to 20 bar; is heated isothermally by absorbing 3500 kJ/kg of heat; is expanded adiabatically to an unspecified final pressure; and is finally cooled isothermally until the steam returns to its initial state (steam of quality 50% at 1 bar). It is further reported that 53% of the heat added during the heating step is rejected during the cooling step. What is your evaluation of this process?

Problem 6.2: The power generation unit in your plant uses a hot exhaust gas from another process to produce work. The gas enters at 10 bar and 350 °C and exits at 1 bar and 40 °C. The process produces a net amount of work equal to 4,500 J/mol and it exchanges an unknown amount of heat with the surroundings.
a) Determine the amount of heat exchanged with the surroundings. Is this heat absorbed or rejected by the system?
b) Calculate the entropy change of the exhaust gas.
c) As a young and ambitious engineer you seek ways to improve the process. What is the maximum amount of work that you could extract from this system? Assume that the inlet and outlet conditions of the exhaust gas remain the same.
Additional data: Assume the surroundings to be at the constant temperature of 25 °C and the exhaust gas to be ideal with $C_P = 29.3$ J/mol K.

Problem 6.3: You are responsible for a high-temperature process that produces two exhaust streams, stream A at 600 °C, 10 bar, with molar flow rate 100 mole/s; and stream B at 200 °C, 20 bar, with molar flow rate 50 mole/s. A young engineer in your team comes to you with an idea to utilize these streams to produce heat and work which will save costs in your process. She quickly puts together a sketch ~~(see below)~~ for a process that produces 220 kW of heat, 1700 kW of work, and delivers the exhaust gases as a single stream at 1 bar. The heat will be used to produce saturated steam at 1 atm by boiling the saturated liquid.
a) What is the temperature of the exit stream?
b) Should you take this idea to your superiors for further discussions?
c) Could you use the heat from this process to boil water at 10 bar?
Additional information: Assume the exhaust gases can be treated as an ideal gas with $C_P = 30$ J/mole K.

Problem 6.4: You are in charge of a unit that produces two streams, A at 600 °C, 10 bar, with molar flow rate 100 mole/s; and B at 200 °C, 20 bar, with molar flow rate 50 mole/s. Those streams are currently throttled to 1 bar. An engineer in your team comes to you with an idea to utilize these streams to produce heat and work. She believes she can extract 1700 kW of work and ~~220~~ kW of heat that will be used to boil water at 1 bar. Her process, whose details are yet to be determined, will receive streams A and B as inlet and will have a single outlet stream that will be delivered at 1 bar.

500 kW

a) What is the temperature of the exit stream?
b) Should you take this idea to your manager for further discussions?
c) Could you use the heat from this process to boil water at 10 bar?
Additional information: Assume the exhaust gases can be treated as an ideal gas with $C_P = 30$ J/mole K.

Problem 6.5: Liquid propane boils in a constant pressure boiler to produce propane vapor at 30 bar and 245 °C. At the inlet of the boiler the propane is saturated liquid.
a) Draw a PV graph and show this process. Show all the relevant temperatures and pressures as well as the critical isotherm and the critical pressure.
b) Calculate the entropy change of propane between the inlet and outlet of the boiler. Explain your calculations and procedure clearly.
Additional data
1. The saturation temperature at 30 bar is 78 °C.
2. The heat of vaporization at 78 °C is 8780 J/mol.
typeset as C_P
3. The ideal-gas CP of propane vapor is 112 J/mol K.

Problem 6.6: Steam flows in a long, noninsulated pipe under a constant pressure of 2 bar. At the inlet of the pipe the temperature is 300 °C. Due to losses to the surroundings, the temperature at the exit of the pipe is 60 °C. Assume the surroundings to be at 25 °C.
a) Draw a PV graph for the steam. Show the path of the process and all the relevant pressures and isotherms.
b) Calculate the amount of heat removed from the steam.
c) Calculate the entropy change of the steam.
d) Calculate the entropy change of the surroundings. What is the entropy generation?

