Some policymakers believe that **carbon taxes,** i.e., taxes based on the amount of carbon contained in a fuel rather than upon its total mass, should be instituted as a disincentive to use fossil fuels, especially coal, since it generates more CO_2 per joule of energy produced than does natural gas. In fact, the hydrogen-to-carbon ratio of the average global fuel mix has been continuously increasing over the last century and a half, as we moved from economies whose energy source was dominated by wood (H/C ratio of about 0.1) to coal (~1.0 ratio) to oil (about 2.0) and now to natural gas (4.0); this is the same direction as moving to lower CO_2/energy ratios, as implied above.

We conclude by commenting upon the paradox that faces humanity today concerning the enhancement of the greenhouse effect. On the one hand, there exists the slight possibility that doubling or quadrupling the CO_2 concentration will have much less of an effect on climate than predicted, and that efforts taken to prevent such an increase not only would represent an economic burden for both the developed and the developing worlds, but would perhaps be wasted in the outcome.

On the other hand, if the predictions of scientists who model the Earth's climate turn out to be realistic, but we do nothing to prevent further buildup of the gases, both present and future generations will collectively suffer from rapid and perhaps cataclysmic changes to the Earth's climate. While the *precautionary principle* was invoked and action was taken to mitigate the destruction of the ozone layer (Chapter 2), the governments of the world have been unable to come to a consensus on action to mitigate climate change, even though the consequences or *external costs* of inaction will likely be extremely high.

Review Questions 23–29 are based on material in the preceding sections.

Review Questions

1. Define the term *commercial energy*.

2. What is the equation relating exponential growth to the annual increase in a quantity?

3. How does the rate of energy usage by a country depend on its population and its GDP?

4. Define the term *energy intensity*. Describe how the energy intensity has changed over the last few decades (a) globally, (b) for the United States, and (c) for China.

5. What are the five main global sources of primary commercial energy?

6. What are the ultimate origins of coal, oil, and natural gas? Which fuel is in greatest reserve abundance?

7. What is the main component of *natural gas*? Write out the balanced chemical equation illustrating its combustion.

8. Why is natural gas considered to be an environmentally superior fuel to oil or coal? What phenomenon involved in its transmission by pipeline might offset this advantage?

9. What is meant by the term CNG? What are the advantages and disadvantages to fueling vehicles with CNG? What is meant by *LPG*?

10. What are the three important classes of hydrocarbons present in crude oil?

11. What is meant by the term *heavy oil?* Why does it require a large amount of energy to extract petroleum from Alberta oil sands?

12. What is meant by *engine knocking*? How is the *octane number* rating scale for fuels defined?

13. What is meant by the *BTX fraction* of gasoline?

14. List several ways in which the octane number of fuels can be increased by the addition of other compounds to straight-chain alkane mixtures.

15. What is meant by the term *carbon sequestration*?

16. Name two techniques whereby carbon dioxide could be stripped from power-plant emission gases, and two techniques that are more appropriate to more concentrated sources of the gas. For each technique, specify whether a chemical or a physical process is involved.

17. Define *oxycombustion*, and state its advantages and limitations.

18. Sketch qualitatively the phase diagram for CO_2, showing the lack of a liquid state under ambient pressure.

19. What is mean by a *supercritical fluid*? What are some of its characteristics?

20. Explain the difference between *ocean acidic* and *ocean neutral* techniques of storing CO_2 in oceans. How does depth of disposal play an important role in sequestering carbon dioxide in seawater?

21. Define *enhanced oil recovery* and explain its relationship to the underground storage of carbon dioxide.

22. What are *saline aquifers*? Explain how they might be used to store carbon dioxide.

23. Define the two meanings of the term *carbon intensity*. What equation relates them to the Kaya identity?

24. Explain why the concentration of CO_2 in air is expected to rise linearly with time if its rate of emission remains a constant.

25. Explain the reasons why sea levels are expected to rise as global air temperatures increase.

26. List some of the consequences, including those affecting human health, that may occur as a result of climate change in the future. Why might soil in some areas be too dry for agriculture even though more rain falls on it?

27. What was the *Kyoto Protocol*? What gases are limited in their emissions under it?

28. Describe the *cap-and-trade* scheme whereby a nation's allocation of carbon dioxide emissions could be traded on a market. Describe two schemes by which initial allocations could be made.

29. What is a *carbon tax*, and what are the arguments in favor of it? Why do you think many people oppose it?

Green Chemistry Questions

1. The formation of polylactic acid (PLA) from biomass developed by Cargill Dow won a Presidential Green Chemistry Challenge Award.

(a) Which of the three focus areas (see page xxviii) for these awards does this award best fit into?

(b) List three of the twelve principles of green chemistry (see pages xxiii–xxiv) that are addressed by the green chemistry developed by Cargill Dow.

2. What are the environmental advantages of using PLA in place of petroleum-based polymers?

3. Why does the use of biodegradable polymers (to replace petroleum-based polymers) not offer complete solutions to energy and environmental problems?