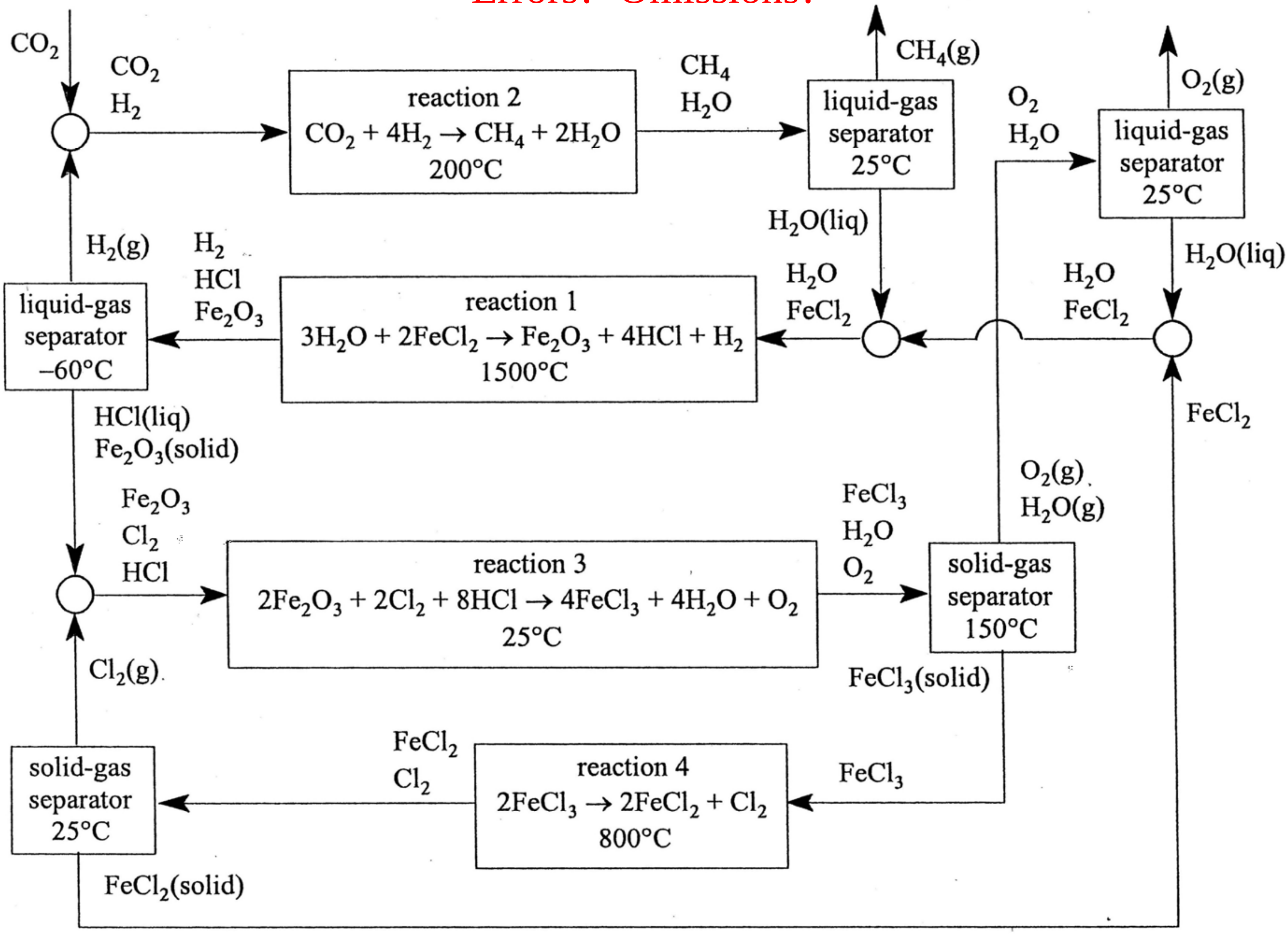
Methane from CO_2 and Thermal Energy

Overall Reaction: $CO_2 + 2H_2O \rightarrow CH_4 + 2O_2$

Errors? Omissions?



EngrD 2190 – Lecture 5

Concept: Process Design – Chemical Reaction Cycles, continued

- Dealing with solid reactants and solid products
- Using a reactant in excess.

Context: Producing CH_4 from CO_2 and thermal energy, continued
(exercise 2.30 – solution is posted)

Defining Questions:

How to handle solids in a chemical process?

Why does an excess reactant deplete the other reactant(s)?

(Optional) Read Exercises 2.36 and 3.126 for Lecture 6.

EngrD 2190 – Lecture 5

Homework 1 due today at noon.

Write team code and names of all *contributing* team members on all solutions.

Indicate this week's Team Coordinator.

