CHEMMATTERS

September 2005 Teacher's Guide

About the Guide

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Puzzle: Crostic Quote

Instructions: Guess the words defined below and write them over the numbered dashes. Transfer letters from numbered dashes to corresponding numbered squares in the diagram. Black squares indicate word endings. The filled diagram will contain a quotation reading from left to right. Once you begin to get the sense of the quote, you will be able to work backwards to fill in letters in clue words left unsolved on the first pass. The majority of the clues are “chemical”, a few are quite general. As an extra help, the <u>answers</u> to the clues are arranged alphabetically.
The quote comes from the famous chemist, A. Nonymous., dealing with the bond angle of 105^{o} .

F 1	I 2	B 3	A4		O 5	K 6		N 7	H 8		E 9	G 10	J 11	L 12		I 13	L 14		M 15
E 16	H 17	C 18	F 19		I 20	B 21	O 22		E 23	I 24	F 25	H 26	O 27		B 28	L 29		K 30	C 31
N 32	D 33	J 34		K 35	G 36	B 37	A 38	H 39	F 40	M 41	B 42	J 43		D 44	M 45	I 46		N 47	
C 48	B 49	G 50	N 51	I 52	M 53		J 54	E 55	B 56	H 57	J 58	M 59	B 60	N 61	E 62		K 63	H 64	A 65
	O 66	J 67	F 68	A 69		I 70	C 71	J 72	L 73		E 74	I 75	B 76	_	K 77	I 78	H 79	G 80	A 81

A) __ __ __ __ __ John _____, maker of farm tractors.
65 4 38 81 69

B) __ __ __ __ __ __ __ __ Element whose only stable isotope has 10 neutrons.
3 37 60 21 56 28 76 42

C) __ __ __ __ Inventor of cheap process for extracting Al from its ores.
71 31 18 48

D) __ __ Noble gas with the highest ionization energy (symbol).
44 33

E) <u>K E T O N E</u> R-$\overset{O}{\overset{//}{C}}$-R’ where neither R nor R’ is hydrogen.
9 23 55 16 74 62

F) __ __ __ __ __ Gruesome, ghastly (often violent and/or sensational).
1 40 68 25 19

G) __ __ __ __ SI prefix for one-billionth.
10 80 50 36

H) __ __ __ __ __ __ __ Home of the protons and neutrons in an atom.
64 17 39 79 8 57 26

I) __ __ __ __ __ __ __ __ __ __ What happens at the ANODE of an electric cell.
75 24 13 46 52 70 2 78 20

J) __ __ __ __ __ __ __ __ Disaccharide made from glucose and fructose.
43 72 58 34 11 54 67

K) __ __ __ __ __ Wet, spongy land, like the Okefenokee ____.
6 30 63 35 77

L) __ __ __ __ __ Jonathan ______, author of Gulliver’s Travels.
73 12 49 29 14

M) __ __ __ __ __ Fish by dragging along the sea bottom.
59 53 45 15 41

N) __ __ __ __ __ The “toxin” Bob Becker has labelled DHMO (dihydrogen monoxide).*
7 47 32 51 61

O) __ __ __ __ Unit of power.
66 5 22 27

Puzzle Answers

"Life as we know it would not exist if water molecules had a linear structure and were thus non-polar."

A. Deere
B. Fluorine
C. Hall
D. He
E. Ketone
F. Lurid
G. Nano
H. Nucleus
I. Oxidation
J. Sucrose
K. Swamp
L. Swift
M. Trawl
N. Water
O. Watt