Problem 6.7: Steam at 5 bar, 300 °C is condensed to saturated liquid in at 5 bar in a heat exchanger at a mass flow rate of 1 kg/s. Cooling is provided by water, which enters the heat exchanger at 20 °C 1 bar and exits at 60 °C. Neglecting pressure drop in pipes and heat losses to the surroundings, determine the flow rate of the cooling water, the amount of heat that is exchanged, and the rate of entropy generation.

Problem 6.8: Steam enters a cooling tower at 200 °C and exits at 60 °C. Cooling is supplied by the surroundings which are assumed to be at 30 °C. The process takes place under atmospheric pressure (1 bar).
a) Calculate the amount of heat removed from the steam.
b) Calculate the entropy change of the steam.
c) What is the entropy generation?
d) Draw a PV graph and show the path of this process.

duplicate problem

Problem 6.9: Steam enters a cooling tower at 200 °C and exits at 60 °C. Cooling is supplied by the surroundings which are assumed to be at 30 °C. The process takes place under atmospheric pressure (1 bar).
a) Calculate the amount of heat removed from the steam.
b) Calculate the entropy change of the steam.
c) What is the entropy generation?
d) Draw a PV graph and show the path of this process.

Problem 6.10: Stream 1 enters a tank carrying steam at 5 bar, 300 °C at the rate of 1 kg/s. The stream is cooled by adiabatic mixing with water at 5 bar, 40 °C (stream 2). If the resulting stream is a vapor-liquid mixture with quality 18%, calculate the mass flow rate of stream 2, the entropy generation, and the lost work.

Problem 6.11: A steam turbine generates power by expanding steam from 30 bar, 450 °C to 8 bar.
a) Determine the amount of work and the exit temperature if operation is reversible.
b) Repeat the calculation assuming an efficiency of 80%. How much is the lost work due to the reduced efficiency?

Problem 6.12: A thermally insulated turbine generates 750 kW of power by expanding steam from 500 C and 3.5 MPa to 200 C and 0.3 MPa.
a) What is the mass flow rate of steam through the turbine?
b) Because of failure in the insulation there is a loss of 60 kJ per kg of steam. What is the power produced by the turbine if all inlet and outlet conditions remain the same?
Assume negligible kinetic and potential energy changes.

Problem 6.13: Steam at 500 C and 40 bar passes through two turbines arranged in parallel, and their exit streams are combined into one stream. Turbine 1 has 100% efficiency, while the efficiency of turbine 2 is 75%. Both turbines exhaust at 1 bar. The stream that is formed by combining the exhausts of the two turbines is saturated vapor.
a) Determine the fraction of the total flow rate that passes through each turbine.
b) Determine the rate of entropy generation. What are the irreversible feature of this process?

Problem 6.14: A steam turbine generates 800 kW of work by expanding steam from 50 bar, 400 °C to 1 bar. At the exit of the turbine the steam contains 2% moisture.
a) Determine the flow rate of steam through the turbine.
b) Determine the efficiency.
c) Determine the rate of entropy generation in kJ/K s.

Problem 6.15: Methane passes through a compressor and is subsequently cooled in a heat exchanger. Methane enters the compressor at 1 bar, 20 °C with volumetric flow rate 30 $\mathrm{ft}^3/\mathrm{min}$; it exits the heat exchanger at 10 bar, 20 °C. The compressor efficiency is 80%. Assuming methane to be in the ideal-gas state with $C_P^{\mathrm{ig}} = 36.3$ J/mol K, do the following:
a) Calculate the work in the compressor (in J/s)
b) Calculate the required heat in the heat exchanger.
c) Calculate the entropy generation.

Problem 6.16: Air is compressed in a steady-state, ~~insulated flow device~~ compressor. The air enters at 1 bar, 25 °C and exits at 5 bar, 200 °C.
a) Determine the amount of work ~~needed for this compression~~.
b) Calculate the entropy generation.
c) What is the ~~minimum~~ amount of work ~~necessary to compress~~ for reversible compression of air air from 1 bar, 25 °C to 5 bar?
d) What would be the temperature at the exit of the compressor in part (c)?
Assume air to be an ideal gas with $C_p = 30$ J/molK.

