# ChE 456
# Spring 2006
# Major 2

# Production of Ethyl Benzene

## Problem Background

Following your preliminary report on the feasibility of the design of an 80,000 tonne/yr ethyl benzene (EB) plant using benzene and ethylene as the feedstock, XYZ Corporation has decided to commission a further study. The purpose of this study is to assess the economic feasibility of building a grass roots or "green field" facility to produce 100,000 tonne/yr of 99.8 mol% EB from a stream of petrochemical grade benzene and ethylene. Your design should be an optimized process, and should include all unit operations necessary to produce the desired amount and purity of ethyl benzene. The specifications for the ethyl benzene are the same as those given in the previous project (Major 1). You are free to use the results of the previous study, and you may want to use them as a base case for starting this project. Both catalysts presented in the first project are available.

For the current study, the following constraints apply:

Economic Parameters

- Ethylene is available (at $0.72/kg) with the following composition
  93 mol% ethylene
  7 mol% ethane
- The benzene is available (at $1.00/kg) as a light aromatics cut with the following composition
  90 mol% benzene
  10 mol% toluene
- A stream factor of 95% should be used.
- Optimization of the process should be carried out using the after-tax, break-even price of EB as the objective function. In other words, you should optimize the process to give the lowest EB price yielding a zero NPV for the project.
- The design should be for a new, grass-roots facility.
- The cost of operating labor is $57,500 per operator per year.
- Land costs are negligible.
- Taxation rates are 45% per year.
- MACRS depreciation of capital investment over a period of 5 years may be applied.
- An interest (hurdle) rate for this project is 10% after taxes.
- The project length is 10 years after start up, which occurs at the beginning of year 3.
- There is no salvage value
- Working capital is 3 months supply of raw materials + 3 months of labor costs.

- Construction period is 3 years with a distribution of fixed capital investment as 50%, 30%, 20%, at the ends of years 0, 1, and 2, respectively.

Process Design Parameters

- All steam generated in the EB facility will be consumed in the sister styrene facility that will be designed by another group. You should assume that all steam generated can be exported and the conditions and value of the exported steam is given below:
  HP (41 barg - saturated) = $7.50/GJ
  MP (20 barg - saturated) = $6.75/GJ
  LP (4 barg - saturated) = $6.25/GJ
  Note that the conditions of the MP and LP steam are different from that given in your textbook.
- Toluene may be separated and returned to the supplier for the same price as the feed benzene, namely $1.00/kg. The purity of the toluene should be greater than 99.5 mol%.
- Any fuel gas generated may be credited against fuel consumption at a rate of $6.00/GJ.
- All distillation columns must be simulated using rigorous unit operations (either TOWR or SCDS in Chemcad). Failure to use rigorous algorithms in the final case will result in a loss of credit. Preliminary screening using short-cut methods is acceptable.
- The UNIFAC *K*-value and latent heat Enthalpy options should be used for the Chemcad simulation.

**Report Format**

This report should be comprehensive and should conform to the guidelines. It should be bound in a folder that is not oversized relative to the number of pages in the report. Figures and tables should be included as appropriate. An appendix should be attached that includes items such as Chemcad output and sample calculations. These calculations should be easy to follow. The confidentiality statement should be the very last page of the report.

The written report is a very important part of the assignment. Reports that do not conform to the guidelines will receive severe deductions and will have to be rewritten to receive credit. Poorly written and/or organized written reports may also require re-writing. Be sure to follow the format outlined in the guidelines for written reports.

The following information, at a minimum, must appear in the main body of the final report:

1. a computer-generated PFD (not a Chemcad PFD) for the recommended optimum case,

2. a stream table containing the usual items,

3. a list of new equipment for the process, including bare module and installed costs, plus equipment specifications (presented with a reasonable number of significant figures),

4. a summary table of all utilities used,

5. a clear summary of alternatives considered and a discussion, supported with figures, of why the chosen alternative is superior,

6. a clear economic analysis which justifies the recommended case

7. a Chemcad report only for your optimized case (in the Appendix). This must contain the equipment connectivity thermodynamics, and overall material balance cover pages, stream flows, equipment summaries, tower profiles, and tray design specifications (if you use Chemcad to design the trays). It should not contain stream properties. Missing Chemcad output will not be requested; credit will be deducted as if the information is missing.

**Oral Presentation**

You will be expected to present and defend your results some time between February 20, 2006 and February 24, 2006. Your presentation should be 15-20 minutes, followed by about a 30 minute question and answer period. Make certain that you prepare for this presentation since it is an important part of your assignment. You should bring at least one hard copy of your slides to the presentation and hand it out before beginning the presentation.

**Other Rules**

You may not discuss this major with anyone other than the instructors. Discussion, collaboration, or any other interaction with anyone other than the instructors is prohibited. Violators will be subject to the penalties and procedures outlined in the University Procedures for Handling Academic Dishonesty Cases (http://www.arc.wvu.edu/rightsa.html)

Consulting is available from the instructors. Chemcad consulting, *i.e.*, questions on how to use Chemcad, not how to interpret results, is unlimited and free, but only from the instructors. Each individual may receive five free minutes of consulting from the instructors. After five minutes of consulting, the rate is 2.5 points deducted for 15 minutes or any fraction of 15 minutes, on a cumulative basis. The initial 15-minute period includes the 5 minutes of free consulting.

**Late Reports**

Late reports are unacceptable. The following severe penalties will apply:

- late report on due date before noon: one letter grade (10 points)
- late report after noon on due date: two letter grades (20 points)
- late report one day late: three letter grades (30 points)
- each additional day late: 10 additional points per day