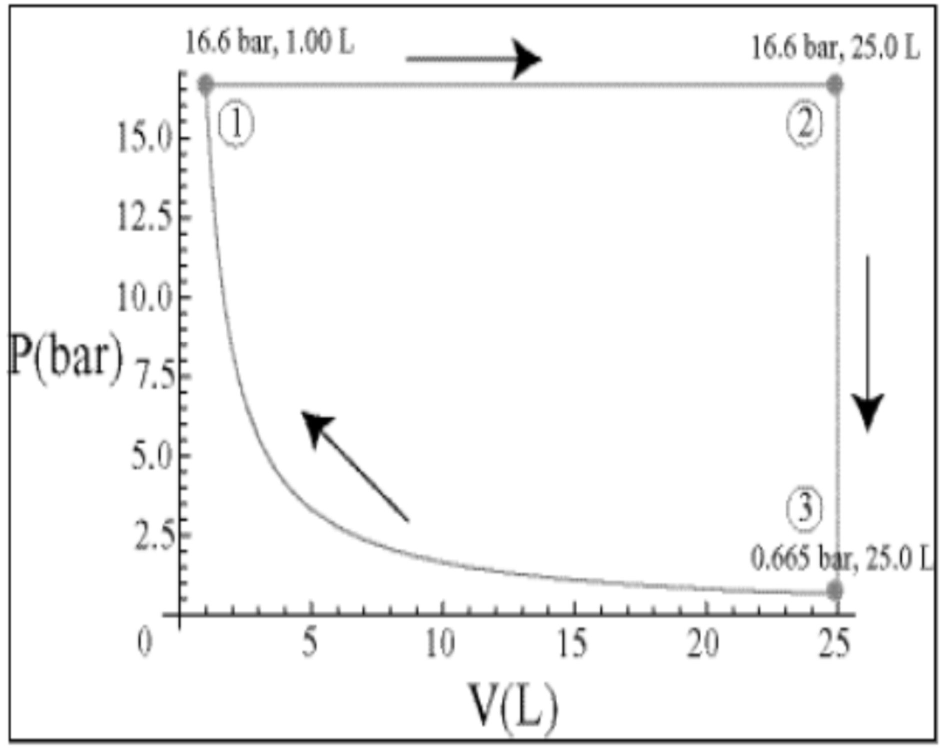
Question 1

A system containing 2.50 mol of an ideal gas for which C_V =20.79 $J\ mol^{-1}K^{-1}$ is taken through the cycle shown with the direction indicated by the arrows. The curved path corresponds to $PV= nRT$, where $T=T_1=T_3$

Calculate q, w, and the changes in U and H for each segment, and for the cycle.



Path	q	w	ΔU	ΔH
1→2	139.4 kJ	-39.8 kJ	99.6 kJ	139.4 kJ
2→3	-99.6 kJ	0	-99.6 kJ	-139.4 kJ
3→1	-5.35 kJ	5.35 kJ	0	0
cycle	34.5 kJ	-34.5 kJ	0	0

Question 2

From the Clapeyron equation derive an equation to express the vapor (saturation) pressure as a function of temperature. State your assumptions. The Clapeyron equation is given by:

$$\frac{dP^{sat}}{dT} = \frac{\Delta S^{lv}}{\Delta v^{lv}}$$

$$\Delta V \approx V^{gas}$$

$$\frac{dP}{dT} = \frac{\Delta S_m^{vaporization}}{\Delta V_m^{vaporization}} \approx \frac{\Delta H_m^{vaporization}}{TV^{gas}} = \frac{P\Delta H_m^{vaporization}}{RT^2}$$

$$\frac{dP}{P} = \frac{\Delta H_m^{vaporization}}{R}\frac{dT}{T^2}$$

$$\int_{P_i}^{P_f}\frac{dP}{P} = \frac{\Delta H_m^{vaporization}}{R}\int_{T_i}^{T_f}\frac{dT}{T^2}$$

$$\ln\frac{P_f}{P_i} = -\frac{\Delta H_m^{vaporization}}{R}\left(\frac{1}{T_f} - \frac{1}{T_i}\right)$$

