a material that mimics the response of human hemoglobin to carbon monoxide. In the presence of carbon monoxide gas, the amount of infrared light, which will pass through, the sensing material declines. Alarms using this kind of sensor use external circuitry to monitor the transmittance of infrared light through the sensor. The rate of change of the transmittance is used to calculate carbon monoxide gas concentrations.Biomimetic sensors demonstrate acceptable immunity to other gases that may be present.Biomimetic sensors are mechanically simple devices.Alarms using these sensors have field demonstrated a dependable sensor life in excess of three years.

One main drawback that remains is that the sensor can non-reversibly accumulate carbon monoxide and other contaminants over time, which can eventually lead to false and/or nuisance alarms. Some chem-optical (gel cell) alarms on the market today contain an expensive replacement battery and/or sensor, which must be replaced periodically.

ELECTRO-CHEMICAL

Electro-chemical technology alarms are usually battery powered. This type of sensor typically has a limited lifetime of about 2 - 5 years. Some manufacturers' models will require its battery and/or sensor to be changed periodically by installing an expensive replacement. Other manufacturers' models have sealed housing that requires the entire unit to be discarded once the battery power supply is depleted.

Electrochemical sensors typically use platinum as a catalyst and acid as an electrolyte to break down carbon monoxide gas and release electrons. The electrons induce a small current that creates a change in potential at external measurement points. Alarms utilizing this type of sensor use external circuitry to monitor the changes in potential and use this information to calculate the concentration of CO gas.

Electrochemical sensors are mechanically much more complex than semiconductor sensors but can provide more accurate measurements of CO concentrations. Modern electrochemical sensors demonstrate good immunity to interferent gases. Careful design and processing is necessary to ensure accuracy across humidity extremes. Historically, electrochemical sensors have been prone to leakage due to:

- Corrosion of electrical contacts
- Destruction of sealing surfaces in the body of the sensor
- Expansion of the electrolyte volume

The current that flows between the two electrodes is proportional to the amount of CO present. This means that the detector can give an accurate reading (in parts per million of CO), from low levels that may be hazardous over long periods of time, to high concentrations that present an immediate danger.

SEMICONDUCTOR TECHNOLOGY

There are a variety of CO alarms that utilize semiconductor or tin dioxide technology available on the market today. Unlike alarms that utilize chem-optical or electro-chemical technology, semiconductor detectors do not require expensive replacement sensors. However, not all semiconductor CO alarms are alike. Some manufacturers utilize semiconductor sensors that are not designed to be used in a CO specific alarm and may be prone to false and/or nuisance alarms.

Semiconductor sensors utilize a controlled quantity of tin dioxide (SnO_2) as a sensing element. The sensing material is heated by a small electric heating element and carbon monoxide gas is catalytically broken down at the surface of the sensing element. Electrons are released in this process and are absorbed by the sensing element. This increase in charged particles lowers the resistance of the sensor. In an alarm using semiconductor sensors, electronics are used to measure the sensor resistance and from this to calculate the carbon monoxide concentration. Semiconductor sensors are mechanically simple and are electronic in nature, therefore, they are very long-lived and very reliable.

Current designs demonstrate excellent immunity to other gases that may be present. Millions of semiconductor CO alarms manufactured over the past ten years have provided historical data that demonstrates a dependable sensor life of more than ten years.

SAFETY PATCH

Another type of CO detector that you may have seen consists of a small plastic square with a patch of orange crystals on it, which turn black if CO is present. These detectors are designed to be stuck to a wall near a gas fire or boiler, and provide a cheap and easy safety check. The orange-to-black color change is the result of simple redox chemistry. The orange crystals contain palladium (II) chloride which is reduced by CO to form palladium (0), i.e. metallic palladium, which is dark grey:

CO + PdIICl2.2H2O ® CO2 + Pd0 + 2HCl + H2O

The crystals also contain copper (II) chloride. This oxidizes the palladium metal back to palladium (II) chloride, when the sensor is exposed to CO-free air. The copper (II) chloride is reduced to copper (I) chloride in the process:

Pd0 + 2CuIICl2.2H2O ® PdIICl2.2H2O + CuI2Cl2

The final stage in regeneration of the system is oxidation of the copper (I) chloride back to copper (II) chloride by atmospheric oxygen:

CuI2Cl2 + 2HCl + H2O + 1/2O2 ® 2CuIICl2.2H2O

http://www.chemistry.org/portal/a/c/s/1/feature_ent.html?id=04dd47d40b8211d7f0856ed9fe800100

