Lecture 3 – How to solve thermo problems

Purdue ME 200, Thermodynamics I

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Outline

Problem-solving approach

Example

In your head. . .

- carefully read the problem statement
- **given:** list stuff you know
- **find:** list stuff you don't know, but want to

On paper/tablet...

- **system diagram:** draw the system, boundary, inputs, outputs
- **assumptions:**
  - write down assumptions in the problem statement
  - e.g. 'closed', 'rigid', 'adiabatic', 'polytropic', ...
  - add any further (reasonable) assumptions that you make
  - write down the implication(s) of each assumption
- **basic equations:**
  - pull up the class equation sheet
  - write down equations relating knowns and unknowns
  - need at least as many equations as unknowns
- **solution:**
  - solve equations for unknowns and simplify
  - find numbers in problem statement or class property sheets
  - plug in numbers and calculate unknowns
  - don't forget units!

Outline

Problem-solving approach

Example

Problem statement

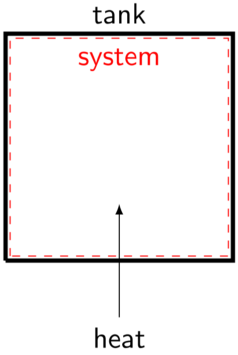
A rigid tank contains an ideal gas with a molecular weight of 30 g/mol. The gas is heated from an initial temperature of 20 $^\circ$C and atmospheric pressure to a final temperature of 50 $^\circ$C.

(a) Find the initial specific volume of the gas.
(b) Find the final pressure of the gas.

Given and find

- **given:**
  - ◇ molecular weight $M = 30$ g/mol $= 30$ kg/kmol
  - ◇ initial temperature $T_1 = 20\ ^\circ\mathrm{C} = 293$ K
  - ◇ initial pressure $p_1 = p_{\mathrm{atm}} = 101$ kPa
  - ◇ final temperature $T_2 = 50\ ^\circ\mathrm{C} = 323$ K
- **find:**
  - ◇ initial specific volume v_1
  - ◇ final pressure p_2

System diagram



Assumptions and basic equations

- **assumptions:**
  - ◇ 'rigid' means constant volume
  - ◇ let's also assume the tank is sealed, so mass is constant
  - ◇ since m and V are constant, specific volume $v = V/m$ is too
  - ◇ 'ideal gas' means we can use the ideal gas law
- **basic equations:** none
- but we'll use a model and some definitions:
  - ◇ $pV = mRT$ (ideal gas law, a model)
  - ◇ $R = \bar{R}/M$ (definition of gas constant R)
  - ◇ $v = V/m$ (definition of specific volume v)

Solution to part (a)

- $pV = mRT$ and $v = V/m$, so $pv = RT$
- $\bar{R} = 8.31$ kJ/K/kmol and $M = 30$ kg/kmol, so

$$R = \frac{\bar{R}}{M} = \frac{8.31\ \text{kJ/K/kmol}}{30\ \text{kg/kmol}} = 0.277\ \frac{\text{kJ}}{\text{kg K}}$$

- so the initial specific volume is

$$v_1 = \frac{RT_1}{p_1} = \frac{(0.277\ \text{kJ/kg/K})(293\ \text{K})}{101\ \text{kPa}} = 0.802\ \frac{\text{kJ}}{\text{kg kPa}}$$

- units check: $\text{kJ/(kg kPa)} = \text{(kN m)/(kg kN/m}^2\text{)} = \text{m}^3\text{/kg}$

Solution to part (b)

- from the assumptions, $v_2 = v_1 = 0.802\ \text{m}^3/\text{kg}$, so

$$p_2 = \frac{RT_2}{v_2} = \frac{(0.277\ \text{kJ/kg/K})(323\ \text{K})}{0.802\ \text{m}^3/\text{kg}}$$
$$= 111.7\ \text{kPa}$$