Content Reading Guide

National Science Education Content Standard Addressed As a result of activities in grades 9-12, all students should develop understanding	**Clearing the Air**	**How Earth Got Its Aura**	**Equilibrium**	**Flight of WB-57F**	**Student Gardens & Air Quality**
Science as Inquiry Standard A: of abilities necessary to do scientific inquiry				✔	
Science as Inquiry Standard A: about scientific inquiry.	✔	✔	✔	✔	✔
Physical Science Standard B: of the structure and properties of matter.			✔		
Physical Science Standard B: of chemical reactions.	✔		✔		
Physical Science Standard B: of conservation of energy and increase in disorder.	✔		✔		
Life Science Standard C: of interdependence of organisms.	✔		✔		
Physical Science Standard D: of energy in the Earth system	✔		✔		
Physical Science Standard D: of geochemical cycles.	✔	✔	✔		✔
Science and Technology Standard E: about science and technology.	✔	✔	✔	✔	
Science in Personal and Social Perspectives Standard F: of science and technology in local, national, and global challenges.	✔	✔	✔	✔	✔
Science in Personal and Social Perspectives Standard F: of natural resources.	✔		✔		
Science in Personal and Social Perspectives Standard F: of environmental quality.	✔	✔	✔		✔
History and Nature of Science Standard G: of science as a human endeavor.	✔	✔	✔	✔	✔
History and Nature of Science Standard G: of the nature of scientific knowledge.	✔	✔	✔	✔	✔
History and Nature of Science Standard G: of historical perspectives.	✔	✔	✔	✔	

Anticipation Guides

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

Directions for all Anticipation Guides: 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.

Clearing the Air—Treaties to Treatments

Me	Text	Statement
		1. London smog and Los Angeles smog are formed by similar processes.
		2. The 1992 Montreal Protocol, signed by more than 180 countries including the U. S., set a timetable to phase out ozone depleting chemicals.
		3. The 1997 Kyoto Protocol aims to cut greenhouse gas emissions.
		4. There is only one significant greenhouse gas, and that is CO_2.
		5. “Brown clouds” usually remain over the high population areas where they are formed.
		6. Greenhouse gas emissions are tied to our energy use.

How Earth Got Its Aura

Me	Text	Statement
		1. The Aura satellite mission depends on the skills of scientists, engineers, technicians, and many more experts.
		2. Global temperatures and atmospheric chemistry affect each other.
		3. There are two instruments on the Aura spacecraft.
		4. The Aura mission is collecting information for the United States only.
		5. The Aura spacecraft was launched from Cape Canaveral in Florida.
		6. The Aura satellite has an equatorial orbit around Earth.
		7. The Aura satellite orbits Earth at a speed of about 25 200 km/h.
		8. Aura is able to retrieve ozone data even with cloud cover.
		9. Aura is limited to collecting ozone depletion and climate change data in the Western Hemisphere.

What's So Equal About Equilibrium?

Me	Text	Statement
		1. When a process reaches equilibrium, there are no further changes.
		2. To show a chemical equilibrium, chemists use a double arrow.
		3. Natural and human-generated changes can change the equilibrium in our atmosphere.
		4. The stratosphere is warming.
		5. Using Le Chatelier's principle, it is easy to predict how the equilibrium of a system will shift in response to changing conditions.

Flight of the WB-57F

Me	Text	Statement
		1. The instruments on the Aura spacecraft constantly scan a variety of surfaces.
		2. The WB-57F makes measurements of the same atmosphere as the Aura instruments in order to validate the data collected by Aura.
		3. Even breathing 100% oxygen is insufficient for human lungs at the low atmospheric pressure where the WB-57F flies.
		4. All of Aura's instruments are mounted on the bottom of the spacecraft.
		5. Balloons are used to take direct measurements of temperature and water vapor in the atmosphere.
		6. Data is collected at only one altitude on the WB-57F.
		7. Scientists expect that Aura's instruments work well for five years with no repairs.

Reading Strategies

These content frames, matrices, and organizers 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. 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

Clearing the Air—Treaties to Treatments

Compare and contrast the Montreal Protocol and the Kyoto Protocol in the chart below.

	Montreal Protocol	**Kyoto Protocol**
Year signed		
Countries that signed		
Purpose		
How the goal is to be met		
Problems in implementing the pact		

How Earth Got Its Aura

Complete the chart below describing the Aura spacecraft and its instruments.

