Thermodynamics tutorhour 3

November 22nd 2023

Questions about the lecture or course matter?

Phase transitions:

If a substance S is being heated (at constant pressure) from T_A (below melting point, T_{fus}) to T_X (above boiling point, T_{vap}), we can calculate the heat needed for this process with this formula:

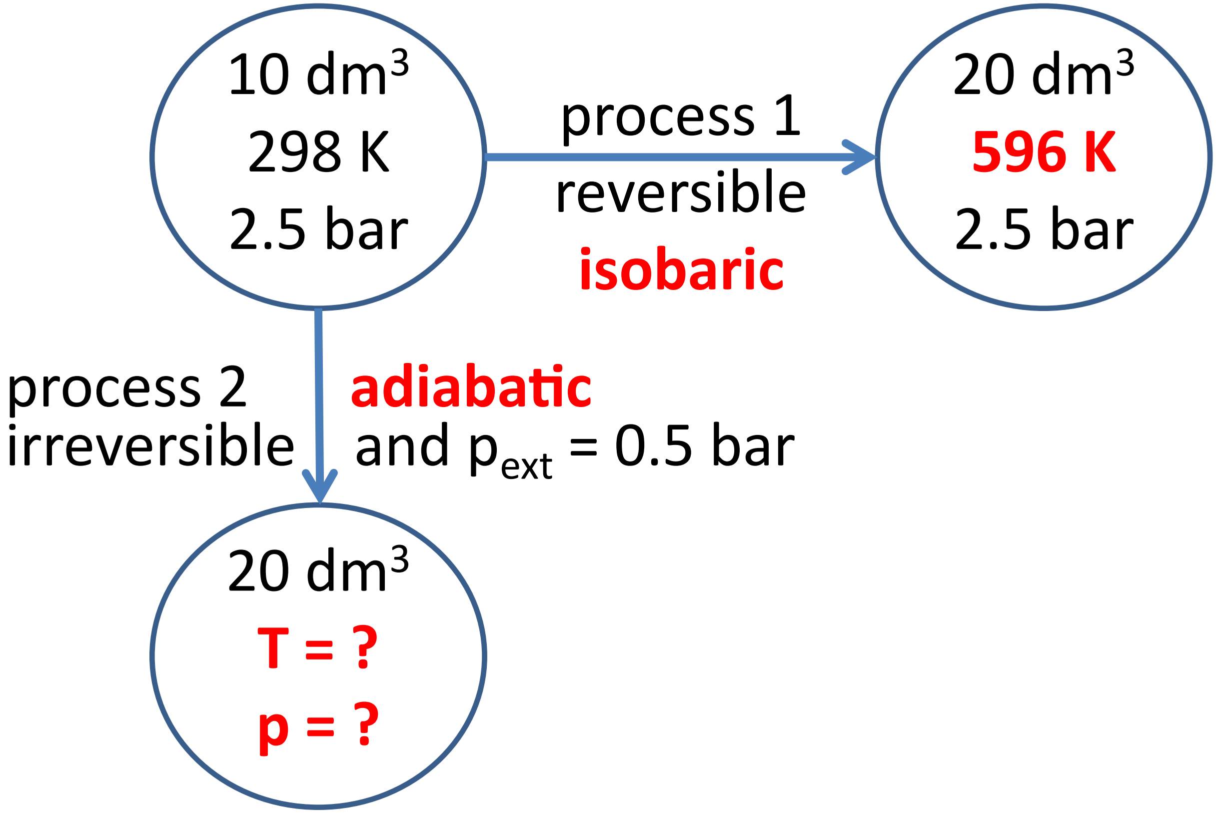
$$\Delta H = \int_{T_A}^{T_{fus}} c_{p,solid} \mathrm{d}T + \Delta_{fus}H + \int_{T_{fus}}^{T_{vap}} c_{p,liquid} \mathrm{d}T + \Delta_{vap}H + \int_{T_{vap}}^{T_X} c_{p,gas} \mathrm{d}T$$

$$\Delta S = \frac{q^{rev}}{T}$$ and at constant pressure $\Delta H = q$

The cummulative entropy change in this case is:

$$\Delta S = \int_{T_A}^{T_{fus}} \frac{c_{p,solid}}{T} \mathrm{d}T + \frac{\Delta_{fus}H}{T_{fus}} + \int_{T_{fus}}^{T_{vap}} \frac{c_{p,liquid}}{T} \mathrm{d}T + \frac{\Delta_{vap}H}{T_{vap}} + \int_{T_{vap}}^{T_X} \frac{c_{p,gas}}{T} \mathrm{d}T$$