Topic: Physiology of Oxygen Transport

Introduction to the Chemistry and Physiology of Blood

Our bodies consist of cells that are organized into many specialized organs and tissues to perform a variety of functions. Our stomachs digest food so that the nutrients contained in the food can be distributed to the rest of the body. Our lungs take in the oxygen needed by the body from the air and release carbon dioxide as a waste product. Our muscles allow the body to move. Our brains coordinate all of these (and many other) activities of the body. These processes are based upon many different chemical reactions, and the sum total of the chemical reactions in the body is known as the body's metabolism. The metabolism includes the reactions needed for normal everyday activities such as eating, sleeping, and studying. When we exercise, the metabolism increases to allow our body to cope with the increased demands and stress of exercising. All of our specialized body parts are united by their fundamental need for a particular chemical environment that will enable the body's metabolic reactions. This environment must include a supply of nutrients (e.g., sugars and vitamins, to supply the building blocks for cells and enable biochemical reactions) and oxygen (to provide energy for the body. This environment is provided by bathing our body's cells in blood.

Blood is part of the body's circulatory system, and thus is continually being pumped through our bodies as long as we are alive. The blood distributes oxygen and nutrients to the many different cells in the body, carries CO_2 generated by the cells to the lungs for exhalation, and carries other waste products to the kidneys and liver for processing and elimination. Many finely tuned chemical processes occur in the blood to allow the blood to carry out all of these functions and provide for the needs of the body.

Oxygen Transport via Metal Complexes

An adult at rest consumes the equivalent of 250 ml of pure oxygen per minute. This oxygen is used to provide energy for all the tissues and organs of the body, even when the body is at rest. The body's oxygen needs increase dramatically during exercise or other strenuous activities. The oxygen is carried in the blood from the lungs to the tissues where it is consumed. However, only about 1.5% of the oxygen transported in the blood is dissolved directly in the blood plasma. Transporting the large amount of oxygen required by the body, and allowing it to leave the blood when it reaches the tissues that demand the most oxygen, require a more sophisticated mechanism than simply dissolving the gas in the blood. To meet this chAllange, the body is equipped with a finely tuned transport system that centers on the metal complex heme.

Metal Complexes in the Body

The ability of metal ions to coordinate with (bind) and then release ligands in some processes, and to oxidize and reduce in other processes makes them ideal for use in biological systems. The most common metal used in the body is iron, and it plays a central role in almost all living cells. For example, iron complexes are used in the transport of oxygen in the blood and tissues.

Metal-ion complexes consist of a metal ion that is bonded via "coordinate-covalent bonds" (Figure 1) to a small number of anions or neutral molecules called ligands. For example the ammonia (NH_3) ligand used in this experiment is a monodentate ligand; i.e., each monodentate ligand in a metal-ion complex possesses a single electron-pair-donor atom and occupies only one site in the coordination sphere of a metal ion. Some ligands have two or more electron-pair-donor atoms that can simultaneously coordinate to a metal ion and occupy two or more coordination sites; these ligands are called polydentate ligands. They are also known as chelating agents (from the Greek word meaning "claw"), because they appear to grasp the metal ion between two or more electron-pair-donor atoms. The coordination number for a metal refers to the total number of occupied coordination sites around the central metal ion (i.e., the total number of metal-ligand bonds in the complex).

Oxygen-Carrying Protein in the Blood: Hemoglobin

Hemoglobin is the protein that transports oxygen (O_2) in human blood from the lungs to the tissues of the body. Proteins are formed by the linking of amino acids into polypeptide chains. An individual amino acid in a protein is known as a "residue." The arrangement and interactions of the amino-acid residues within the protein determine the protein's shape and contribute substantially to its function. Hemoglobin is a globular protein (i.e., folded into a compact, nearly spherical shape) and consists of four subunits, as shown in Figure 2. Each protein subunit is an individual molecule that joins to its neighboring subunits through intermolecular interactions. These subunits are also known as peptide chains.

Topic: Recommendations on CO Detectors in the Home

Prevention is always better than cure

The best course of action is to take steps that prevent carbon monoxide becoming a problem in the first place.