Question 2 (continued)

The normal boiling temperature of benzene is 80.1°*C*, and the vapor pressure of liquid benzene is 10.4 *kPa* at 20.0°*C*. Calculate (a) Δ*H* (*b)* Δ*S* and (*c*) the percentage error between the value obtained in part (*i*) and the experimentally determined heat of vaporization

a) We can calculate $\Delta H_m^{vaporization}$ using the Clapyeron equation because we know the vapor pressure at two different temperatures

$$\ln\frac{P_f}{P_i} = -\frac{\Delta H_m^{vaporization}}{R}\left(\frac{1}{T_f}-\frac{1}{T_i}\right)$$

$$\Delta H_m^{vaporization} = -\frac{R\ln\frac{P_f}{P_i}}{\left(\frac{1}{T_f}-\frac{1}{T_i}\right)} = -\frac{8.314J\,mol^{-1}K^{-1}\ln\frac{101325Pa}{10000Pa}}{\left(\frac{1}{273.15+80.09K}-\frac{1}{273.15+20.0K}\right)}$$

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$$\Delta H_m^{vaporization} = 33.2kJ\,mol^{-1}$$

b) $$\Delta S_m^{vaporization} = \frac{\Delta H_m^{vaporization}}{T_b} = \frac{33.2\,x10^3\,J\,mol^{-1}}{273.15+80.09K} = 93.9J\,mol^{-1}K^{-1}$$

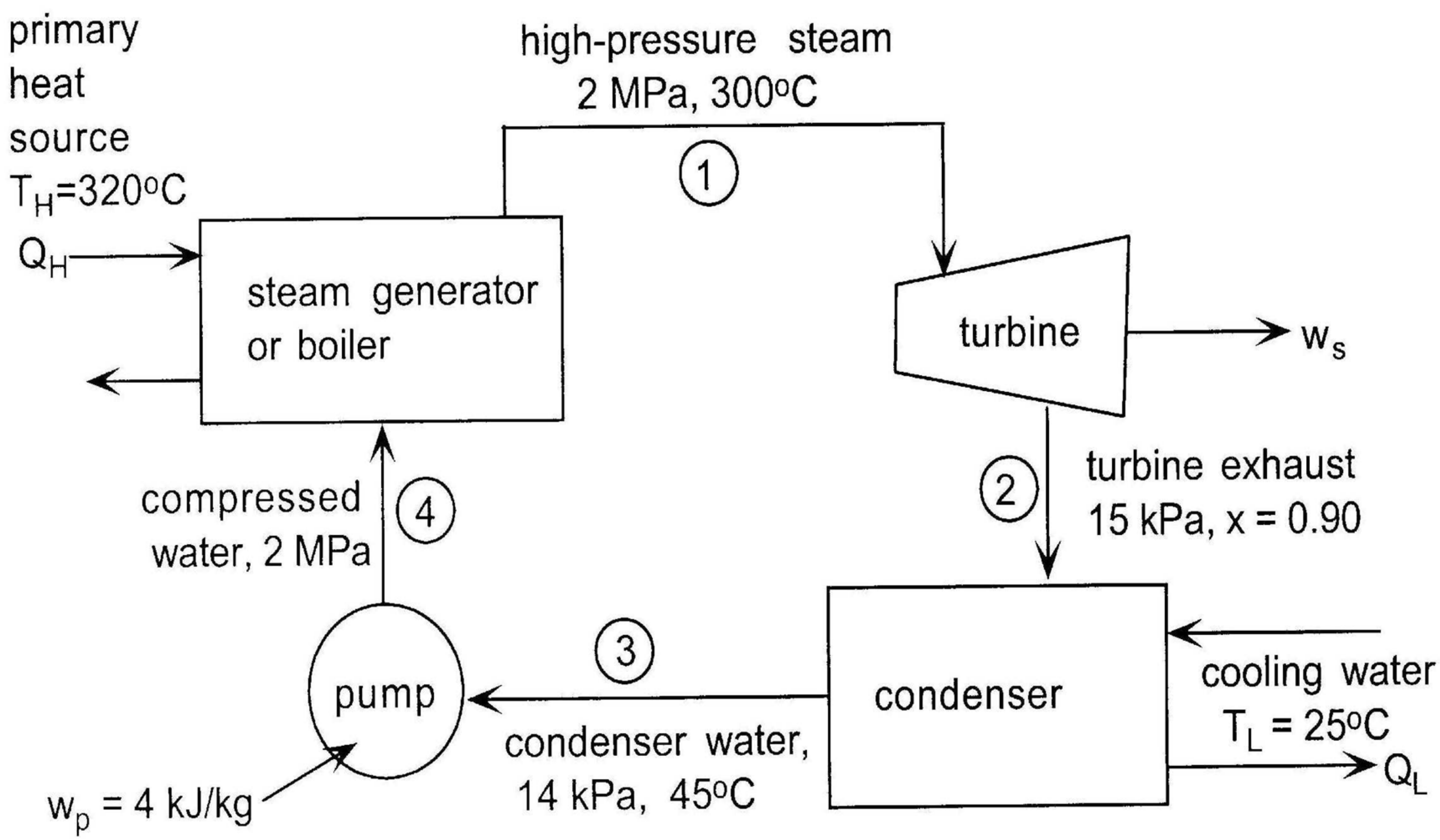
c) From Table B.2, $\Delta H^{Vaporiztion}$ = 30.72 *kJ mol*$^{-1}$

