Making Connections

7. A few things that would not work/exist if hydrocarbons disappeared:

Automobiles, airplanes, ships, trains — so everything perishable we import from other places (farther than a day away on a mule) would disappear.

Electricity would be in short supply — so no television, vacuum cleaners, or stereos. Since the home furnace would not work either, the lack of television might not be the biggest concern — especially in winter.

There would be no plastics, few pharmaceuticals, no cosmetics, no deodorants, and a much narrower selection of cleaners.

11.3 COMBUSTION OF HYDROCARBONS

PRACTICE

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Understanding Concepts

1. The major use of hydrocarbons (by amount) is for fuels. Some minor uses (by amount) are for making plastics, pharmaceuticals, chemicals and cleaners.
2. $2\ C_{14}H_{30(l)} + 43\ O_{2(g)} \rightarrow 28\ CO_{2(g)} + 30\ H_2O_{(g)}$
3. The substance has molecules with 4 C atoms and 10 H atoms, so it must be butane, $C_4H_{10(g)}$.
4. The benefit of fossil fuel combustion is nothing less than our level of civilization. The disadvantage is that the resource is finite, and someday we are likely to run out.

Making Connections

5. (a) Jet fuel fires outside are fought primarily with chemical foams, which cover and smother the liquid fuel, and trap most of the vapour. Jet fuel vapour is heavier than air, which actually makes it much more dangerous, because the flammable vapour will stay near the ground and not disperse into the atmosphere.
   (b) Inside passenger aircraft, dry-chemical fire extinguishers must be used, because the passengers must remain able to breathe (releasing oxygen masks in such an event is definitely not a good idea).
   (c) Students will find that all airports have some materials for firefighting. The question is whether they are adequate, especially at small, uncontrolled airports.

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Reflecting

6. Without hydrocarbons, there would be a dramatic drop in new clothing available, and most common consumer items (anything made of/with or packaged in plastic). That might be noticed fairly soon. Possibly the increased amount of cycling and walking would be noticed early (no fossil fuels). More likely, though, is that the most immediate problem would be a lack of food, which is harvested on and transported from farms to markets and processing plants by vehicles that use fossil fuels (tractors, trucks, ships, trains, planes). More long-term effects would include injury or death from exposure.

PRACTICE

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Understanding Concepts

7. The greenhouse effect is essential. Without it the planet would be permanently frozen, with an average surface temperature of about –19°C instead of the actual average value of about 15°C. The concern is that a small increase in the effect can influence climate conditions, creating problems for people and other living things.
8. Carbon dioxide is absorbed by plants, and released by decomposition, as a cycle in the biosphere.
9. If global warming effects become significant, Canada's biomes would change noticeably. The prairies might become too dry for agriculture, for example.

10. Carbon trading allows a nation to purchase "credits" from another nation that is more successful at curbing its greenhouse gas emissions.

11. (a) $CH_{4(g)} + 2\,O_{2(g)} \rightarrow CO_{2(g)} + 2\,H_2O_{(g)}$

1.00 g $\qquad$ m

16.05 g/mol $\qquad$ 44.01 g/mol

(b) $n_{CH_4} = 1.00\ \cancel{g} \times \dfrac{1\ \text{mol}}{16.05\ \cancel{g}}$

$n_{CH_4} = 0.0623\ \text{mol}$

$n_{CO_2} = 0.0623\ \text{mol} \times \dfrac{1}{1}$

$n_{CO_2} = 0.0623\ \text{mol}$

$m_{CO_2} = 0.0623\ \cancel{\text{mol}} \times \dfrac{44.01\ \text{g}}{1\ \cancel{\text{mol}}}$

$m_{CO_2} = 2.74\ \text{g}$

or

$m_{CO_2} = 1.00\ \cancel{g}\ \cancel{CH_4} \times \dfrac{1\ \cancel{\text{mol}}\ \cancel{CH_4}}{16.05\ \cancel{g}\ \cancel{CH_4}} \times \dfrac{1\ \cancel{\text{mol}}\ \cancel{CO_2}}{1\ \cancel{\text{mol}}\ \cancel{CH_4}} \times \dfrac{44.01\ \text{g}\ CO_2}{1\ \cancel{\text{mol}}\ \cancel{CO_2}}$

$m_{CO_2} = 2.74\ \text{g}$

The mass of carbon dioxide formed is 2.74 g.

