Fuels and Lubricants

Practice Problems

1. Provide names for the following alkanes.

   \[
   \begin{array}{c}
   \text{a.} \\
   \text{b. } \text{C}_5\text{H}_{12} \\
   \text{c. } \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3
   \end{array}
   \]

2. Provide molecular formulas and Lewis structures for each of the following.

   \[
   \begin{array}{c}
   \text{a. methane} \\
   \text{b. ethane} \\
   \text{c. octane}
   \end{array}
   \]

3. What is the percent composition of carbon and hydrogen (by mass) in octane (C\textsubscript{8}H\textsubscript{18})?

4. The combustion of 3.795 mg of liquid G, which contains only C, H, and O, with excess oxygen, gave 9.708 mg of CO\textsubscript{2} and 3.969 mg of H\textsubscript{2}O. In a molar mass determination, 0.205 g of G vaporized at 1.00 atm and 200.0°C and occupied a volume of 89.8 mL. Derive the empirical formula, molar mass, and molecular formula of G.
5. What does a gasoline’s octane rating refer to?

6. Rank the compounds below in order of increasing boiling point based on what you know about intermolecular forces. Briefly explain your answer.

\[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 \quad \text{C}_2\text{H}_6 \quad \text{C}_6\text{H}_{14} \]

7. Of the compounds given in the question above, which would you expect to have the highest vapor pressure at 25 °C? Briefly explain your answer.

8. Pentane and 2-methylbutane both have the formula, \( \text{C}_5\text{H}_{12} \), and the structures and boiling points shown below. Based on the intermolecular forces present, explain the relative boiling points of pentane and 2-methylbutane.

\[ \begin{array}{c}
\text{pentane} \\
\text{36 °C}
\end{array} \quad \begin{array}{c}
\text{2-methylbutane} \\
\text{30 °C}
\end{array} \]

9. Write the balanced equation for the combustion of liquid 2,2,4-trimethylpentane to give steam and carbon dioxide. The Lewis structure is given below.

\[ \text{H}_3\text{C} \quad \text{CH}_3 \quad \text{CH}_3 \quad \text{CH}_3 \quad \text{C} \quad \text{H}_2 \text{CH} \quad \text{CH} \quad \text{CH}_3 \]

10. Based on the balanced equation above and given the following standard heats of formation (\( \text{CO}_2 \text{(g)} \Delta H^\circ_f = -393.5 \text{ kJ/mol}; \text{H}_2\text{O} \text{(g)} \Delta H^\circ_f = -241.8 \text{ kJ/mol}; 2,2,4\text{-trimethylpentane (l)} \Delta H^\circ_f = -259.3 \text{ kJ/mol} \)), calculate the heat of combustion for 2,2,4-trimethylpentane in \text{kJ/mol}, \text{kJ/g}, and \text{kJ/mL}. (The molecular weight of 2,2,4-trimethylpentane is 114.23 \text{ g/mol} and the density is 0.692 \text{ g/mL})
11. Using the average bond dissociation energies given in your textbook, calculate the standard enthalpy of combustion of 2,2,4-trimethylpentane.

12. Explain any difference in the values obtained in the previous two questions. Did you get the same value? If not, why not?

13. How many grams of propane are required to bring 100.0 ml of 25°C water to a boil given that the heat of combustion for propane is -2220 kJ/mol? Assume that none of the heat is lost to the surroundings.

14. What volume of air is required to react with the propane used in the previous problem assuming that air is 21.0% oxygen by volume, the temperature is 25°C, and the pressure is one atm?

15. The reaction below between aluminum and ammonium perchlorate is used in the solid booster rockets of the space shuttle. What elements are oxidized and reduced in the reaction?
   
   \[ 3 \text{NH}_4\text{ClO}_4(s) + 3 \text{Al}(s) \rightarrow \text{Al}_2\text{O}_3(s) + \text{AlCl}_3(s) + 6 \text{H}_2\text{O}(g) + 3 \text{NO}(g) \]
16. According to the NASA website (http://www.ksc.nasa.gov), the propellant for each solid rocket motor weighs 1,100,000 pounds and is composed of 69.6% ammonium perchlorate and 16% aluminum set in a polymer resin. What is the limiting reagent in this reaction? What volume of water and nitrogen monoxide gas, at 1 atm, are produced in this reaction after they have cooled to 25°C? See the previous question for the reaction.

17. The first stage of the *Saturn V* rocket used in the Apollo missions reacted 5.50 × 10⁵ kg of kerosene with sufficient liquid oxygen. Assuming that kerosene is C₁₂H₂₆, provide the balanced equation for the combustion of kerosene to give gaseous carbon dioxide and water. If the standard enthalpy change for this reaction is -7513 kJ per mol of kerosene, what is the specific enthalpy in kJ/g? If it takes 2.5 minutes to burn the first stage of the *Saturn V* rocket what is the horsepower of this rocket given that 1 J/s = 1 watt; 745.7 watts = 1 horsepower?

18. Describe the relationship between viscosity and intermolecular forces.