Thermodynamics of Energy Conversion

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EXERCISES 4

1) Calculate the temperature increase for nitrogen compressed from 0.5 to 50 bar, when the initial temperature is -50°C.

$p/p_0 = (T/T_0)$^(c_V/R+1)
100 = (T/T_0)^(3.5)
T/T_0 = 3.7 i.e. T = 3.7*223K = 831 K = 558°C

2) What assumptions make it impossible to build a Carnot engine?

The calculation is time independent, i.e. infinitely slow process. Isotherms and adiabats can not be realized.

3) Calculate the Carnot efficiency and the "real" efficiency for an engine working between 600°C and 200°C ?

Efficience Carnot engine = $\Delta T/T_h$ = 400K/873.15K = 45.8%
Efficience of "real" Carnot engine =1 -sqrt(T_c/T_h = 1 - sqrt(473.15K/873.15K) = 26.3%

4) Calculate the efficiency for a steam engine with a max. pressure of 8 bar and 50 bar.

ΔH_{vap} (100 °C) = 40.63 kJ/mol, ΔS_{vap} (100 °C) = 0.109 kJ/mol

p = 8 bar corresponds to T_1 = 442 K, T_2 = 373 K;
idea Carnot efficiency = 15.6% ; real Carnot efficiency = 8.1%;
p = 50 bar corresponds to T_1 = 530 K, T_2 = 373 K;
idea Carnot efficiency = 29.6%; real Carnot efficiency = 16.1%

Rankine cycle:
p = 8 bar corresponds to T = 442 K, T_0 = 373 K; $\Delta S(T)$ = 6.663 - 2.046 = 4.617 J/(mol·K), $\Delta S(T_0)$ = 7.359 - 1.303 = 6.056 J/(mol·K)
$\Delta S_0/\Delta S \approx$ 1.3, efficiency = 68K·2.3/(442K·2.3+373K·0.3) = 13.8%
p = 50 bar corresponds to T_1 = 530 K, T_2 = 373 K; $\Delta S(T)$ = 5.973 - 2.920 = 3.050 J/(mol·K)
$\Delta S_0/\Delta S \approx$ 2, efficiency =157K·3/(530K·3+373·1) = 24%.

5) Show that Antoine's equation is equal to the pressure calculated by the Gibb's free energy.

Antoine equation: p[mmHg] = exp(20.386 - 5132/T[K])
p[Pa]/ 101325 = 1/760· exp(20.386 - 5132/T[K])
ln(p[Pa]/101325) = -ln(760) + 20.386 - 5132/T[K]
ln(p[Pa]/101325) = 13.7 - 5132/T[K]