	Main Idea	***Details***
Who?		
What?		
Why?		
Where?		
How?		
What has been learned?		

What's So Equal About Equilibrium?

	Equilibrium Examples
Everyday Equilibrium	**Dynamic**
	Shifting
Chemical Equilibrium	**Dynamic**
	Shifting
Atmospheric Equilibrium	**Dynamic**
	Shifting

Flight of the WB-57F

Compare and contrast the WB-57F and Aura spacecraft in the table below. At the bottom, list similar measurements that are made for validation purposes.

WB-57F	Aura
Measurements made by both	

What's Equal About Equilibrium?

Background

From *ChemCom*, 4th Edition. Producing ammonia from nitrogen gas and hydrogen gas is a terrific example of how an understanding of chemical equilibrium helps us control chemical reactions. The first reason is that molecular nitrogen (N_2) is very stable. This means that nitrogen fixation—the chemical combination of nitrogen gas with other elements—has a substantial activation-energy barrier. A reaction with a large energy barrier requires that either the reactant particles must have substantial kinetic energy or that a catalyst is found to reduce the energy required to initiate the reaction.

A second reason the reaction of nitrogen gas with hydrogen gas is difficult is that some ammonia molecules tend to decompose back to nitrogen gas and hydrogen gas under the conditions of the ammonia-**synthesis** reaction. This type of reaction—one in which products re-form reactants at the same time that reactants form products—is known as a reversible reaction. The double arrows used below indicate that both forward and reverse reactions are occurring simultaneously and at the same rate.

$$N_2\ (g) + 3\ H_2\ (g) \rightleftharpoons 2\ NH_3\ (g)$$

How do chemists and chemical engineers these obstacles to produce ammonia?

The rate or speed at which nitrogen fixation occurs determines the time required for a certain amount of ammonia to form. The **reaction rate** expresses how fast a particular chemical change occurs. In chemistry, the study of reaction rates is often referred to as **kinetics**. High temperatures increase the reaction rate by providing more reacting molecules with sufficient energy to overcome the activation energy barrier. Catalysts, on the other hand, increase the reaction rate by lowering the activation energy required for the reaction to occur.

Although a higher reaction temperature increases the average kinetic energies of the nitrogen and hydrogen molecules that react to form ammonia, ammonia itself becomes increasingly unstable at higher temperatures. The result is that ammonia decomposes back to nitrogen gas and hydrogen gas. If the reaction takes place at lower temperatures, however, fewer nitrogen and hydrogen molecules have enough energy to overcome the activation energy barrier, thus slowing the net rate of ammonia formation (even though less ammonia decomposes at that lower temperature). What can be done to increase the rate and yield in the production of ammonia?

The major breakthrough that led to workable, profitable ammonia production was the discovery of a suitable catalyst. Catalysts made it possible to produce ammonia at lower temperatures (450–500 °C), thus slowing the rate of ammonia decomposition. Haber and his colleagues spent a great deal of time and energy in the early 1900s systematically searching for good catalysts. Today, the ammonia industry employs a catalytic mixture of iron oxides and aluminum oxide.

Any reversible reaction appears to "stop" when the rate at which the product forms becomes equal to the rate at which it reverts back to reactants—that is, when the reactants and products attain **dynamic equilibrium**. At equilibrium, both forward and reverse reactions continue, but there are no further net changes in the amounts of reactants or products. At the point of dynamic equilibrium the two opposing changes are in exact balance.

The net amount of ammonia that can be formed from a certain amount of nitrogen gas and hydrogen gas at constant temperature is limited. One way to increase the amount of ammonia produced is to cool and remove the ammonia as soon as it forms, thus preventing it from decomposing back to reactants. If ammonia is continuously removed, the rate of the reverse reaction (the decomposition of ammonia) is decreased dramatically because there is less gaseous ammonia available to decompose. This causes the overall reaction to favor production of more ammonia.