(c) $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$

2.00 g $\qquad$ m

12.01 g/mol $\qquad$ 44.01 g/mol

(d) $n_C = 2.00\ \cancel{g} \times \dfrac{1\ \text{mol}}{12.01\ \cancel{g}}$

$n_C = 0.167\ \text{mol}$

$n_{CO_2} = 0.167\ \text{mol} \times \dfrac{1}{1}$

$n_{CO_2} = 0.167\ \text{mol}$

$m_{CO_2} = 0.167\ \cancel{\text{mol}} \times \dfrac{44.01\ \text{g}}{1\ \cancel{\text{mol}}}$

$m_{CO_2} = 7.33\ \text{g}$

or

$m_{CO_2} = 2.00\ \cancel{g}\ \cancel{C} \times \dfrac{1\ \cancel{\text{mol}}\ \cancel{C}}{12.01\ \cancel{g}\ \cancel{C}} \times \dfrac{1\ \cancel{\text{mol}}\ \cancel{CO_2}}{1\ \cancel{\text{mol}}\ \cancel{C}} \times \dfrac{44.01\ \text{g}\ CO_2}{1\ \cancel{\text{mol}}\ \cancel{CO_2}}$

$m_{CO_2} = 7.33\ \text{g}$

The mass of carbon dioxide formed is 7.33 g.

(e) Natural gas produces much less carbon dioxide per unit of energy produced, so is a better fuel from that point of view.

(f) Coal is a plentiful and inexpensive fuel source in many places.

Making Connections

12. Emissions trading allows a nation to purchase "credits" from another nation that is more successful at curbing its greenhouse gas emissions. The first nation might decide that purchasing credits later is a better investment than purchasing technology, changing lifestyles, or reducing industrial output now. Depending on the market for credits, this gamble could prove beneficial or detrimental. The second nation, which has purchased the technology or changed the ways its citizens live, benefits through the cash-back scheme of selling the credits it has accumulated, which may or may not cover a significant amount of that nation's original costs, again depending on the market.

    It could be expected that if many nations are diligent in reducing emissions, the value of credits will be low; if many nations let others do the work, the value of credits will be high.

It would be possible for the international community to apply pressure to smaller nations who did not curb emissions and balked at the high cost of credits, and so ensure their compliance. However, it is not clear how powerful nations or nation groups could be punished or coerced if they decided that defecting from emissions trading (by emitting over quota and refusing to purchase credits) was convenient.

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Explore an Issue

Take a Stand: How Can Technology Help Canadians Reduce CO_2 Gas Emissions?

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(a) In general, the technologies the students investigate will all, if properly used, result in lower use of fossil fuels.

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(b) The key element in the promotion is that it be convincing, i.e., the right benefits should be presented to the target audience. It does not have to be scrupulous in offering all of the drawbacks of the technology.

(c) This report should be comprehensive in its evaluation of the benefits and drawbacks of a technology. For example, improving mass transportation by making it more broadly available and making trips more frequent would result in more use of the system, and in significantly less use of fossil fuels in the community that implemented it. It could also result in less traffic congestion in the community, and improved air quality. However, in a typical North American community (widely spread; large separation between centres), it is unlikely that the increased use would make the system less dependent on subsidy. The requirement for more vehicles, drivers and other employees, and support infrastructure would probably require more taxpayer dollars. This might be of little consequence to a frequent user of the system or someone who lives in the community's centre (the increased convenience and other benefits might well be perceived as a bargain compared to the increased cost), but would be seen as a major drawback by someone who has little use for transportation systems (say, those who work at home), and those whom the system does not reach (people who live in outlying areas; people in communities whose taxes support the system, but who do not directly benefit from it). Whether the costs could be recouped from decreased maintenance of infrastructure to support automobile transport or decreased expansion of that infrastructure is open to debate. It is possible for society to encourage use of mass transportation by incentive and by restricting use of automobiles. However, any restriction on freedom of movement to force use of mass transport is likely to be seen as a major drawback by some citizens. The system would have to improve dramatically, especially in intercommunity transportation, to persuade a large number of people to abandon use of automobiles completely (a significant financial benefit). Finally, manufacture of vehicles and producing the raw materials for that manufacture is a significant part of the Canadian economy. Reduced use of automobiles would result in much disruption in the lives and employment of hundreds of thousands, perhaps millions, of Canadians. Many of these aspects of the improvement of mass transportation might be skipped over in a promotion campaign, depending on who was targeted (for example, residents of the town or city concerned vs. residents of a province).

