2007

Indoor Air Pollution

STORM Project

Chemistry and Environmental Sciences

Indoor Air Pollution

Objectives: Students will learn about indoor air pollutants the types and legal concentrations and affects on human health. The students will also determine the pathway for the formation of radon.

National Science Education Standards:

As a result of their activities in grades 9-12, all students should develop an understanding of the structure of the atoms; environmental quality; and natural and human-induced hazards.

As a result of their activity the students will have a better understanding of the atom's parts and how the atom disintegrates and interacts with the environment. The students should have a better understanding of the possible pollutants that contribute to indoor pollution.

Teacher Notes: Most of our time up to 89% is spent indoors. Only about 5% of our time is spent outside. In United States approximately 6% of our time is spent in vehicles. Even in undeveloped countries the majority of the time 79% for urban people and 65% for rural people is spent indoors. There are many regulations for outdoors, for businesses and indoor public places in terms of air quality. Our homes are not regulated nor are they checked for pollutants unless the home owner takes the responsibility. Air pollution is measured in small quantities such as parts per million (ppm) or parts per million by volume (ppmv) and parts per billion (ppb) and also Pico curies which is one trillionth of a curie.

The important Indoor Air Pollutants and Their Emission Sources

Pollutant	Emission Sources
Gasses	
Carbon dioxide	metabolic activity, combustion, garage exhaust, tobacco smoke
Carbon monoxide	Boilers, gas or kerosene heaters, gas stoves, wood stoves, fireplaces, tobacco smoke, garage exhaust, outdoor air
Nitrogen dioxide	Outdoor air, garage exhaust, kerosene and gas space heaters, wood stoves, gas stoves, tobacco smoke
Ozone	outdoor air, photocopy machines, electrostatic air cleaners
Sulfur dioxide	Outdoor air, kerosene space heaters, gas stoves, and coal appliances
Formaldehyde	Particle board, insulation, furnishings, paneling, plywood, carpets ceiling tile, tobacco smoke.
Volatile Organic Compounds	Adhesives, solvents, building materials, combustion appliances,paints, varnishes, tobacco smoke, room deodorizers, cooking, carpets, furniture, draperies
Radon	Diffusion from soil
Aerosol Particles	
Allergens	house dust, domestic animals, insects, pollens
Asbestos	Fire retardant materials, insulation
Fungal spores	Soil. Plants, foodstuffs, internal surfaces
Bacteria, viruses	People, animals, plants, air conditioners
Polycyclic aromatic hydrocarbons	Fuel combustion, tobacco smoke

Carbon dioxide is produced indoors from breathing and combustion. It does not pose a health problem until the mixing ratio reaches 15,000 ppmv (parts per million by volume). At 30,000 ppmv health affects include headaches, dizziness or nausea. Such mixing ratios usually do not occur.

Carbon Monoxide is a tasteless, colorless and odorless gas. CO is one of the seven pollutants called criteria air pollutants for which U. S. national Ambient Air Quality Standards (NAAQS) were set by the U. S. E.P. A. Clean Air Act. Exposures to 300 ppmv of CO for only one hour cause headaches exposures to 700 ppmv for one hour causes death. CO poisoning occurs when it dissolves in blood and replaces oxygen as an attachment to hemoglobin.

Nitrogen dioxide is a brown gas with a strong odor. NO2 is also a criteria air pollutant for which outdoor ambient air standards are set. Although exposures to high mixing ratios of NO2 harms the lungs and increases respiratory infections epidemiologic evidence indicates that exposure to typical mixing ratio has little effect on the general population. Children and asthmatics are more susceptible to illness associated with high NO2 than adults. At level greater than 80 ppbv (parts per billion by volume) resulted in increased sore throats, colds and missing school. Exposures of 300 to 800 ppbv reduce lung capacity by 10%.