All reversible reactions in closed containers eventually reach equilibrium if conditions such as temperature remain constant.

When an equilibrium system is disturbed to cause one reaction (either forward or reverse) to be favored over the other, the initial equilibrium will shift in the direction of the favored reaction. This phenomenon, first described by the French chemist Henri LeChatelier, is commonly referred to as **LeChatelier's Principle**.

The external disturbance imposed on a system at equilibrium, sometimes called a "stress," can be a change in the concentration of a particular reactant or product, a change in the temperature of the system, or—for a system including gases—a change in the total pressure. In the case of the industrial production of ammonia, the removal of ammonia (a change in its concentration in the reaction vessel) results in the initial equilibrium position being shifted toward the right producing a larger amount of product (ammonia).

Another external disturbance (stress) used to increase ammonia production is to add reactant molecules—nitrogen gas and hydrogen gas—continuously under high pressure. This increases the concentration of reactants, which favors the forward reaction—and thus increases the amount of ammonia that can be formed.

In many cases changing the temperature can also cause an equilibrium system to shift. The direction of that effect depends on whether the forward reaction is exothermic or endothermic. For example, the synthesis of ammonia is exothermic:

$$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g) + \text{Heat}$$

That is, heat (thermal energy) can be considered a product of the forward reaction. Stressing the equilibrium by raising the temperature would favor the reverse reaction—the chemical change that removes heat. The result is that at higher temperatures less ammonia is formed at equilibrium. The temperature must be high enough to provide the nitrogen and hydrogen molecules with adequate kinetic energy to react. A delicate balance is needed—the temperature must be high enough to produce significant amounts of ammonia, but not so high that the rate of ammonia decomposition is excessively promoted.

From *SourceBook*-Fritz Haber, a German, received the Nobel Prize in chemistry in 1919 for synthesizing ammonia from its elements, nitrogen and hydrogen. Haber's life was filled with ironic tragedies. His motivation for developing a method for producing ammonia was to make possible unlimited supplies of fertilizer to replace the limited supply of natural fertilizers (from nitrate deposits in Chile). Many were predicting massive starvation in Europe unless this was done. Ironically, ammonia could also be used to produce explosives. As a result Germany was able to produce its own explosives during World War I despite a blockade of nitrate compounds by the Allied powers. Haber was a patriot and German nationalist and as a consequence threw himself into the German war effort. One of his contributions was development of mustard gas, a horrible instrument of war that caused much suffering. Ironically, many compounds related to mustard gas have been use as anti-cancer agents, ultimately saving lives. The Nobel Prize he received was criticized by British, American, and French scientists. A final irony in Haber's life occurred when he was driven out of Germany before World War II because of his Jewish ancestry, despite his proven loyalty to his country.

Connection to Chemical Concepts

- Physical and chemical equilibrium; chemical dynamics; and chemical reactivity.
- Chemical equilibrium is a dynamic process that is significant in many systems (biological, ecological and geological).
- Chemical reactions occur at different rates.
- Factors that affect the rate of a chemical reaction (temperature, concentration) and the factors that can cause a shift in equilibrium (concentration, pressure, volume, temperature). *:*

Student Misconceptions

1. "**Reactions always go to completion."** The way we write chemical equations could imply that reactants completely become products. This is not necessarily true, especially in systems that establish equilibrium. The double reaction arrows serve to illustrate the fact that both reactants and products remain in a system at equilibrium.

2. "**Reactions at equilibrium have equal concentrations of reactants and products.'** Actually, this is seldom the case at equilibrium. Values of equilibrium constants indicate the extent to which reactants form products. Large values represent reactions that go farther to the right before equilibrium is established.

3. "**Reactions at equilibrium have stoichiometrically related concentrations."** Some students think that the amounts of reactants and products in a reaction at equilibrium are fixed by the coefficients of the equation. The coefficients fix the relative amount that will react, not the amounts that are present.