Two processes
with a monoatomic
perfect gas:



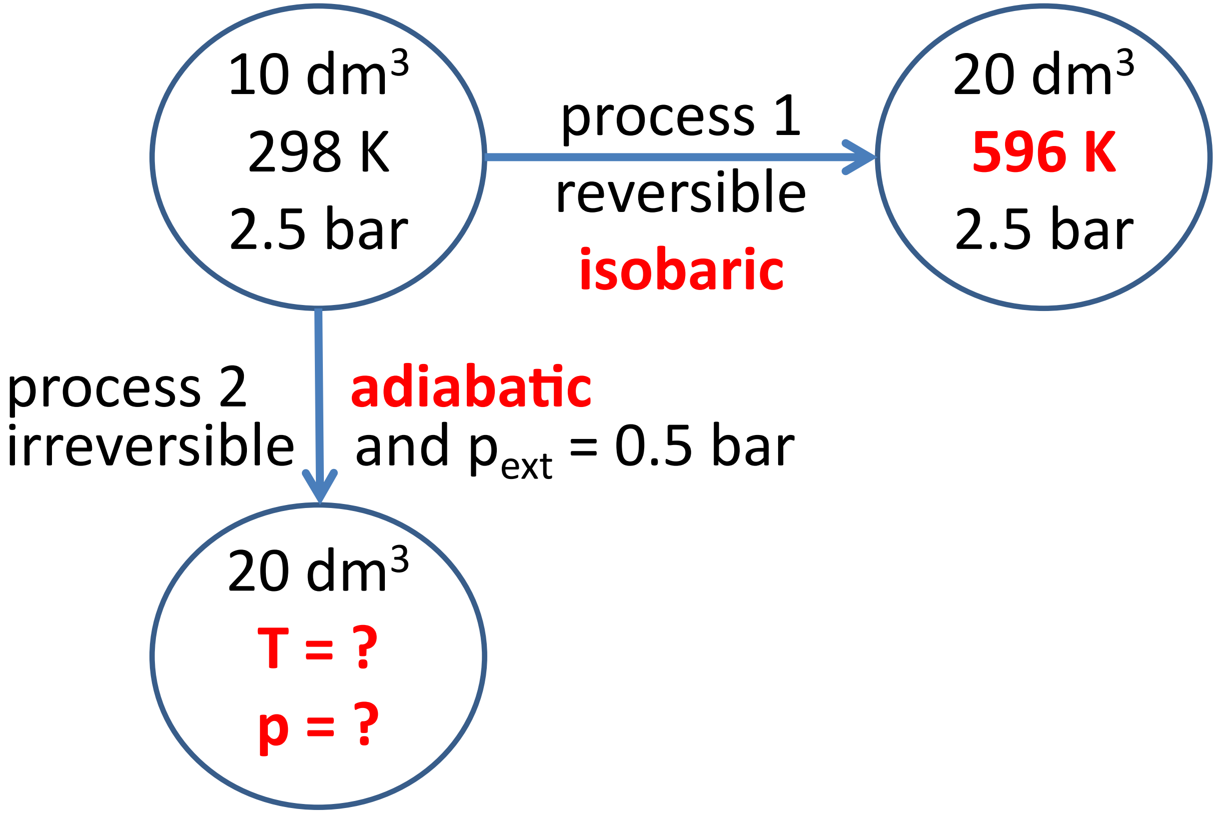
a) Derive a formula to calculate the exerted work w for each of the two processes, using the formula:

$$w = -\int p\mathrm{d}V$$

No	kind of process	*w*	*q*	*ΔU*
1	isobaric	$-p_{ext}\Delta V$		
2	adiabatic	$-p'_{ext}\Delta V$		

Two processes with a monoatomic perfect gas:

b) Derive a formula for each of the processes 1 and 2 to calculate the heat q.
c) Derive an expression for ΔU.