Ozone is rarely produced indoors because it involves UV sunlight to photolysis the nitrogen oxide and hydrocarbons. The major source of indoor ozone is outside air. Photocopy machines and electrostatic air cleaners emit sufficient UV radiation to produce ozone indoors. Ozone emits an odor when its mixing ratios exceed 0.02 ppmv. Ozone causes headaches at mixing ratios greater than 0.15 ppmv, chest pains at ratios greater than 0.25 ppmv and sore throats and coughing at ratios greater than 0.30 ppmv. Ozone decreases lung capacity for people who exercise steadily for more than an hour while exposed to concentration greater than 0.30 ppmv.

Sulfur dioxide is a colorless gas that exhibits a taste at levels greater than 0.3 ppmv and strong odor at levels grater than 0.5 ppmv. Bronchiolar constrictions and respiratory infections can occur at mixing ratios greater than 1.5ppmv. Long-term exposure to SO2 is likely to suffer from impaired lung function and other respiratory ailments.

Formaldehyde (HCHO) is a colorless gas with a strong odor at higher than 0.05 ppmv. Indoor mixing ratios range form 0,07 to 1.9 ppmv and usually exceed outdoor amounts. At 0.05 to 1.5 ppmv has neurophysiologic effects; at 0.01 to 2.-0 ppmv it caused eye irritation; at 0.1 to 25 ppmv it cause irritation of the upper airway and at 5 to 30 ppmv it causes irritation of the lover airway and pulmonary problems at 50 to 100 ppmv it can cause pulmonary edema pneumonia and greater than 100 ppmv can result in coma or death.

Volatile Organic Compounds are organic compounds with relatively low boiling points (50 -260 C). More than 350 VOC's have been measured with a mixing ratio of greater than 1 ppbv. Carpets alone can emit at least 90 VOC's. Some of the most common VOC's are propane, butane, pentane, hexane, benzene, toluene and acetone. Some of the most common ailments from VOC's are respiratory irritation, dizziness, headaches and liver damage. Use 1.0 ppm.

Radon is a radioactive but chemically unreactive it is colorless, odorless and forms naturally in soils. The source of all radon is decay of uranium 238. Outdoor concentrations are generally low and do not pose a health risk. Indoor concentrations depend on the abundance of radon in soil and the porosity of the floors. Radon gas itself is not unhealthy but it quickly disintegrates into polonium 218 and lead 214 which enter the lungs enter the lungs directly or attached to aerosol particles are highly carcinogenic (causes cancer). The recommended level for indoor air quality is less than 4 Pico curies per liter. A curie is 3.7×10^{10} disintegrations per second. 4 Pico curies corresponds to 0.15 disintegrations per second for each liter of house air. It is estimated that 6% of the houses in the United States have unacceptable levels of radon. Radon levels can be reduced by sealing basement walls and floors and installing fans in crawl space to speed the mixing with the outside air.

The atom is composed of many smaller parts; the three main ones are the proton, the neutron and the electron. The proton and neutron are located in the nucleus and the electron is located spinning around the nucleus. The proton and neutron are similar in mass and contribute the majority of the atom's mass. The electron is so light it does not enter into the mass of the atom when determining the atomic weights. When a radioactive material changes it is due to a change in the nucleus. The nucleus may undergo an alpha decay which is the release of a particle that contains 2 protons and 2 neutrons. With the alpha particle release the parent material (the original atom) will change its mass by 2 and its atomic number by 2. Another type of radioactive decay is the beta emission, which is approximately the same as a proton changing into an electron. When the atom under goes a beta decay the parent atom will retain its atomic mass, producing a daughter atom that has the same atomic mass but increased the atomic number by one which is another element.

When Uranium238 undergoes many decays it will change into other "daughter" atoms. By a series of changes both alpha and beta the atomic mass, the total of the protons and neutrons, will change and the atomic number, number of protons will change and thus change the material into some other atom.

When U 238 undergoes an alpha decay it becomes Th 234. Uranium started with the atomic number of 92 and with an atomic mass of 238. By losing 2 protons it became the element with 90 protons and the mass will be 4 less than 238 which we started with.