4. "**Equilibria are static."** It is common for students to see chemical equilibrium as a static balance rather than a dynamic balance between forward and reverse interactions of molecules.

5. "**The right and left sides of an equation represent different regions of the reaction vessel."** A chemical equation is simply a formalized way to depict the chemical system, and the terms "left" and "right" refer only to the written equation. There is no "sidedness" to the chemical system itself. Reactants and products are intermingled.

Sourcebook, Chemical Equilibrium, Copyright 2004

Demonstrations and Lessons

The Equilibrium Game- A model of chemical equilibrium.

Materials (per pair of students)
2-25 ml graduated cylinders
2 glass tubing of differing diameter (such as 4mm and 12 mm, actual size does not matter), long enough to reach the bottom of the graduated cylinders.
Water.

Procedure

Students will work in pairs. Label the graduated cylinders A and B. Fill A with 20 mL of water. B begins empty. Students begin the simulation by transferring water from A to B and B to A. The transfer is done by lowering the glass tubing to the bottom of the cylinder and then placing a finger over the top end. The tube is then lifted with the water in it and moved to the other cylinder. When the student lifts their finger the water is deposited. Their tube is returned to their original cylinder. One full transfer consists of student A moving one tube of water from cylinder A to B followed by student B transferring one tube of water from B to A. (Note that as B begins empty, the first few transfers will not transfer much water.)

Students should make a chart to record the initial volumes of each cylinder, and then record the volume of each cylinder after every three transfers. Have students continue until they believe they have reached equilibrium. Have the students raise their hands when they believe they are at equilibrium.

This game yields interesting results. At first students do not think the system will ever come to equilibrium. They often think they are at equilibrium when there is equal volume in each cylinder. Use leading questions to challenge this notion. Let them know that if they are truly at equilibrium the volume should remain constant with additional transfers. Of course, with this set-up it does not. Equilibrium is not reached until the height of the water in the cylinder with the narrow tube is sufficiently high so that the amount of water in the slender tube is equal to that in the wider tube dipping into a cylinder with a lower height of water.

This situation is analogous to the concentration (height of water) times the rate of reaction (diameter of the tube.). The rate in that has a high concentration and lower rate, can be balanced by a rate in the other direction that has a lower concentration but higher rate of reaction. Graphing the results will help illustrate what is going on.
LeChatelier's principle can be demonstrated by adding a 5 mL 'stress' to one side or the other. Have students continue with transfers until a new equilibrium is reached. Ask students to decide where the addition winds up. Does it all go the other side, stay where it was added, or shift until it is present on both sides, increasing the volume of each, but in proportion to the original ratio of heights.

Suggestions for Student Projects

Have students research issues relating to the evidence for global warming and report on how the scientific issues relate to the concept of equilibrium.

Anticipating Student Questions

1. Students may be surprised that at the end of a reaction there will be some concentration of all the reactants AND products. The presence of all reactants and products in a reaction vessel is not expected by students who have generally been exposed earlier only to reactions that "go to completion."

2. Students sometimes get the idea that higher temperatures drive reactions towards completion. If dissolution is treated as an equilibrium (Solute + Solvent Solution), for example, increasing the temperature is thought to increase the concentration of the solution. Although this is most often true with solid/ liquid combinations, there are exceptions (e.g., Li_2SO_4). The solubility of NaCl is hardly affected by temperature at all. The solubility of a gas decreases with increased temperature. Opening a warm can of soda pop amply demonstrates this fact.

3. Solubility equilibria are an excellent chance to challenge student ideas about physical vs. chemical changes. Ask students if a reaction resulting in a precipitate is a physical or chemical change [M(aq) + A(aq) $\rightleftharpoons$ MA (s)]. Then ask if the dissolution of an ionic salt is a physical or chemical change [MA(s) $\rightleftharpoons$ M(aq) + A(aq)]. Then show them that both reactions can be represented as one equilibrium reaction. Adapted from *SourceBook*.