Therefore the error is 8.1%

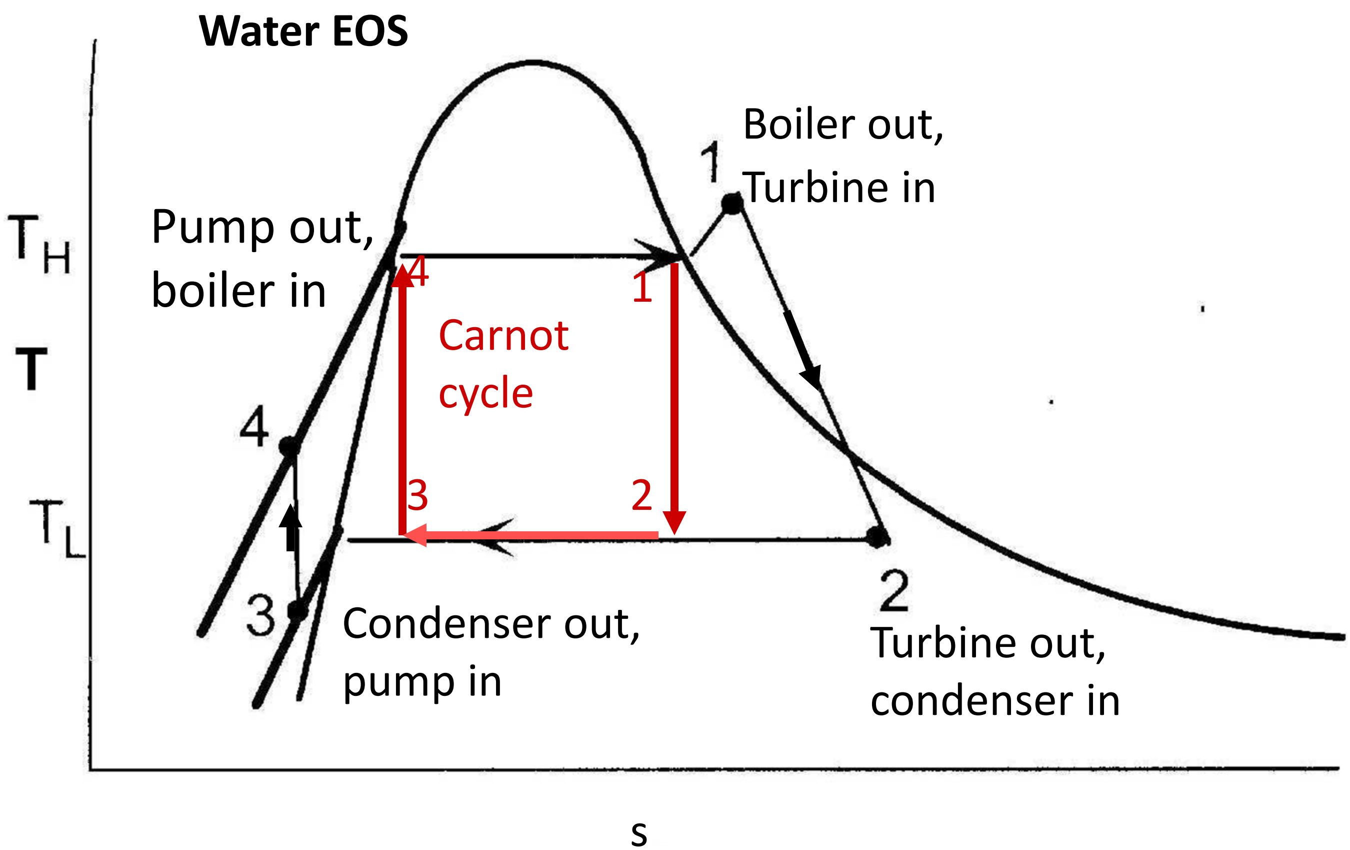
Question 3

For the power cycle shown below (assume 100% efficiency for the pump and turbine):

- Sketch the cycle on a *T-S* diagram.
- Calculate the work produced by the turbine.
- Calculate the change in entropy of the surroundings.
- Calculate the overall efficiency.
- If the rating of the cycle is 20.0 MW what is the steam flow rate?
- Is the cycle below realistic? If yes, why and if no, then why not?



Question 3



Water EOS
T_H
T
T_L
Boiler out,
1
Turbine in
Pump out,
boiler in
4
1
Carnot
cycle
4
3
2
3
Condenser out,
pump in
2
Turbine out,
condenser in
s

Question 3

Site	p,kPa	T,°C	x	h	s
1.	2000	300	1.0	3025	6.77
2.	15	54	0.9	2364	7.29
3.	15	45	0	186	0.637
4.	2000	45	0	**190**	0.649
1.	2000	300	1.0	3025	6.77

Process	work	heat
turbine	**661**	0
condenser	0	**2178**
pump	**4**	0
boiler	0	**2835**

Black: given

red: STEAM TABLES

blue: 1ST law

Question 3

- Work produced = 661 kJ/kg