By knowing what type of decay or knowing which element the decay would form we can determine the element or the type of decay.

Engage:

In 3 corners of the room have a material that would produce an odor such as a common perfume or bleach or scented candle. In the final corner of the room have a container such as water that should not have an odor. Have the students walk around the room and ask them to identify the odor in each corner of the room. Have them try to write down what they believe the particular scent is and how do they know that particular odor. The students should also list which one they think could cause them any physical discomfort. The students will be puzzled by the corner without any smell and most will probably state that if they can not smell or detect anything it must not be harmful. Share with them the correct answers and point out that the perfume has an agent to carry the scent that is usually composed of an alcohol. Point out that common household bleach is made from chlorine which was used in World War I as a chemical to kill people. Tell the students if you had the candle lit that the products of combustion include carbon monoxide and carbon dioxide and nitrogen dioxide. Be aware of the one that you could not detect, it may be the most dangerous.

Allow the students to volunteer by a show of hands if they have any of the things listed in their homes that are sources of indoor pollutants. Have the students reflect on what they may do to reduce or minimize the concentration of the pollutants in their homes.

Explore: Share with the students the Teacher information and pass out the handout on indoor air quality with the concentrations and health risk listed. Have the students do the following:

1. List the indoor air pollutants that are gases in order starting with the ones with the smallest concentration that cause health problems to the one with the highest concentration before it causes any health problems.

Air Pollutant	Concentration
________________________	________________________
________________________	________________________
________________________	________________________
________________________	________________________
________________________	________________________
________________________	________________________
________________________	________________________
________________________	________________________

2. Determine how many particles (molecules or atoms) of each pollutant must be present in this room to reach the lowest unsafe limit. Determine the dimensions of the room to determine the volume. Multiply the length by width by height in meters to obtain cubic meters. According to Avogadro's hypothesis one mole of any gas at STP will occupy 22.4 liters. If one cubic centimeter is equal to one milliliter, we could determine how many moles of gas would occupy the room knowing its size in cubic meters. If we know how many moles are in the room total we can determine the number of particles of the pollutant by using the parts per million. Knowing the number of particles we should be able to determine the mass of the pollutant in the room that would cause an unhealthy environment. Convert number of atoms or molecules into moles and then multiply by the atomic mass of the pollutant. Assume the room is at STP.

Express that in grams.

Pollutant	Number of particles	Mass
Carbon dioxide	________________	________
Carbon monoxide	________________	________
Nitrogen dioxide	________________	________
Ozone	________________	________
Sulfur dioxide	________________	________
Formaldehyde	________________	________
Radon (optional)	________________	________

3. Determine the pathway for the formation of lead 206 from the disintegration of Uranium 238. Please fill in each blank with the correct atomic symbol with the atomic number and atomic mass

U_{92}^{238} undergoes an alpha decay to form _______________ which will that will undergo a beta decay and form _____________ which will release a beta particle and change into ________________, this will change by an alpha release into _____________________ which also has an alpha release into ___________________ this also releases an alpha particle to become____________________ and another alpha particle release turns this into _________________ which undergoes an alpha decay to form_______________________ now this releases a beta particle and the newly formed element is ________________ which also releases a beta particle to form __________________ now this will undergo an alpha release and become _______________ and another beta release makes ____________________ and this also has a beta release to become _______________________ and finally this last step undergoes an alpha decay to form_________________

Explain: The materials that cause indoor air pollution do not all have the same concentrations for health problems because of the chemical reactions they have with the body. Radon is radioactive and the alpha and beta rays are strong enough to cause ionizing radiation which in small amounts can cause cancer or mutations. Materials such as carbon dioxide can occur at very large amounts before being considered a health problem because it is naturally a part of our atmosphere and necessary for the plants. It takes a lot of carbon dioxide in terms of concentration before we notice any health problems. If a small levels of carbon dioxide would cause us health problems we would have a very difficult time co-existing with the plants that need the carbon dioxide in the atmosphere to use for photosynthesis.