<u>Websites for Additional Information</u>
Sourcebook Chemical Equilibrium
http://intro.chem.okstate.edu/ChemSource/chemequil/ertable.htm
Simulation of chemical equilibrium in gases

http://www.chm.davidson.edu/ronutt/che115/EquKin/EquKin.htm
Tutorial from Stephen Lower at Simon Fraser University in British Columbia
http://www.chem1.com/acad/webtext/chemeq/index.html
A slide presentation on equilibrium by Scott Goode at the University of South Carolina
http://www.chem1.com/acad/webtext/chemeq/index.html

Clearing the Air—Treaties to Treatments

Background

International treaties for solving global environmental crises present political challenges unparalleled in other categories of human interaction. The central question of this article is: Why are these treaties so difficult?

You and your students might want to prepare for reading this article by thinking about other instances and situations in which action is called for before outcomes can be predicted with certainty. In daily life, we are urged to adopt healthy lifestyles without the guarantee they will insure long life. Adults invest money in stocks based on certain hunches and performance patterns with no guarantee that they will increase in value. Our government ordered pre-emptive military action be taken based on uncertain intelligence reports with no guarantee that the action would improve national security. In short, it is not unusual for individuals and nations to take action even when outcomes are uncertain. As the article points out—deciding to take NO action is also a decision.

What makes global environmental agreements even more difficult is the uneven distribution of sacrifice and risk they require. Is it fair to ask a developing country to make the same economic sacrifice that a prosperous industrial power makes? On the other hand, is it fair to expect disproportionate cutbacks on the part of industrial nations while neighboring countries continue to pollute the atmosphere with environmentally destructive industrial practices?

And all of this decision making takes place while the global climate changes in a slow, often uneven manner. Some locales even report cooler than average temperatures as weather patterns slowly shift with changing ocean and air currents.

Excellent additional background for this article may be found on the NASA Goddard Spaceflight website called Earth Observatory. The site map is at http://earthobservatory.nasa.gov/masthead.html. The "Features" option is especially rich with articles on evidence of global climate change.

For a look at serious policy issues facing global decision making efforts, see the Pew Center on Global Climate Change. The web page describes the current status of policy making, both national and international: http://www.pewclimate.org/

Connection to Chemical Concepts

More about the release of CO_2 into the atmosphere from human activities

The technical term that is applied to materials released into the atmosphere because of human activities is *anthropogenic*. For example, there is a "natural" greenhouse effect that is the result of the normal concentration of carbon dioxide, water vapor and other gases that would be in Earth's atmosphere even if humans did not exist. Then there are the additional gases, especially carbon dioxide, that enter the atmosphere as a result of human activities, particularly the burning of fossil fuels. This results in what is called the *enhanced greenhouse effect.*

The amount of carbon dioxide released into the atmosphere is astounding. A table containing a vast amount of data from a large number of countries can be found at:
http://www.emep.int/emis_tables/tab7.html

If you access any of this data, one thing should probably be kept in mind. Anthropogenic emissions are typically expressed in terms of metric tons of carbon. This means that if you are looking at anthropogenic emissions of carbon dioxide, for example, you need to convert the values to an equivalent amount of carbon. This is accomplished simply by using the relative molecular weight of the molecule in question compared to the atomic weight of carbon. For example, an anthropogenic emission of 5500 million metric tons of carbon dioxide is equivalent to:

(5550)(12/44) = 1514 million metric tons of carbon

Because the molar mass of carbon dioxide is 44, while the atomic weight of carbon is 12.

An interesting table of conversion factors relating to different carbon containing compounds can be found at: http://www.eia.doe.gov/oiaf/1605/gg00rpt/appendixf.htm

Some interesting statistics

Population and energy consumption statistics will vary, depending upon the source of the information, so the data below should not be taken to represent definitive values, but rather as reasonable estimates.

The total population of the World is about 6,400,000,000, and is growing at about 150 people per minute.