b) heat q: / c) ΔU

For a **monoatomic perfect gas** is defined: $U = 3/2 \cdot nRT$ so $\Delta U = 3/2 \cdot nR\Delta T$

and: $c_V = 3/2 \cdot nR$

and: $c_p = 5/2 \cdot nR$

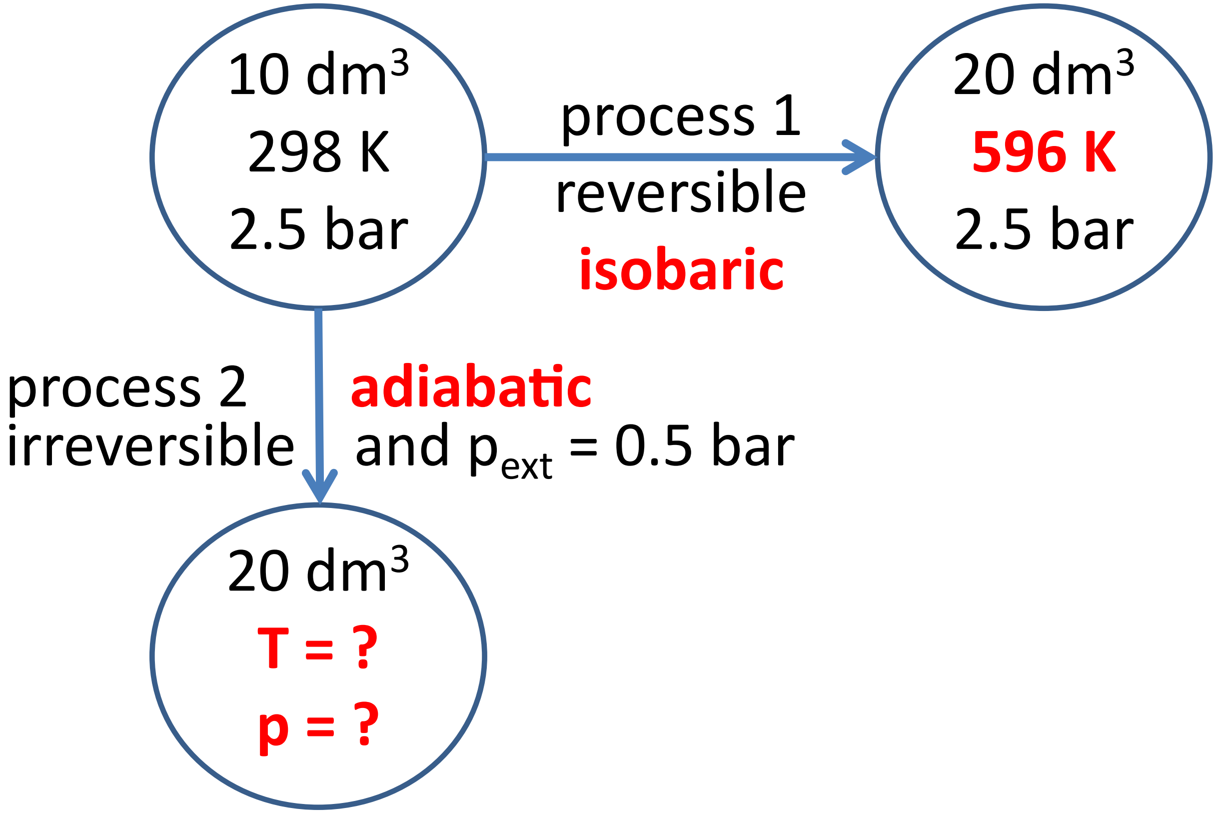
Nr	kind of process	w	+ q	= ΔU
1	isobaric	$-p_{ext}\Delta V$ / $-nR\Delta T$ / $-p_{sys}\Delta V$	$5/2 \cdot nR\Delta T$ / $c_p\Delta T$	$5/2 \cdot nR\Delta T - p\Delta V$ / $3/2 \cdot nR\Delta T$ / $c_p\Delta T - p\Delta V$
2	adiabatic	$-p'_{ext}\Delta V$	0	$-p'_{ext}\Delta V$

Perfect gas law: $pV = nRT$; $p = \frac{nRT}{V}$

Two processes
with a monoatomic
perfect gas:

d) Derive the change of entropy ΔS for process 1 using:

$$dS = \frac{dq_{rev}}{T}$$



d) Derive the change of entropy ΔS for process 1 using:

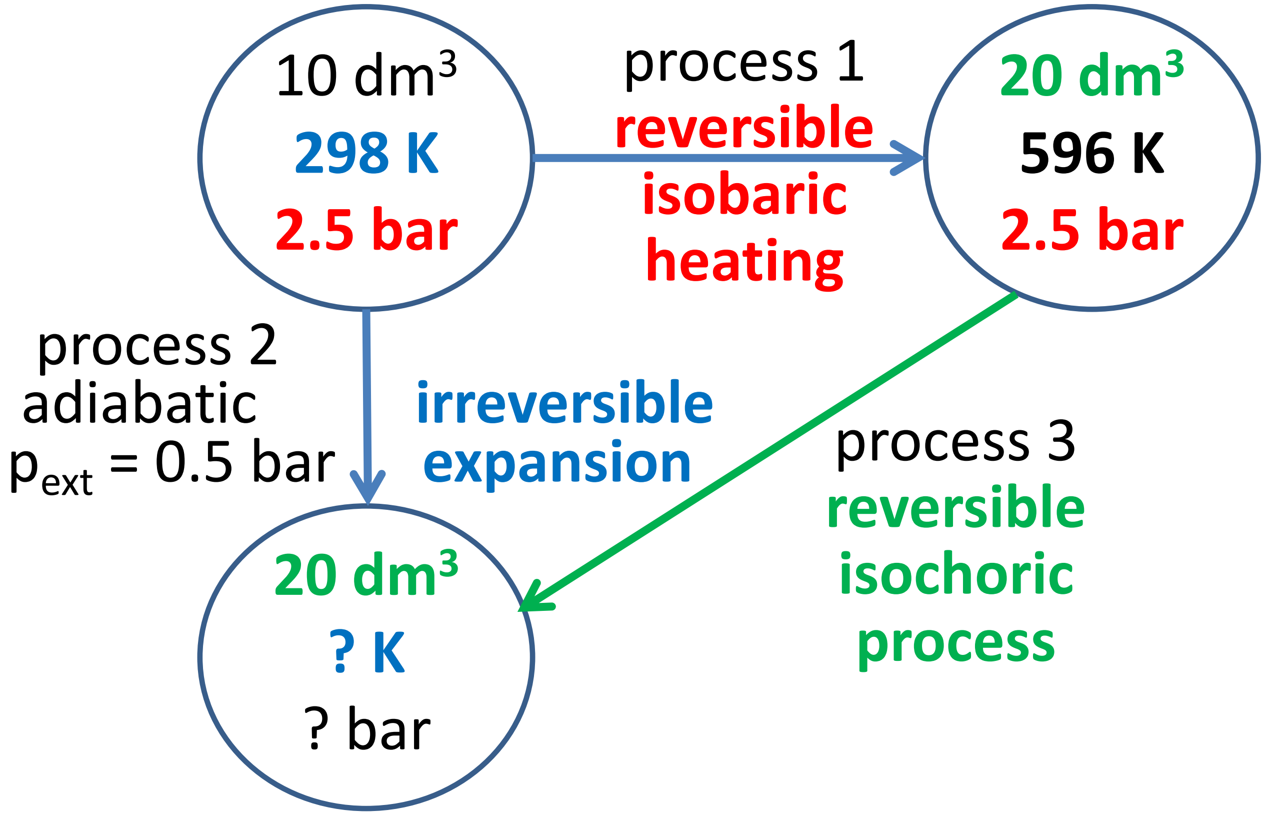
$$dS = \frac{dq_{rev}}{T}$$

Nr	kind of process	dq	$\int \frac{dq_{rev}}{T}$	$= \Delta S$
1	isobaric	$c_p dT$	$\int \frac{c_p}{T} dT$	$c_p \ln \frac{T_f}{T_i}$
2	adiabatic	0		

e) irreversible process: you *have to* construct an alternative reversible path

two processes
with a monoatomic
perfect gas:

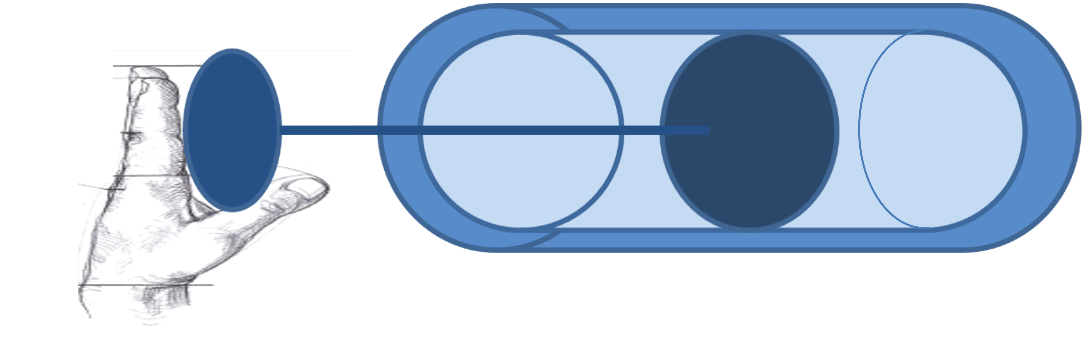
e) How could you calculate the change of entropy ΔS for process 2?



Question 2

We could perform process 2 in the following manner. We take an isolated cylinder with a frictionless piston. On the right hand of the piston there is one mole of a monoatomic perfect gas, p = 2.5 bar, and on the left of the piston there is a p_{ext} = 0.5 bar. The initial temperature of the gas is 298 K. Both compartments measure 10 dm^3.

After withdrawing the hand, the piston moves to its maximum volume: 20 dm^3.



a) Calculate the temperature when the maximum volume is reached.
   Use $\Delta U = -p_{ext}\Delta V$ and $\Delta U = \frac{3}{2}nR\Delta T$
b) Calculate the change of entropy, ΔS, of the system.

Question 2

a) $\Delta U = -p_{ext}\Delta V = -0.5 \cdot 10^5 \cdot 10 \cdot 10^{-3} = -500\ \mathrm{J}$

$$\Delta U = \frac{3}{2} nR\Delta T$$

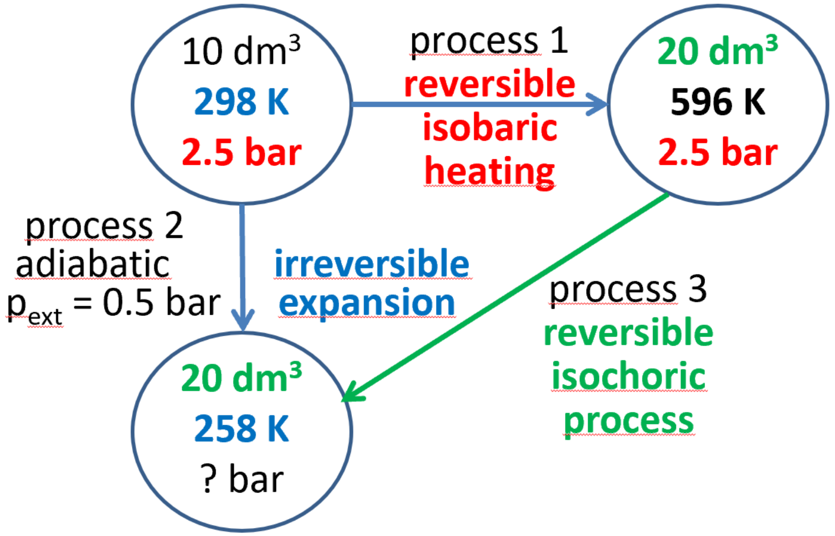
$$\Delta T = \frac{2\Delta U}{3nR} = \frac{2(-500)}{3(1.0 \cdot 8.3145)} = -40\ \mathrm{K}$$

$$T_f = 298 - 40 = 258\ \mathrm{K}$$

b) We have to construct an alternative reversible path!

Question 2

b) The alternative reversible path for process 2 is successively process 1 and process 3:



$$\Delta S_{\text{process 1}} = \int \frac{dq_{rev}}{T} = \int \frac{C_p}{T} dT = c_p \ln \frac{T_f}{T_i} = c_p \ln \frac{596}{298} = c_p \ln(2)$$

$$\Delta S_{\text{process 3}} = \int \frac{dq_{rev}}{T} = \int \frac{C_V}{T} dT = c_V \ln \frac{T_f}{T_i} = c_V \ln \frac{258}{596} = c_V \ln(0.4329)$$

$$\Delta S_{\text{process 2}} = \Delta S_{\text{process 1}} + \Delta S_{\text{process 3}}$$

$$= c_p \ln(2) + c_V \ln(0.4329)$$

$$= \frac{5}{2} nR \ln(2) + \frac{3}{2} nR \ln(0.4329) = 14.41 - 10.44 = 3.97 \text{ J K}^{-1}$$