- Raise the general awareness of the risks associated with carbon monoxide by communicating the relevant information to friends, family and work colleagues.
- Be aware of the sources of carbon monoxide especially in domestic properties where a number of appliances could be responsible.
- Get appliances professionally installed and regularly serviced to ensure they work efficiently and safely.
- Ensure adequate ventilation for all fuel burning appliances.
- Install monitoring devices for the early detection of excess carbon monoxide.
- Recognize the early signs and symptoms of carbon monoxide poisoning, particularly when more than one family or work member is affected, and seek medical advice promptly.

Deployment of Detectors

The following is the Code of Massachusetts Regulation governing Carbon Monoxide Alarms

31.03: General Installation Provisions

1. Any carbon monoxide alarm using an ac (alternating current) primary power source and any other wired carbon monoxide alarm protection equipment shall be installed and maintained in accordance with the Massachusetts Electrical Code, 527 CMR 12 and in accordance with M.G.L. c. 143, s.3L and MGL 141, s. 1A, if applicable.

2. Buildings or structures owned or operated by the Commonwealth or any local housing authority are exempt from the requirements of 527 CMR 31.04 until January 1, 2007.

3. Buildings or structures constructed or substantially renovated for which building permits have been issued on or after March 31, 2006, shall comply with any stricter carbon monoxide alarm requirements of The State Building Code, if applicable.

31.04 Specific Installation Provisions

1. Residential Structures: Effective March 31, 2006 every Residential Structure that presently or in the future contains Fossil Fuel Burning Equipment or has enclosed parking shall be equipped, by the owner, landlord or superintendent, with working and Listed Carbon Monoxide Alarm Protection.

(a) A Single Station Carbon Monoxide Alarm shall be located in each level of each Dwelling Unit including Habitable portions of basements, cellars and attics, but not including crawl spaces. The installation of said unit shall be in located in accordance with the manufacturer's instructions.

(b) When mounting a carbon monoxide alarm on a level of a Dwelling Unit with a sleeping area, the alarm shall be installed in the immediate vicinity of the sleeping area, not to exceed 10 ft. as measured in any direction from any bedroom door.

(c) Alternative Compliance Option: Such Residential Structures, as an alternative to providing Carbon Monoxide Protection within each level of each Dwelling Unit, may provide protection in the following areas of the structure, if applicable.

1. Areas or rooms containing Centralized Fossil Fuel Burning Equipment and all Adjacent Spaces: All areas or rooms containing Centralized Fossil Fuel Burning Equipment shall employ Single Station Carbon Monoxide Alarm Protection meeting UL 2034 and UL 2075 and using either an ac (alternating current) primary power source with battery back up that meets the requirements of NFPA 720, 5.2.2. or a low voltage or wireless system. Such installation shall be in accordance with the manufacturer's instructions. Such protection shall be monitored in accordance with NFPA 720, 5.3.9. In accordance with NFPA 720, 5.3.9.3 (1) the retransmission of the signal shall be at the discretion of the head of the fire department.

2. Adjacent Spaces of Enclosed Parking: All Adjacent Spaces of Enclosed Parking shall employ Single Station Carbon Monoxide Alarm Protection meeting UL 2034 and UL 2075 using either an ac (alternating current) primary power source with battery back up that meets the requirements of NFPA 720, 5.2.2. or low voltage or wireless system. Such protection shall be monitored in accordance with NFPA 720, 5.3.9. In accordance with NFPA 720, 5.3.9.3 (1) the retransmission of the signal shall be at the discretion of the head of the fire department.

3. Carbon Monoxide Alarm Protection shall also be installed in any Dwelling Unit that contains Fossil Fuel Burning Equipment in accordance with 527 CMR 31.04(1)(a) and (b).

Topic: Symptoms and Treatment of Carbon Monoxide Poisoning

What are the symptoms of carbon monoxide poisoning?

One of the difficulties with diagnosing carbon monoxide poisoning is that many of its symptoms are similar to those of other conditions. Often the onset of symptoms is gradual, occurring without the individual or doctor being fully aware of what is happening. Coupled with this is the fact that the severity of the poisoning depends on:

- the concentration of carbon monoxide present in the environment.
- the duration you are exposed to carbon monoxide.
- the age of the individual concerned - elderly, children and the fetus are all at greater risk.
- the general state of health.
- the extent of physical activity - effects are increased with higher activity levels.

The most common symptoms (with frequency of occurrence in brackets) include:

- headache (90 per cent)
- nausea and vomiting (50 per cent)
- vertigo (50 per cent)
- altering states of consciousness (30 per cent)
- weakness (20 per cent).