The population of the United States is about 277,000,000, and is growing at the rate of about 5-6 people per minute.

So the U.S. represents about 4.5% of the total population of the world.

We account for about 35% of the world's energy consumption.

Less than 8% of our energy consumption is comes from renewable resources.

About 85% of our energy consumption comes from fossil fuels, almost half of which is imported.

Possible Student Misconceptions

There is a lot of misunderstanding about what the "greenhouse effect" really is. Perhaps one of the most common is that the only reason a greenhouse becomes warm is that light energy enters, but cannot escape. While that may basically be true, the major reason the greenhouse becomes hot is due to the fact that it is more or less sealed up and cannot exchange its inside air with outside air. There is an interesting discussion of this at:
http://www.ems.psu.edu/~fraser/Bad/BadGreenhouse.html

You may also need to consider the common misconception about the term "proof" in science. Scientists gather information and conduct experiments to support and, in some cases, reject theories. And a theory is simply the best statement that can be made based upon all available verifiable information. Scientists understand uncertainties, and they easily accept that knowledge and understanding advances without achieving 100% certainty. For the general public, this acceptance does not come as easily. The moment a theory is questioned and revised with new information, many voices rise to say, "Again, a major theory is disproved!"

For people deliberating treaties for controlling global climate change, the prospect of taking action, often expensive action, in the context of uncertainties makes progress especially difficult.

Demonstrations and Lessons

The article suggests that finding a solution to the world's energy crises will loom large in decades to come. *ChemMatters* April 2003 featured an activity titled "Green Energy—It's Your Decision". The activity challenged students to select the most efficient method in terms of energy and cost for heating 200 mL of water to a required temperature. They were to consider a laboratory hot plate, a bunsen burner, and a microwave oven. The activity was adapted from *Introduction to Green Chemistry: Instructional Activities for Introductory Chemistry,* published by the American Chemical Society, 2002. The activity is included on the 20-year CD Rom of *ChemMatters* articles available for purchase on this *ChemMatters* website.

Suggestion For Student Projects

There are many environmental regulations and public policies under scrutiny and debate at the national and intermantional level. Students could work in groups to research the underlying science and the various positions taken by opposing groups. Some of these regulations involve emissions of specific chemicals like arsenic, mercury, and various organic species.

Regulations ofter refer to industry standards for pollutants and emissions. Students will find that these standards translate into the thresholds below which the presence of these substances are legal. Sometimes the decisions made about setting standards revolve around the limits of affordable testing equipment. An amount that can be detected using expensive analytical tests in laboratories might go undetected with the day to day equipment used in the field. Students might interview water-quality or air-quality experts for more information on the subject of regulations and standards.

Anticipating Student Questions

What would the climate be like if we got rid of ALL greenhouse gases?

The complete answer involves some complex thinking. Basically, we know how much energy reaches the Earth from the Sun. We know how much of this energy is absorbed by the Earth and how much is reflected. The energy that is absorbed warms the Earth. The Earth, like all objects, emits energy, and if it became warmer, it would emit even more energy. Of course the energy arriving on the Earth and the energy leaving the Earth must be equal. Otherwise the Earth would either be getting hotter or colder. So from this "energy balance," scientists can calculate how warm the Earth would be in order to emit the same amount of energy it receives every day. That comes out to be $-18\ ^{o}C$. Brrrrr.

Is there anything that can be done about the smog problem short of giving up our use of internal combustion automobiles?

Yes, and much has been done already. One of the major technological advances has been the installation of catalytic converters on automobiles. The name suggests what they do. A catalytic converter contains catalysts, often transition metals such as palladium, Pd, or platinum, Pt. These catalysts transform unburned hydrocarbons and carbon monoxide into carbon dioxide while at the same time converting NO_x back into the elements nitrogen and oxygen.

Websites For Additional Information

Several excellent Websites have been cited in this Teacher's Guide entry. Use these cites to find additional links to information about greenhouse gases, ozone, and policy making.