Submit *after* lecture or deliver to EngrD 2190 mailbox in a beige cabinet in the hallway *outside of 116 Olin Hall, in the South entryway to Olin Hall.*

Do not deliver to my mailbox in 116 Olin (ChemE Business Office).

Homework 2

Homework 2 – due Friday 9/12

Problem Redefinition: 2.43, 2.46, and 2.52.

Read preamble on pp. 80-81.

Submit all three problem redefinition exercises on a single page.

Process Design: 2.23 and 2.33.

Append 'take-away' lists for design exercises 2.23 and 2.33.

Submit one solution per homework team.

Homework is your chief means of assessing your command of the material.

Do not copy from other sources, such as graded homework and posted solutions from previous years.

Do not use past solutions to check your answers. Process analysis is part of the assignment. You should be developing methods of assessing your answers.

Peer Evaluations

EngrD 2190
Chemical Process Design & Analysis

Peer Rating of Team Members - First Team Assignments

Name ______________________________ Team # ______

Please write the names of *all* your team members, *including yourself*, and rate the degree to which each member fulfilled his/her responsibilities for team-wide learning. Because the team's goal is to learn, questions are as important as answers, and critical analysis is as important as creative design. Use the following ratings:

Excellent Consistently went above and beyond. Carried more than his/her fair share of the load. Prepared thought-provoking questions and/or educational explanations.

Very Good Consistently fulfilled responsibilities for team-wide learning. Very well prepared and very cooperative.

Satisfactory ficiently prepared

Ordinary inimally prepared

Marginal Rarely prepared.

Unsatisfactory Unprepared.

Superficial Practically no participation.

No show No participation.

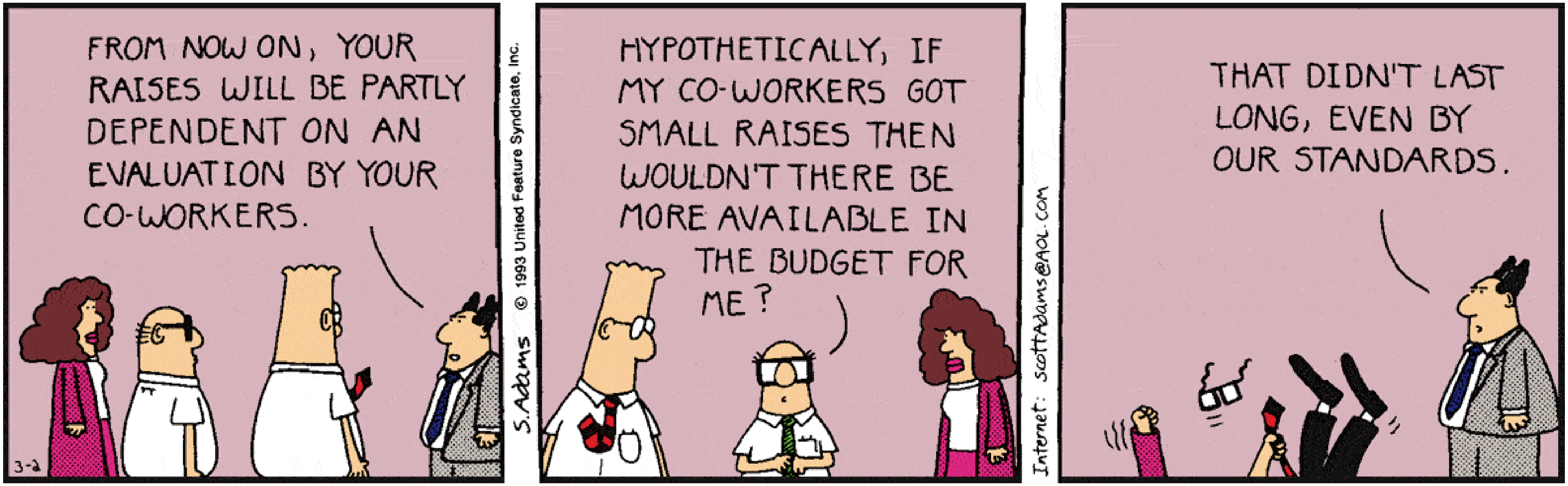
Do not submit until after Homework 4

These ratings should reflect each individual's level of participation, effort, and sense of responsibility, not his or her academic ability.

Name of team member **(include yourself)**	Rating
______________________	______________
______________________	______________
______________________	______________
______________________	______________

Please comment on your team and on the general concept of learning by working homework in teams. If your team was dysfunctional, was it a specific problem with team members or an inherent problem with the concept?

Peer Evaluations



Dilbert, Scott Adams, March 2, 1993.

A payroll is finite. If one worker gets more, others get less.

