Ahmedabad University
School of Engineering and Applied Science

Name: _____ Roll no.: _____

PhD (Chemical Engineering)
Advanced Thermodynamics and Reaction Engineering
CHE509 **End-Term Examination (Max. Marks: 30)**
April 27, 2025, Sunday, 8:00 – 10:00 am

Instructions:

1 Figures to right indicate full marks.
2 All acronyms carry their usual meaning.
3 Assume suitable data wherever necessary and specify it clearly in your answers.
4. It is an Open Book Examination.

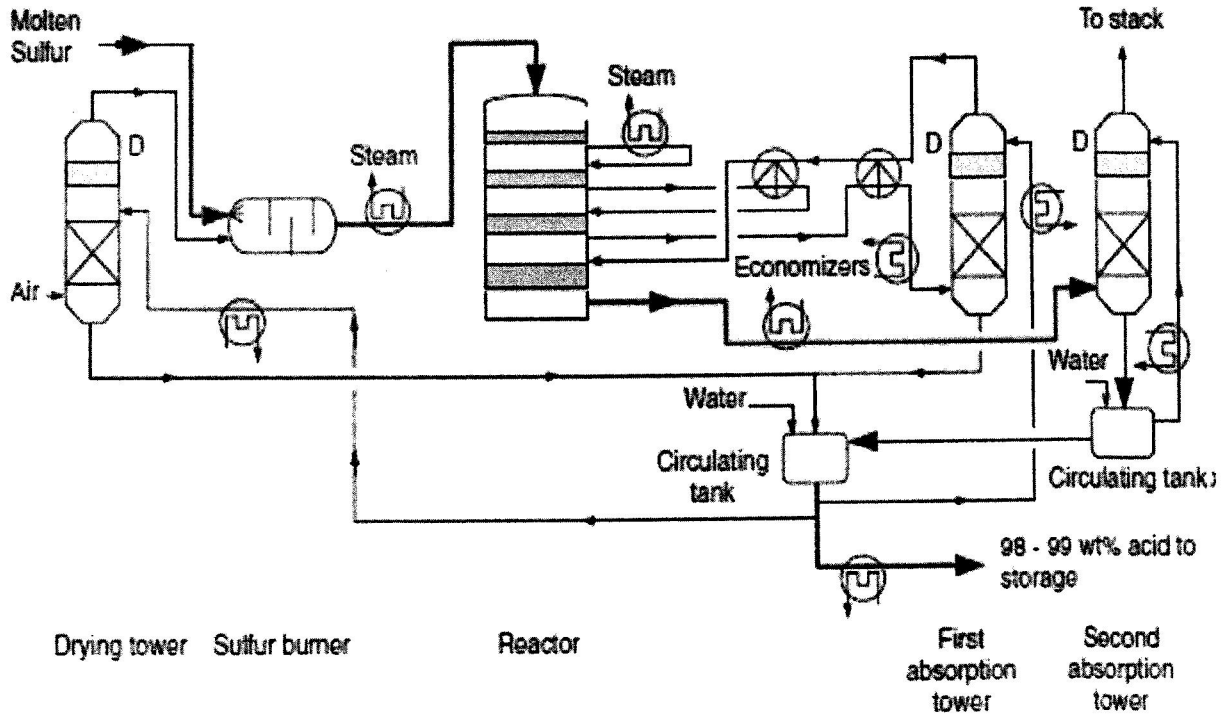
Sulfuric acid is produced by Double Contact Double Absorption (DCDA) Process. The raw materials are molten sulfur and air. The reactions are:

$$S(l) + O_2(g) \rightarrow SO_2(g) \qquad \Delta_r H_{298} = -298.3 \text{ kJ/mol}$$

$$SO_2(g) + 1/2\,O_2(g) \rightleftarrows SO_3(g) \qquad \Delta_r H_{298} = -98.5 \text{ kJ/mol}$$

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l) \qquad \Delta_r H_{298} = -130.4 \text{ kJ/mol}$$

The production flow sheet is shown below:



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Dried air and atomized molten sulfur are introduced at one end of the sulfur burner, which is a horizontal, brick-lined combustion chamber. A high degree of atomization and good mixing are key factors in producing efficient combustion. Atomization typically is accomplished by pressure spray nozzles or by mechanically driven spinning cups. Some sulfur burner designs contain baffles or secondary air inlets to promote mixing. Handling of molten sulfur requires keeping the temperature between 410 and 425 K, where its viscosity is lowest. Therefore, it is transported through heated lines. Most of the heat of combustion is used to generate high-pressure steam in a waste heat boiler, which reduces the gas temperature to the desired inlet temperature of the first catalyst bed. The heat of reaction of sulfur dioxide oxidation raises the temperature in the first bed significantly. The hot exit gases are cooled before entering the second bed, where further conversion takes place. The gas leaving this bed is cooled by heat exchange with cold gas leaving the first absorption tower. It subsequently undergoes further conversion in the third bed, after which it is cooled and fed to the first absorption tower. Here, most of the sulfur trioxide produced is absorbed in a circulating stream of sulfuric acid. The gas leaving the absorption tower is reheated by heat exchange with gas from the third and second converter beds and then enters the fourth catalyst bed, where most of the remaining sulfur dioxide is converted to sulfur trioxide (overall conversion >99.7%). The final absorption tower removes this sulfur trioxide from the gas stream before release to the atmosphere.

Assume that engineers need to design the process. Considering DCDA process, answer the following questions:

1 List out the thermodynamic properties for each equipment those are more important during process design. 05

2 What kind of thermodynamic equilibrium data is needed for each piece of equipment while it is being designed? Also, list the devices that don't need thermodynamic equilibrium data. 05

3 Create a step-by-step process (flow chart or algorithm) with equations to determine the equilibrium data for applicable equipment. 20