- ΔS = entropy change of system (water/steam) in cycle

$\Delta S = \Delta S_{turbine} + \Delta S_{condenser} + \Delta S_{pump} + \Delta S_{boiler}$

$= (7.29 – 6.77) + (0.64 – 7.29) + (0.65 – 0.64)$

$+ (6.77 – 0.65) = 0$

$\Delta S_{irr} = 0.649 – 0.637 + 7.29 – 6.77 = 0.53$

(pump) (turbine)

$\Delta S_{surr} = Q_{condenser}/T_L + Q_{boiler}/T_H$

$= 2178/298 + (-2835)/593 = 2.52$

$\Delta S_{tot} = 0.53 + 2.52 = 3.05$ kJ/Kg. K

- Overall efficiency = (661 -4)/2835 = 0.23 = 23% (compared to 45% Carnot efficiency)
- Steam flow rate = 20,000/ (661-4) = 30.4 kg/s

Question 4

(a) VdW:

V_{liq} = 161 cm^3/mol

V_{vapour} = 4650 cm^3/mol

(b) PR:

V_{liq} = 95 cm^3/mol

V_{vapour} = 4087 cm^3/mol

Bonus

At the conditions specified (i.e. 5 bar and 320 K) Carbon Tetrachloride is a liquid because the vapour pressure (0.372 bar calculated from the Antoine equation, Table B.2) is lower than the operating pressure, and the normal boiling point temperature (349.8 K from table B.1 is higher than the operating temperature)