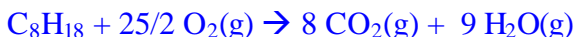


Consider a cylinder in a 4 liter V-8 engine (i.e. 8 cylinders with a total expanded volume of 4 liters). Let's look at the work extracted during expansion in two phases:

- I. Isothermal expansion
- II. Adiabatic cooling and expansion

1. Calculate the maximum isothermal work of expansion possible when 0.05 moles of n-octane is combusted perfectly in a cylinder at a temperature of 500 K. Assume that H<sub>2</sub>O in the combusted products is a gas. Assume that the initial headspace volume during fuel injection is 0.002 L. Assume further that the isothermal expansion is carried out only to 0.142 L.

Solution: According to the chemical reaction for combustion, for each of mole of octane combusted 17 moles of gas are produced.



Thus, there are 0.85 moles of gas.

$$w = -nRT \ln(V_2/V_1) = -(0.85 \text{ mol})(8.31 \text{ J/mol-K})(500 \text{ K}) \ln(0.142/0.002) = -15 \text{ kJ}$$

2. The ambient temperature is 300 K. Assuming that the gas in the cylinder cools adiabatically, how much further would the gas expand. You may assume that the heat capacity for a diatomic gas applies here.

Solution: For an adiabatic expansion of a diatomic ideal gas the following applies

$$V_2 = V_1 \left( \frac{T_1}{T_2} \right)^{5/2} \text{ for an ideal diatomic gas}$$

$$V_2 = (0.142 \text{ L}) \left( \frac{500}{300} \right)^{5/2} = (0.142)(3.58) \text{ L} = 0.5 \text{ L}$$

3. Calculate the work done during the adiabatic expansion.

Solution: for the adiabatic expansion  $q = 0$  so  $w = \Delta U = C_V \Delta T$ .

$$\begin{aligned} \text{Therefore, } w &= 3 nR(T_2 - T_1) = 3(0.85 \text{ mol})(8.31 \text{ J/mol-K})(300 \text{ K} - 500 \text{ K}) \\ &= -4238 \text{ J} \end{aligned}$$

4. Imagine that the design for the engine was very poor and that the isothermal step in question 1 was a one step expansion against an external pressure of 1 atm. Calculate the work of expansion in this case (again from 0.002 to 0.142 L).

$$\text{Solution: } w = -P_{\text{ext}} \Delta V = -(1 \text{ atm})(0.142 - 0.002) \text{ L} = 0.14 \text{ L-atm} = -14.18 \text{ J}$$

5. Assume that an adiabatic expansion is carried out following the single-step irreversible expansion. Calculate the final volume.

Solution: It is the same as in question 2. Internal energy is a state function.

6. Calculate the work of adiabatic expansion following the single-step irreversible expansion step of question 4.

Solution: It is the same as in question 3. Internal energy is a state function.