The likely symptoms in adults and children are shown in the table below:.

Symptoms	Adult	Child
General	Dizziness, fatigue, weakness	Dizziness, fatigue, weakness
Neurological	Headache, drowsiness, disorientation	Headache, drowsiness, uncoordinated movement
Stomach/intestine	Nausea, vomiting, stomach pains	Vomiting, stomach pains, loss of appetite, diarrhea
Heart	Chest pain, wheeziness, palpitations, hyperventilation	Hyperventilation

How is carbon monoxide poisoning diagnosed?

Individuals can either be exposed to high levels of carbon monoxide over a relatively short period of time (acute exposure) or to lower levels of exposure over a longer period of time (chronic exposure).

Acute exposure is easier to diagnose as the symptoms are more pronounced, but it is the more common chronic exposure symptoms that are more subtle and difficult to tell apart from other conditions. Where whole families are affected by suspected 'food poisoning' this has been known to be due to carbon monoxide exposure.

Where such symptoms are reported repeatedly, domestic carbon monoxide poisoning should be suspected. Clues that point towards a problem within the home include:

- more than one family member being affected
- symptoms appear or get worse when gas appliances are in use
- symptoms are worse in the winter when gas boilers/heaters are in use
- symptoms improve when family members are not at home, but recur on their return.

Important information can also be obtained by inspecting gas-operated heating appliances within the home. Indicators of CO production include black soot marks on gas fire burners or on walls near cookers, boilers, gas fires or a yellow gas flame color, rather than the blue color it should be.

http://www.chemistry.org/portal/a/c/s/1/feature_ent.html?id=04dd47d40b8211d7f0856ed9fe800100 chemistry

Treatment of CO Poisoning

The goal of treatment for carbon monoxice poisoning is to remove carbon monoxide from the hemoglobin in your blood and bring the oxygen level in your blood back to normal.

For the immediate treatment of carbon monoxide poisoning, it is important that you are removed from the area where the gas may be present. If carbon monoxide poisoning is known or suspected:

- Get out of the building or car where the carbon monoxide is present.
- Keep still. (This will conserve oxygen in the blood, which is already at a low level because carbon monoxide has partially replaced it.)

Once you are taken to the hospital, oxygen therapy may be given. The most common type of oxygen therapy, called 100% oxygen therapy, involves breathing oxygen through a tight-fitting mask. If you have severe carbon monoxide poisoning and can't breathe on your own, a breathing machine may be used to help you breathe and to provide extra oxygen. In some cases you may receive hyperbaric oxygen therapy, in which you are put into a full-body chamber that applies air pressure (hyperbaric chamber) to remove the carbon monoxide faster. There is no medicine that can be used to remove carbon monoxide from the blood.

Several factors are considered when treating carbon monoxide poisoning. Tests are done to determine the amount of carbon monoxide in the blood. Infants, small children, older adults, or people with health problems are more severely affected by carbon monoxide in the blood. Treatment usually includes oxygen therapy to treat severe symptoms and lower carbon monoxide levels in the blood as quickly as possible.

If treatment is timely, most people are able to recover from carbon monoxide poisoning. If it is not treated, severe carbon monoxide poisoning can lead to heart or brain damage or death. Even after treatment, a person who survives a severe case of carbon monoxide poisoning may have permanent memory loss or brain damage. However, most people who are critically injured or die from carbon monoxide poisoning never received treatment. It is especially important to be aware of the warning signs and to seek immediate treatment if carbon monoxide poisoning is suspected.

What To Think About:

- Oxygen therapy should not be delayed while tests are being done.
- After treatment, any changes in vision, coordination, or behavior in the following weeks should be reported to your health professional.
- If a pregnant woman has carbon monoxide poisoning, treatment must be continued even after carbon monoxide is no longer found in her blood, because there still may be carbon monoxide in the blood of the fetus.

http://www.webmd.com/hw/home_health/aa7408.asp

Topic: Uses of Carbon Monoxide

Industrial Uses

Carbon monoxide is an important industrial gas, which is widely used as a fuel. It is also an important reducing agent in the chemical industry. The following are the major industrial uses of carbon monoxide:

