Your company has decided to produce $P$ and $Q$ by the reaction $A \rightarrow P + Q$. The reaction is irreversible. The reaction is incomplete; the reactor effluent contains reactant $A$. $P$ and $Q$ have the same molecular weight.

Unfortunately, $A$ is available only as a mixture with inert compound $I$. Because $A$ and $I$ have the same boiling point and the same melting point, $A$ and $I$ cannot be separated.

Gas-liquid separators can produce pure $P$ and pure $Q$, but the separators recover less than 100% of each.

A generic process is shown below. To produce and sell product $P$, you need only a reactor and separator I. If you wish to also sell less-valuable product $Q$, you must purchase a second separator. If you purchase a second separator, you may send only a portion of the flow through the separator; a fraction of the bottoms from separator I may be directed to the stream labeled “bypass.” If you set the bypass fraction equal to 1.0, your process will not include a second separator.

Finally, you must decide what fraction to purge.

There are two options for the reactor: type 1 and type 2. Reactor Type 1 has a higher conversion of $A$ but is more expensive and costs more to operate.

There are two options for separator I. Both options produce pure $P$, but differ by the amount of $P$ in the liquid bottoms. Separator I Type 1 recovers more of the product $P$ but is more expensive and costs more to operate.

If one decides to purchase a second separator, there are two options for separator II. Both options produce pure $Q$, but differ by the amount of $Q$ in the gas tops. Separator II Type 1 recovers more of the product $Q$ but is more expensive and costs more to operate.

Because $I$ is toxic, disposal requires special treatment and is expensive. The disposal cost is determined by the total amount of any effluent that contains $I$. That is, the disposal cost for 1 kg of a mixture with 10% $I$ is the same as the disposal cost for 1 kg with 90% $I$. 
Engineering and Economic Data for Manufacturing $P$ and $Q$ from $A$.

Equipment specifications, equipment costs, operating costs, chemical costs, and disposal costs vary with Design League and Division. Identify your team’s League and Division and then download the data from the EngrD 2190 homepage - see “Design Competition.”

Wednesday Design League: Keynes Division: Teams T1 - T6
Smith Division: Teams T7 - T12
Wednesday Design League: Friedman Division: Teams W1 - W7
Galbraith Division: Teams W8 - W14
Ricardo Division: Teams W15 - W21

Reactor and separator prices are given by the formula $\text{price} = k \times (F_T)^{0.6}$, where $k$ is a constant conversion factor, $F_T$ is the flow through the unit, in kg/day, and $\text{price}$ is in $. For example, a reactor with double the capacity costs only 1.5 times as much. Operating costs for reactors and separators are given by the formula $\text{operating cost} = c \times F_T$; the units of $\text{operating cost}$ are $$/year.

All economic parameters - equipment prices, operating costs, chemical prices, and disposal cost - are constant. Equipment depreciation is calculated with straight-line formula, with a lifetime of 10 years. The process operates 365 days/year.

Equipment purchase costs are paid at the beginning of the year. Operating costs are paid during the year. Revenue from sales of $P$ (and perhaps, $Q$) is received at the end of the year.

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**Goal:** Start with $10,000,000 and maximize the ROI for your process.

You must decide what type of reactor, separator I, and separator II (if any) to purchase, and the capacity of each. You must specify the fraction of Separator I bottoms to bypass Separator II and the fraction to be purged. You also must decide how much reactant to purchase.

Annual Plans are due by 2:30 p.m. on the day of your Calculation Session, either October 17 or October 18. You will receive an Annual Report of your team’s results by Friday, October 19.

If your team achieves a positive Return On Investment, your team will receive 25 homework points. If your ROI is greater than 0.2, your team will receive an additional 10 points. If your team has the highest Return On Investment in your Division, your team will receive an additional 10 points.
In addition to buying reactant mixture \( A+I \) and selling products \( P \) and \( Q \), you may buy and sell intermediate compositions by trading with other companies. For example, you may decide to buy only a reactor – no separators. Because the reactor price scales non-linearly, your reactor should be able to produce reactor effluent cheaper than smaller reactors. You should be able to supply other companies with reactor effluent at a price below their cost to manufacture reactor effluent. Both companies benefit.

Or perhaps your company may decide to invest in a large separator II. Perhaps your company can charge less than the disposal cost for purge streams. So other companies will give you their purge streams and pay you a fee less than the disposal cost. Because your large separator II costs less on a basis of $/kg \( Q \), you can purify product \( Q \) cheaper than any other company. All companies may benefit.

Thus the process flowsheet is modified as follows:

What price to charge for reactor effluent? What price to pay for reactor effluent? What fee to charge for disposing purge streams? Prices and fees must be negotiated between companies.

Trading with other companies is optional; you may eschew intercompany entanglements and operate independently.

**Rules:**

This is a new competition. Every team is starting with $10,000,000 and no equipment. The costs and equipment specifications are unchanged from the previous competition.

Annual Plans and (optional) Contracts are due by 3:00 p.m. on the day of your Calculation Session, either October 24 or October 25. You will receive an Annual Report of your team’s results by Friday, October 26.
More Rules.

Teams may write contracts with other teams in their League and Division only.

Because a company will depend on another company fulfilling the contract, the contracts have a provision for penalties. For example, if a company agrees to supply Reactor Type-1 effluent at 50.0 kg/day, but fails to do so, that company must pay the penalty stated on the contract.

Services and cash from contracts (see below) exchange during the year.

Company X may not give its money to company Y, even if company X has a contract to be repaid by company Y, with interest or a share of the profits. Such a contract is essentially a merger of two companies into a single company with twice the assets. The competition is intended to exercise engineering design and negotiation skills, so all companies should start with the same resources.

Every contract must be a reasonable exchange of process streams and/or cash. Every contract must be explicit. Cash amounts must be specific numbers. For example, contracts with payments described as “half the profits” will not be accepted.

Equipment may not be exchanged between companies. If your company needs additional processing capacity and another company has excess processing capacity, your companies should arrange to exchange process streams, such as reactor effluent, or separator I bottoms, for example.

In summary, Annual Plans and InterCompany Contracts must be unambiguous. Add comments to indicate precisely how each equipment purchase is to be used. If you have questions, please ask. I will try to respond promptly to e-mail by the next business day and I am available during office hours, 1:30-3:30 p.m. Mondays.

Goal: Start with $10,000,000 and maximize the ROI for your process

If your team achieves a positive Return On Investment, your team will receive 25 homework points. If your ROI is greater than 0.2, your team will receive an additional 10 points. If your team has the highest Return On Investment in your Division, your team will receive an additional 10 points.