PRACTICE

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Understanding Concepts

13. Incomplete combustion should leave traces of solid carbon (soot or smoke).
14. Complete combustion of hydrocarbons produces only carbon dioxide and water vapour. Incomplete combustion of hydrocarbons produces carbon dioxide, water vapour, carbon monoxide, and carbon.
15. There is no way to know in advance what fraction of a reactant undergoes incomplete combustion, so no balanced equation can be written.
16. (a) $C_7H_{16(l)} + 11\ O_{2(g)} \rightarrow 7\ CO_{2(g)} + 8\ H_2O_{(g)}$

    (b) $4\ C_7H_{16(l)} + 37\ O_{2(g)} \rightarrow 14\ CO_{2(g)} + 14\ CO_{(g)} + 32\ H_2O_{(g)}$

17. 15 ppt = 1.5 parts per hundred = 1.5%

MAKING CONNECTIONS

18. Carbon monoxide detectors usually work by one of three technological systems — all of which represent quite new (and not completely reliable) technology. These are: gel-cel technology, semiconductor technology, and electrochemical technology. There are wide variations in reliability, sensitivity, useful life, and battery replacement and/or element replacement periods.

    Student reports will probably balance the increased safety against the extra cost and inconvenience of mandatory detector installation.

19. Opinions will vary. Canadians in general tend not to favour taxing gasoline and transport fuels more than heating fuels.

Reflecting

20. The word "burn" often is used in contexts that have nothing to do with "combustion" — it is often substituted for words like "pain" and "heat."

SECTION 11.3 QUESTIONS

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Understanding Concepts

1. Scientific: Incomplete combustion produces carbon monoxide.
   Technological: Incomplete combustion produces less energy.
   Economic: Incomplete combustion increases heating costs.
   Environmental: Incomplete combustion produces toxic gases.
2. *Note:* There are many possible examples that could be given for the incomplete combustion reaction equations (the second equations).

   (a) $2\ C_4H_{10(g)} + 13\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 10\ H_2O_{(g)}$

   $C_4H_{10(g)} + 6\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + CO_{(g)} + 5\ H_2O_{(g)}$

   (b) $C_9H_{20(l)} + 14\ O_{2(g)} \rightarrow 9\ CO_{2(g)} + 10\ H_2O_{(g)}$

   $C_9H_{20(l)} + 13\ O_{2(g)} \rightarrow 7\ CO_{2(g)} + 2\ CO_{(g)} + 10\ H_2O_{(g)}$

   (c) $2\ C_{24}H_{50(s)} + 73\ O_{2(g)} \rightarrow 48\ CO_{2(g)} + 50\ H_2O_{(g)}$

   $C_{24}H_{50(s)} + 31\ O_{2(g)} \rightarrow 13\ CO_{2(g)} + 11\ CO_{(g)} + 25\ H_2O_{(g)}$

Applying Inquiry Skills

3. **Analysis**

   (a) One product is water, as shown by the cobalt chloride diagnostic test.
   The other product is carbon dioxide, as shown by the limewater diagnostic test.

   Evaluation

   (b) The evidence is judged adequate for what it does show, but inadequate in that it does not show whether other products may exist. Any other invisible gases, like carbon monoxide or even unreacted hydrocarbons, would not be detected.

   (c) The design could be improved by adding tests for carbon monoxide gas, and for unreacted hydrocarbons, to establish whether the combustion is complete.

11.4 ALKANES AND CYCLOALKANES

PRACTICE

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Understanding Concepts

1. (a) $C_{11}H_{24}$
   (b) $C_{15}H_{32}$