1. Fuel gas mixtures
   - water gas (44% carbon monoxide)
   - blast furnace gas (30% carbon monoxide)
   - producer gas (34% carbon monoxide)
   - coal gas or illuminating gas (7.4% carbon monoxide)
2. Chemical manufacturing
   - methanol
   - formaldehyde
   - other alcohols and aldehydes
   - ethylene
   - acids
   - esters
   - hydroxy acids
   - aryl esters
   - carboxylic anhydrides
   - amides
   - acrylic acid
3. Recovery of metals from ores
   - nickel
   - cobalt
4. Production of powdered metals of high purity
5. Production of special steels
6. Production of reducing oxides
7. Powder metallurgy for molding
8. Manufacture of metal carbonyl catalysts used in
   - hydrocarbon synthesis
   - hydrogenation of fats and oils

Industrial Accident Prevention Association Carbon Monoxide in the Workplace
http://www.iapa.ca/pdf/carbon_monoxide_feb2003.pdf

"CO is very important in industry, since it is a precursor to a number of important organic chemicals. A mixture of CO and H2 is called synthesis gas, and is used both for the synthesis of methanol and in the 'hydroformylation reaction', in which a H atom and a formyl group (HCO) are inserted into the double bond of an alkene to form an aldehyde. This can be further reduced to an alcohol. Cobalt compounds are often used as catalysts for this process at temperatures of around 150°C and >200 atmospheres pressure. Several million tonnes of C7-C9 alcohols are produced in this way each year. Another important commercial process involving CO is the carbonylation of methanol to give acetic acid using a rhodium catalyst in the presence of iodide ions."
Imperial College: Carbon Monoxide
http://www.ch.ic.ac.uk/rzepa/mim/environmental/html/co_text.htm

"Carbon Monoxide is used in metallurgy, manufacturing acids, chemical industry, lasers and laboratory R&D. Carbon Monoxide is also used as a gas additive in various semiconductor fluorocarbon processes and as a feed gas for semiconductor dry etching."
Spectra Gases: Carbon Monoxide
http://www.spectra-gases.com/Semiconductor/cocopy2/carbon.htm

"Carbon monoxide (CO) can be used by food manufacturers to retain the red color of meat or dark fish prior to vacuum packaging or in the modified atmosphere packaging."
Blackwell Synergy: EFFECT OF HEATING ON RESIDUAL CARBON MONOXIDE CONTENT IN CO-TREATED TUNA AND MYOGLOBIN http://www.blackwell-synergy.com/links/doi/10.1111/j.1745-4514.2004.05303.x/abs/;jsessionid=ko9MtDsXGip8

"The ubiquitous carbon monoxide molecule, CO, is used by astronomers to trace the presence and temperature of molecular gas in everything from galaxies to circumstellar disks. We would rather try to detect H2, but sadly H2 has no permanent electric dipole moment because of its symmetry. Carbon monoxide does have a permanent dipole moment."
http://answers.google.com/answers/threadview?id=494692

Carbon Monoxide in Packaged Meat: Consumer Deception and Public Health Risk

The U.S. Food and Drug Administration (FDA) allows carbon monoxide to be used in packaged beef and pork. There is public concern, however, that CO use which maintains the pink or reddish color associated with meat freshness may mask readily identifiable signs of potentially hazardous food spoilage. Carbon monoxide makes meat appear fresher than it actually is by reacting with the meat pigment myoglobin to create carboxymyoglobin, a bright red pigment that masks the natural aging and spoilage of meats. Meats containing carboxymyoglobin will continue to appear pink or reddish well beyond the point at which they begin to spoil. The presence of carbon monoxide also suppresses bad odors and the presence of slime, other telltale signs that meat is spoiled. Without labels that would inform consumers that carbon monoxide is present, and a public education campaign to inform consumers about the possible effects of carbon monoxide, purchasers of carbon monoxide-treated meats cannot know, merely by looking, that the meat they are buying is fresh or safe.

http://www.co-meat.com/background.html

Answer Key for:

"Oh, Say Can you see CO?" Homework Assignment

1. In my home there is at least one potential source of carbon monoxide.
   Answers will vary.

2. There is a carbon monoxide detector on every level of my home where people work, sleep, or play?
   Answers will vary.

3. I tested the carbon monoxide detectors in my home to be sure they were all working.
   Answers will vary

4. There is/are ___ **Answers will vary** ___ carbon monoxide detectors in my home.

Answer these as true (T) or false (F):

_**F**_ 1. If I detect smoke or the CO detector goes off, I should call 911 then leave the house. (Note: leave house then call 911)

_**F**_ 2. If the power goes out, it is okay to heat the house with a space heater that uses bottled gas.

