1. 

Problem 7-6

First compute the mass in grams of the CO₂, and then using the density, convert it to volume in cm³:

\[ 10^{12} \text{ tonnes} \times 1000 \text{ kg/tonne} \times 1000 \text{ g/kg} \times 1 \text{ cm}^3 / \text{g} = 1 \times 10^{18} \text{ cm}^3 \]

Now convert the volume in cm³ to km³:

\[ 1 \times 10^{18} \text{ cm}^3 \times (0.01 \text{ m/cm})^3 \times (0.001 \text{ km/m})^3 = 1000 \text{ km}^3 \]

The dimension of the cube is the cube root of its volume, so the length of each side is \((1000 \text{ km})^{1/3} = 10 \text{ km}\).

2. See pages 321-236 (5th edition)

3. 3 metric tonnes = 5000 kg = 5 *10⁶ g.
   
   If this was converted into dry ice then the volume would be \(5*10^6 \text{ g}/1.56 \text{ g cm}^3 = 3.2*10^6 \text{ cm}^3\)
   
   \[ R = \left(\frac{3V}{4 \pi}\right)^{1/3} = \left(\frac{3 \times 3.2 \times 10^6}{4\times3.142}\right)^{1/3} = (7.65 \times 10^5 \text{ cm}^3)^{1/3} = 91.5 \text{ cm} \]
   
   \[ D = 183 \text{ cm} = 1.83 \text{ m} \]

4. Assume that the increase in commercial energy consumption follows simple exponential growth \(Q=Q_0e^{kt}\) and that developed countries use 65% of the world’s commercial energy. In how many years will developing countries (4% annual growth rate) use 50% of the world’s commercial energy if developed countries have an annual growth rate of 1%?

\[ Q=Q_0e^{kt} \]

For developing countries \(Q=0.35e^{0.04t}\)

For developed countries \(Q=0.65e^{0.01t}\)

At 50% consumption each Q (developing countries) = Q (Developed countries)

Note: in line 4 of the following solution the left side momentarily switches from 0.538 to 0.0438. Please ignore this error.

\[ \frac{35}{65} = \frac{e^{0.04t}}{e^{0.01t}} \]

\[ 0.538 = e^{0.01t-0.04t} \]

\[ \ln(0.0438) = t(-0.03) \]

\[ t = \frac{\ln(0.538)}{-0.03} = 20.6 \text{ y} \]
5. a) How is the octane rating you see at the pump derived?
   b) Draw isooctane.
   c) What is BTX and what purpose does it serve?

   See pages 280-282 4th ed
   See pages 247-250 5th ed

6. If world consumption to increase at an annual rate of 2.8%, how long it would take to double and sixteen times?

   We can apply the rule of double life
   \[ t_2 = 0.693 \times (100/2.8) = 24.7 \text{ years} \]
   To double \((2)^1\) it will take 24.7 years
   To increase 16 or \((2)^4\) it will take \(24.7 \times 4 = 98.8 \text{ years}\)

7. The major component of natural gas used by the utility companies is methane, \(\text{CH}_4\), the gas used in barbecues is propane \(\text{C}_3\text{H}_8\). Assuming that each of these gases burns completely, compare the amount of energy released by each (a) in terms of \(\text{kJ}/\text{mole of CO}_2\) produced and (b) in terms of \(\text{kJ}/\text{g fuel}\). (Write the chemical reaction; Determine the chemical bonds broken and formed in the combustion reactions. See next page for table)

For methane

\[
\text{CH}_4 + 2\text{O}_2 = \text{CO}_2 + 2\text{H}_2\text{O}
\]

\[
\begin{align*}
4(\text{C-H}) &= 4 \times 410 \\
2(\text{O-O}) &= 2 \times 494 \\
&\text{-------------------------} \\
3438 \text{ kJ} &= 2628 \text{ kJ}
\end{align*}
\]

\[\text{Reaction enthalpy} = (3438 - 2628) \text{ kJ} = 810 \text{ kJ}\]

Or \(810 \text{ kJ}/1 \text{ mole CO}_2\)

Or \(810 \text{ kJ}(1 \text{ mole}/16 \text{ g}) = 50.6 \text{ kJ/g of methane}\)

For propane

\[
\text{C}_3\text{H}_8 + 5\text{O}_2 = 3\text{CO}_2 + 4\text{H}_2\text{O}
\]

\[
\begin{align*}
8(\text{C-H}) &= 8 \times 410 = 3280 \\
5(\text{O-O}) &= 5 \times 494 = 2470 \\
2(\text{C-C}) &= 2 \times 347 = 694 \\
&\text{-------------------------} \\
6444 \text{ kJ} &= 8474 \text{ kJ}
\end{align*}
\]

\[\text{Reaction Enthalpy} = 2030 \text{ kJ}\]

Or \(2030 \text{ kJ}/3 \text{ mole CO}_2 = 676.67 \text{ kJ/mole of CO}_2\)

Or \(2030 \text{ kJ}(1 \text{ mole}/44 \text{ g}) = 46.13 \text{ kJ/g of propane}\)

8. a) What is crude oil composed of?
   b) Describe the distillation process and the kind of materials that can be made from different
sections of the refining column.

See pages 274-279 4th ed
See pages 238-239 5th ed

9. What are the current proposed methods for CO\textsubscript{2} sequestration and which do you think is most likely to be broadly implemented (include why)?

See pages 282-290 4th ed
See pages 252-254 5th ed

10. The enthalpies of combustion for liquid octane and methanol are -5471 and -726 kJ mol\textsuperscript{-1}, respectively.
   a. Write out the balanced chemical equations for the complete combustion of each compound.
   b. Which fuel generates more heat per gram of fuel
   c. Which fuel generates more heat per mole of carbon dioxide produced?
   d. Some service stations offer gasohol (10% methane in gasoline) as an alternative fuel for automobiles. What effect might you predict for engine emissions in a car running on gasohol instead of gasoline? (Assume gasoline is essentially octane.)

\begin{align*}
\text{a. } & C_8H_{18} + \frac{25}{2}O_2 \rightarrow 8CO_2 + 9H_2O \\
& \text{CH}_3\text{OH} + \frac{3}{2}O_2 \rightarrow CO_2 + 2H_2O
\end{align*}

\begin{align*}
\text{(b) For octane: } & 5471 \text{ kJ/mole} \times \frac{1 \text{ mole}}{106 \text{ g}} = 51.61 \text{ kJ/g of octane} \\
& \text{For methanol: } 726 \text{ kJ/mole} \times \frac{1 \text{ mole}}{32 \text{ g}} = 22.68 \text{ kJ/g of octane}
\end{align*}

Octane generates more heat per gram of fuel
(c) For Octane:
Heat released = \frac{5471}{8} \text{ moles of } CO_2 = 683.87 \text{ kJ/mole of } CO_2
For Methanol
Heat released = \frac{726}{1} \text{ mole of } CO_2 = 726 \text{ kJ/mole of } CO_2

Methanol generates more heat per mole of CO\textsubscript{2}

(d) From the calculations in (c), having methanol in Gasohol will produce less CO\textsubscript{2} compared to pure gasoline.