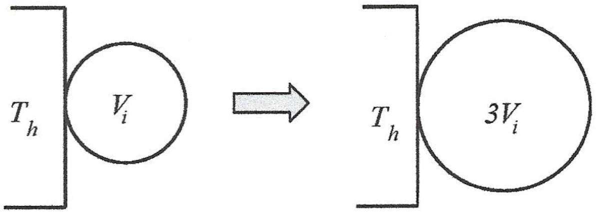
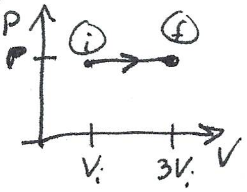
Name: Key

Physics 4C Spring 2020 Test 3 (Thermo)

1. Six (6) moles of a monatomic ideal gas are contained in an expandable balloon. The initial volume of the balloon is V_i and initial temperature is T_i. The balloon is placed in thermal contact with a thermal reservoir at temperature T_h (where $T_h > T_i$) and heat flows irreversibly from the reservoir to the gas until the gas is also at temperature T_h, and the gas now occupies a volume of $3V_i$. During this process the pressure of the gas remains constant. (Assume the thermal reservoir is very large and therefore stays at a constant temperature T_h.)



$\circledast$ The process is irreversible, but the reversible counterpart, w/ the same initial & final points is



You may leave any answers in terms of R, the ideal gas constant.

(a) In terms of T_i only, what is the temperature T_h?

(b) What is the change in entropy of the gas during this process?

(c) What is the change in entropy of the thermal reservoir?

(d) What is the net change in entropy of the reservoir and the gas? Is it positive or negative? And which law of thermodynamics predicts that?

a) $PV_i = nRT_i$ —(1)

$P(3V_i) = nRT_h$ —(2)

$(2) \div (1)$:

$3 = \frac{T_h}{T_i}$

$\boxed{T_h = 3T_i}$

b) (at least) 2 ways:

$\Delta S_{gas} = \int \frac{dQ_r}{T}$ $\circledast$

$= \int_{T_i}^{T_h} \frac{nC_p dT}{T}$

$= nC_p \ln\left(\frac{T_h}{T_i}\right)$

$= n\left(\frac{5}{2}R\right)\ln\left(\frac{3\cancel{T_i}}{\cancel{T_i}}\right)$ $n=6$

$\boxed{\Delta S_{gas} = 15R\ln 3}$

or $\Delta S_{gas} = nC_v \ln\left(\frac{T_f}{T_i}\right) + nR\ln\left(\frac{V_f}{V_i}\right)$

$= n\left(\frac{3}{2}R\right)\ln\left(\frac{3\cancel{T_i}}{\cancel{T_i}}\right) + nR\ln\left(\frac{3\cancel{V_i}}{\cancel{V_i}}\right)$

$= n\left(\frac{3}{2}R + R\right)\ln 3$ $n=6$

$\boxed{\Delta S_{gas} = 15R\ln 3}$

c) $\Delta S_{res} = \int \frac{dQ_r}{T}$, T const

$= \frac{Q_{to\,res}}{T_h}$

$= \frac{-30R\cancel{T_i}}{3\cancel{T_i}} = \boxed{-10R}$

$Q_{to\,res} = -Q_{to\,gas}$

$= -nC_p\Delta T$ (const pressure process)

$= -n\left(\frac{5}{2}R\right)(\overset{1}{3}T_i - T_i)$

$= -30RT_i$

d) $\Delta S_{net} = \Delta S_{gas} + \Delta S_{res}$

$= 15R\ln 3 - 10R$

$= (15\ln 3 - 10)R$

This is +ve $(15\ln 3 > 10)$. The 2nd law says entropy of an isolated system cannot decrease.