_**F**_ 3. It is okay to operate a gas-powered motor in the basement of my house.

_**F**_ 4. If my compact disk player loses power, it is okay to borrow the batteries from the CO detector.

_**F**_ 5. Heating systems and chimney should be checked every two years. (**Note: should be checked once a year**)

Source: "Rochester Healthy Home", June 2006

Suggested Teacher Resources:

An explanation of Poe's poem "The Raven"
http://www.mittelschulvorbereitung.ch/content/english/T620Raven.doc.pdf

Biography of Edgar Allan Poe
http://www.poemuseum.org/poes_life/index.html

To order a Poe t-shirt with a picture of Poe with a raven on his shoulder
http://www.cafepress.com/wacketees/555857 or call toll-free in US 1-877-809-1659

A bibliography of some of the theories of Poe's cause of death.
University of Maryland: September 24, 1996
http://www.umm.edu/news/releases/news-releases-17.html/

- Beating - The United States Magazine Vol.II (1857): 268.
- Epilepsy - Scribner's Monthly Vo1. 10 (1875): 691.
- Dipsomania - Robertson, John W. Edgar A. Poe A Study. Brough, 1921: 134, 379.
- Heart - Allan, Hervey. Israfel. Doubleday, 1926: Chapt. XXVII, 670.
- Toxic Disorder - Studia Philo1ogica Vol. 16 (1970): 41-42.
- Hypoglycemia - Artes Literatus (1979) Vol. 5: 7-19.
- Diabetes - Sinclair, David. Edgar Allan Poe. Roman & Litt1efield, 1977: 151-152.
- Alcohol Dehydrogenase - Arno Karlen. Napo1eon's Glands. Little Brown, 1984: 92.
- Porphryia - JMAMA Feb. 10, 1989: 863-864.
- Delerium Tremens - Meyers, Jeffrey. Edgar A1lan Poe. Charles Scribner, 1992: 255.
- Rabies - Maryland Medical Journal Sept. 1996: 765-769.
- Heart - Scientific Sleuthing Review Summer 1997: 1-4.
- Murder - Walsh, John E., Midnight Dreary. Rutgers Univ. Press, 1998: 119-120.
- Epilepsy - Archives of Neurology June 1999: 646, 740.
- Carbon Monoxide Poisoning - Albert Donnay

Source of Quotes
Donnay, Albert; "Poisoned Poe", *International Edgar Allan Poe Conference*, October 9th, 1999.

Chemistry behind the detectors
Rutherford, Dan, "CO Detection Technology". http://www.
org/portal/a/c/s/1/feature_ent.html?id=04dd47d40b8211d7f0856ed9fe800100 chemistry

Physical Properties of carbon monoxide
O'Leary, Donal, "Properties of Carbon Monoxide"
http://ucc.ie/academic/chem/dolchem/html/comp/co2.html

Sources of carbon monoxide poisoning
Rutherford, Dan, "Where does carbon monoxide come from?"
http://www.chemistry.org/portal/a/c/s/1/feature_ent.html?id=04dd47d40b8211d7f0856ed9fe800
100 chemistry

Physiology of O2/CO2 transport

Casiday, R., Frey R., "Hemoglobin and the Heme Group: Metal complexes in the blood for oxygen transport" Washington University in St. Louis

Prevention of carbon monoxide poisoning

MCS Referral & Resources 618 Wyndhurst Avenue #2, Baltimore, MD 21210, 410-889-6666

Anthology of Poe's Works

"Edgar Allan Poe Complete Tales and Poems", Castle Books, Edison, NJ 2002. (ISBN: 0 7858 1453 1)

Use of Carbon monoxide

http://www.co-meat.com/background.html

NYS Learning Standards and Performance Indicators:

3.1	Explain the properties of materials in terms of the arrangement and properties of the atoms that compose them.
3.1 r	A pure substance (element or compound) has a constant composition and constant properties throughout a given sample.
3.1 v	Elements can be classified by their properties and located on the Periodic Table as metals, non-metals, or metalloids.
3.1 rr	An electrolyte is a substance which, when dissolved in water, forma a solution capable of conducting electricity.
3.2 c	Types of organic reactions include addition, substitution, polymerization, esterification, fermentation, saponification, and combustion.
3.4 f	The rate of a chemical reaction depends on several factors: temperature, concentration, nature of reactants, surface area, and the presence of a catalyst