Prelude: There were 268.8 million registered motor vehicles in the United States in 2017. 98.4% of these vehicles use an internal combustion engine, where fuel (gasoline) is mixed with oxygen in a piston, the mixture is then compressed, and finally the mixture is ignited with a spark.

1. Gasoline can be represented as octane (C_8H_{18}).
   a) Write the balanced chemical equation for the reaction that takes place in the piston.

   b) Is the combustion of octane an endothermic or exothermic reaction? Will the sign of ΔH be positive or negative?

   c) The ΔH_f° of octane (*l*) is –249.9 kJ/mol, the ΔH_f° of CO_2 (*g*) is –393.5 kJ/mol, and the ΔH_f° of H_2O (*g*) is –241.8 kJ/mol.

      Determine ΔH_{rxn}° for the balanced chemical reaction from 1a.

2. Just before combustion, the piston has a volume of 100.0 mL and contains 1.22 g of air (which is 20.0% oxygen) and 0.07625 g octane.
   a) How much energy is released from the reaction taking place in the piston?

   b) In order to be active, octane must first be vaporized. How much heat is required to vaporize 0.07625 g of octane from liquid octane at 20.0 °C if ΔH_{vap}° is 41.1 kJ/mol, c_P is 254 J/(mol·°C), and the boiling point of octane is 126 °C?

3. Most cars have an energy efficiency of 30.0%.
   a) How much work is done by the engine if 1.25 L of octane (which has a density of 0.703 g/mL) are combusted?

   b) How much energy is wasted as heat?

   c) How much H_2O (*g*) and CO_2 (*g*) are produced as byproducts?

4. The wasted heat from the engine is typically removed by circulating water (c_P = 75.3 J/(mol·°C).
   a) What volume of water is needed to remove 2.95×10^7 J of heat if the temperature of water *only* increases from 20.0 °C to 75.0 °C?

   b) Does a typical car contain this volume of water? What would happen if the temperature of the water increased too much (*e.g.*, far beyond 75.0 °C)?

   c) How do you think we prevent the water from getting too hot in cars?