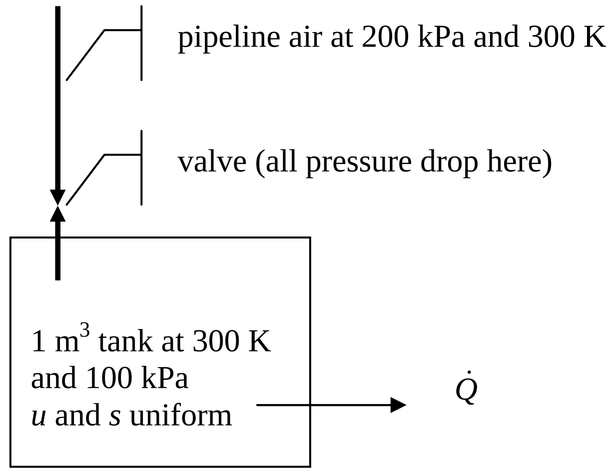
Problem 1

Helium (He) must be supplied at a constant temperature of 70 ^oC for a "batch" pharmaceutical process. The He supply tank is warmed by an electric-resistance heater. The tank volume is 0.2 cubic meters. The tank initially contains He at 70 ^oC and 210 kPa. A valve in the supply line leaving the tank is opened thereby allowing He to be supplied to the process until the pressure in the tank has been reduced by 40%. How much heat must be transferred to the He during the process to maintain the exit temperature of the He at 70 ^oC?

<u>Problem 2</u>

The illustrated rigid tank contains air at 300 K and 100 kPa. The tank is connected through a valve to a pipeline, and it is being charged with air from the pipeline at 300 K and 200 kPa. Assume the tank is a **uniform** state (but **transient**) control volume, so upstream of the valve the pressure is 200 kPa, and downstream the pressure is 100 kPa. Take air to be an ideal gas having a molar mass of 28.97 and having constant specific heats, with 1.40 as the specific heat ratio.



Assume the air in the tank is kept isothermal by heat transfer and that the flow rate of air into the tank is 0.1 kg/sec. Note or recall that the first Gibbs equation may be written as

$$T\frac{ds}{dt} = \frac{du}{dt} + P\frac{dv}{dt} .$$

Take the u of air as zero at 0 K, and s of air as zero at 300 K and 100 kPa.

Find the instantaneous rate of change of the extensive internal energy ($U = m\,u$) of the air in the tank. $\frac{dU}{dt} =$ __________________ units ________

Find the instantaneous rate of change of the extensive entropy ($S = m\,s$) of the air in the tank. $\frac{dS}{dt} =$ __________________ units ________

Find the instantaneous rate of change of the specific volume v of the air in the tank (note that $V = m\,v$) of the air in the tank. $\frac{dv}{dt} =$ __________________ units ________

Find the instantaneous rate at which entropy is generated in the air in the tank.

$\dot{S}_{GEN} =$ __________________ units ________

Problem 3

The cascade vapor compression cycle with refrigerant R134a as the refrigerant is used to achieve refrigeration across a large temperature lift. Saturated vapor at -32^oC enters the first compression stage. The flash chamber and direct contact heat exchanger operate at 4 bar and the condenser pressure is 12 bar. In the flash chamber, the liquid and vapor fractions exiting the high pressure expansion valve are separated and sent to the low pressure expansion valve and direct contact heat exchanger, respectively. Thus, saturated liquid streams at 12 and 4 bar enter the high- and low-pressure expansion valves, respectively. If each compressor operates isentropically:

a) Represent the cycle on a T-s diagram, labeling all states, and find:
b) the coefficient of performance

For clarity in your answers, fill out the values (only the ones that you need to solve the problem) in the following table as you proceed with your calculations.

State	p (bar)	T	x	h	s
1		-32°C	1		
2	4				
3	4				
4	12				
5	12		0		
6	4				
7	4		0		
8		-32°C			
9	4		1