Elaborate:

1. Have the students test their homes for radon and report back to the class on what the results is, the size of the room in which the test was conducted, what do the results mean, what are the physical geological features around the house, type of basement.
2. Have the students find news reports on air pollution and report to class using the terms and relating to our unit on indoor air quality.
3. Take some air quality test in the building using a substance that would catch particulates or radon test kit. Compare results from different parts of the building.
4. Calculate the amount of radon in the room when it is the minimum dangerous level.
5. Take some action or help someone take some action to mitigate or eliminate an indoor air pollutant.

Evaluate: 1. Collect the student worksheets.

2. Have the students report on the radon test at home showing the class the official report from the company that conducted the test.

3. Have the students report to the class on the different air pollutants found in the school

Grading rubric:

1. For each correct answer on the 1st work sheet dealing with the concentration of the air pollutants the students will earn one point. The entire sheet is worth 16 points. The score will indicate my ability to teach the material and the students' ability to comprehend.
2. On the second sheet the students will receive two points for each correct answer; the sheet is worth 24 points.
3. On the third sheet the students will receive one point for each correct answer for a total of 14 points.
4. For each student that has his/her home tested for radon and report back to the class on the points listed in the elaborate section they will receive 20 points.
5. For each news article that students report on covering the points in the elaborate section they will receive 5 points with a 10 maximum of 10 points per student
6. Testing of the indoor air quality in the school building and writing up a data sheet with a conclusion worth 5 points for each room tested with a maximum of 25 points
7. Determine the minimum amount of radon that would make a room dangerous using the 4 Pico curies standards; worth 5 points.

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1. List the indoor air pollutants that are gases in order starting with the ones with the smallest concentration that cause health problems to the one with the highest concentration before it causes any health problems.

Air Pollutant	Concentration
___Radon_______________	_ _4_picocuries_______
___NO2________________	___80 ppb____________
___Formaldehyde___________	___.05 ppm___________
___Ozone_______________	____.15 ppm_________
____V.O.C.'s_____________	____1.0 ppm_________
____SO2_______________	_____1.5 ppm_______
_____CO_______________	_____300 ppm______
_____CO2______________	____15,000 ppm_____

. Determine the pathway for the formation of lead 206 from the disintegration of Uranium 238. Please fill in each blank with the correct atomic symbol with the atomic number and atomic mass

U_{92} ^{238} undergoes an alpha decay to form __234Th90____ which will that will undergo a beta decay and form _234 Pa 91___ which will release a beta particle and change into __234 U 92________, this will change by an alpha release into ___230 Th 90_____________ which also has an alpha release into _226 Rn 88 _____________ this also releases an alpha particle to become__222 Rn 86____________ and another alpha particle release turns this into __218 Po 84______ which undergoes an alpha decay to form____214 Pb 82________ now this releases a beta particle and the newly formed element is __214 Bi 83_____ which also releases a beta particle to form ____214 Po 84______ now this will undergo an alpha release and become __210 Pb 82________ and another beta release makes ____210 Bi 83___________ and this also has a beta release to become _____210 Po 84_____________ and finally this last step undergoes an alpha decay to form__206 Pb 82____________

To determine the area of the room measure the length in meters and multiply that by the width of the room in meters and multiply that by the height in meters to obtain meters cubed.

According to Avogadro we know that for each liter of any gas at S.T.P. it will occupy 22.4 liters of space.

1 liter is equal to 1000 mL

1 mL is equal to 1 cubic centimeter

100 centimeters is equal to 1 meter

Cubic meters 1 mole 1 liter 1 mL 100cm 100 cm 100cm = moles

1 room 22.4 L 1000mL 1000mL 1 m 1m 1m 1 room

Moles 6.02 x 10^{23} particles parts of pollutant = parts (atoms) of pollutant

1 room 1 mole particles (million) 1 room

Parts (atoms) of pollutant 1 mole grams = grams of pollutant

In room 6.02 x 10^{23} atoms 1 mole 1 room