Problem 6.17: A new compressor has just been delivered to your plant. In order to check its performance you order your staff to make a test run using air. Your staff reports to you the following results: air at a flow rate of 50 mol/min was compressed from 1 bar and 25 °C to 10 bar. The temperature at the exit of the compressor was measured and found to be 450 °C.
a) What is the power (in kW) consumed by the compressor?
b) What is the efficiency of the compressor? Assume air to be an ideal gas with $C_P = 3.5R$.

Problem 6.18: During a test of an ~~air compressor~~ gas turbine, the following data were recorded: air at a flow rate of 50 mol/min was expanded compressed from ~~1 bar~~ 10 bar and ~~25 °C~~ 700 C to ~~10~~ 2 bar bar. The temperature at the exit of the ~~compressor~~ turbine was measured and found to be 450 °C.
a) What is the power (in kW) ~~consumed by the compressor~~?
b) What is the efficiency ~~of the compressor~~? Assume air to be an ideal gas with $C_P = 3.5R$.

Problem 6.19: Steam is compressed from 1 bar, 200 °C to 12 bar in a compressor operating at steady state.
a) Calculate the amount of work and the final temperature if compression is reversible.
b) Repeat the calculation if the efficiency of the compressor is 75% and report the lost work.

Problem 6.20: a) Water is throttled from 20 bar, 20 °C to 1 bar. What is the final temperature?
b) Repeat if the final pressure is 0.00706 bar.

15 bar and 20 °C

Problem 6.21: Water at 15 bar is throttled to final pressure such that the temperature is 5 °C. Determine the pressure and the entropy generation. How much work could be produced if instead of throttling the final pressure is reached via expansion in a reversible expander?

Problem 6.22: a) An ideal gas ($C_P = 30$ J/mole) is throttled from 20 bar, 25 °C to 1 bar. What is the temperature at the exit?
b) Water is throttled from 20 bar, 25 °C to 1 bar. What is the temperature at the exit? If a vapor-liquid mixture, report the liquid fraction.
c) A vapor-liquid mixture of water containing 50% liquid is throttled from ~~20 bar to~~ 20 bar, 60°C, to 0.1 bar. What is the temperature at the exit? If a vapor-liquid mixture, report the liquid fraction.

Problem 6.23: Water is pumped at a flow rate of 2.25 kg/min from 1 bar 20 °C to 15 bar. Determine the amount of work and the temperature of water at the exit if the efficiency of the pump is 78%.

Problem 6.24: A 10 kW pump is used to pump liquid ammonia from 5 bar and 0 °C to 25 bar. The efficiency of the pump is 62%.
a) What is the mass flow rate (kg/s) delivered by the pump?
b) What is the temperature at the exit of the pump?
c) Calculate the rate of entropy generation (in kW/K).
Additional data for liquid ammonia: density = 0.64 g/cm^3; $C_P = 1.1$ kJ/kg K; $\beta = 2.095 \times 10^{-3}$ K^{-1}.

Problem 6.25: A flow process utilizes steam as the working fluid. The steam, initially at 30 bar and 700 °C (state A), is cooled under constant pressure to a temperature of 380 °C (state B) and it subsequently expands adiabatically to a final pressure of 1 bar (state C) through a turbine whose efficiency is 75%.
a) Plot the path of a Mollier diagram.
b) Determine the energy balances.

Problem 6.26: A flow process that operates with steam has one inlet stream (A) and two outlet streams (B and C). Stream A is at 20 bar, 25 °C, and has a mass flow rate of 10 kg/s; stream B is saturated liquid at 20 bar and has a flow rate of 7 kg/s; stream C is at 20 bar. The process receives heat at the rate of 14,100 kW from a heat source at 25 °C.
a) What is the temperature of stream C?
b) Determine the entropy generation.