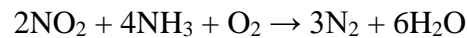


Midterm Examination #1**(145) 1. Flue-Gas Reactive Cleaning with NH₃-Selective Catalytic Reduction (SCR)**

Flue gas released from a coal-fired power plant gas has been analyzed to contain the following composition: 3% NO₂, 7% O₂, and remaining amounts of an unknown inert gas, I. Local regulations require emissions of NO₂ be less than 50 ppm as NO₂ contributes to smog. An economic method to denitrify flue gas is NH₃-based selective catalytic reduction (SCR). The irreversible reaction occurring in the SCR reactor removes NO₂ by converting it into N₂ as shown:



Assume that the conversion of NO₂ is 100% and that the composition of inerts leaving the SRC reactor is 78.3 %.

A stream of pure ammonia (NH₃) and the flue-gas stream are first sent to a mixer, after which the resulting mixed stream is fed to the SCR reactor. NH₃ is fed to the mixer in 75 % excess of the stoichiometric requirement of the given reaction.

- (25) a. Construct a process flow diagram of the proposed system. Label each stream with numbers and also with the species that are present. Fill out the diagram with all of the information that is specified about this process.
- (50) b. Calculate the compositions of O₂ and I (inert gas) in the stream entering the SCR reactor.
- (50) c) Calculate the compositions of O₂ and H₂O in the product stream exiting the SCR reactor.
- (20) d) Explain how it might be possible for this process not to meet the NO₂ 50 ppm design limit.

(125) 2. Inert Atmosphere in a Glovebox

When working with particularly reactive materials, a high purity inert atmosphere is desired. Consider a rigid glovebox of volume V, initially open to the atmosphere. To render the glovebox operational, the box is sealed and the inlet valve is connected to a stream of pure nitrogen of ρ_{N_2} (units of moles per volume) at a constant volumetric flow rate Q. The outlet valve is open to the atmosphere with a molar flow rate out of the box proportional to its difference in pressure. The proportionality constant is α .

- (15) a. What are the units of the proportionality constant α ?
- (35) b. Assuming ideality of gas species and constant temperature, establish a differential equation for P(t) in terms of relevant constants. State initial conditions and classify the ode.
- (20) c. Find an expression for the steady pressure in the glove box.

(20) d. Solve for the $P(t)$. For all $t > 0$, show that $P > P_{\text{atm}}$. Explain why this result is desired.

(30) e. Establish a differential equation for the composition change of oxygen in the glove box. Do not attempt solution. List the initial condition and the steady mole fraction of oxygen in the glove box.