The number of A's is infinite. Everyone that earns an A gets an A.

Fall 2023

Cornell's Co-Ed Professional Chemistry Fraternity

Alpha Chi Sigma is a national chemistry fraternity centered around binding its brothers, advancing ience, and aiding students in chemistry. Our er offers academic, professional, volunteer, and ial fellowship for any major with an interest in chemistry.

Info Sessions in Baker G29C: 7:00 pm
Sept 9th and Sept 11th

Wed,
Sept 17th
Dry Ice Icecream

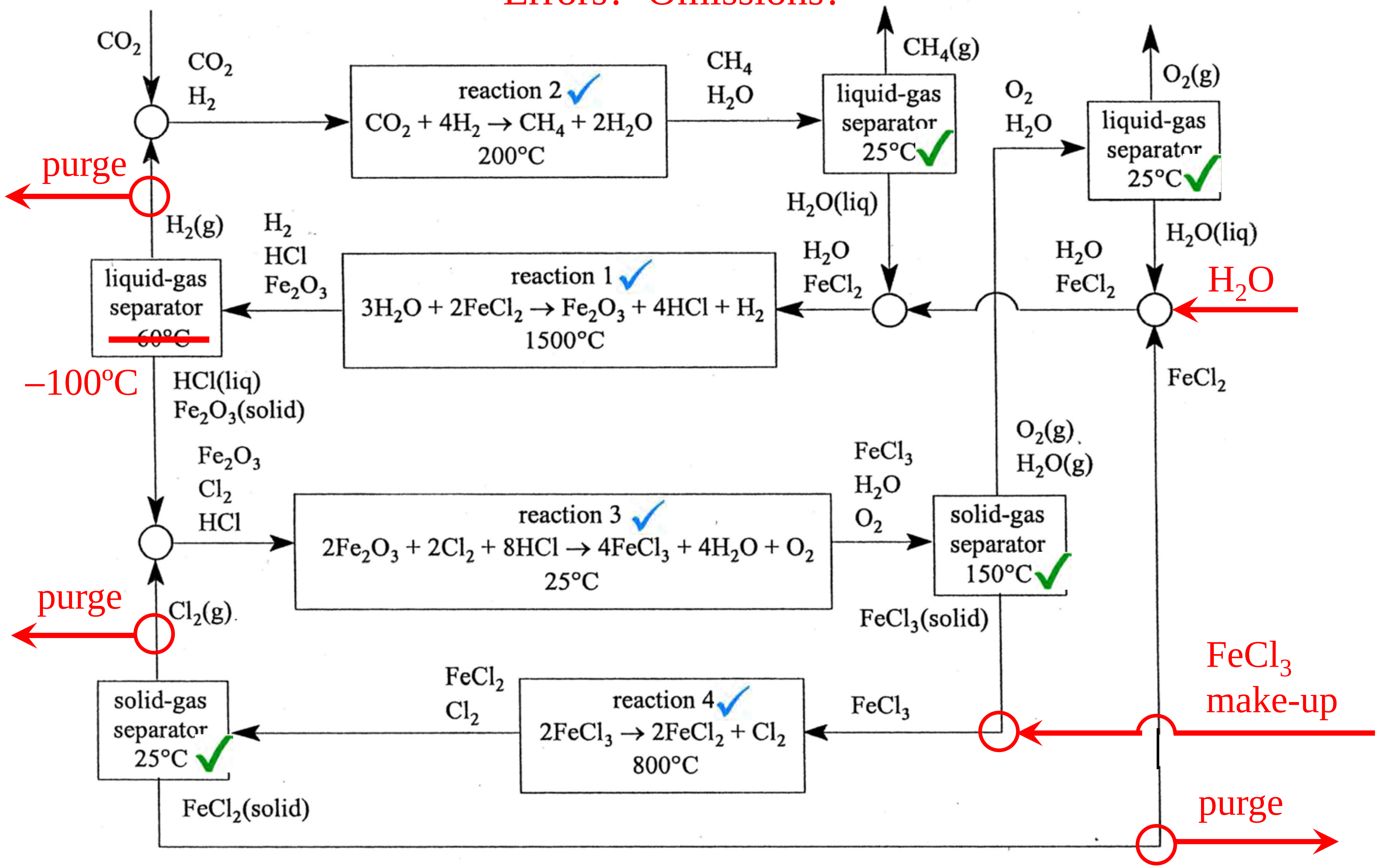
Thurs,
Sept 18th
S'mores Night

Methane from CO_2 and Thermal Energy

1. Check process inputs and outputs
2. Check reactor inputs and outputs
3. Check separator temperatures
4. Recycle loops purged?

Overall Reaction: $CO_2 + 2H_2O \rightarrow CH_4 + 2O_2$

Errors? Omissions?

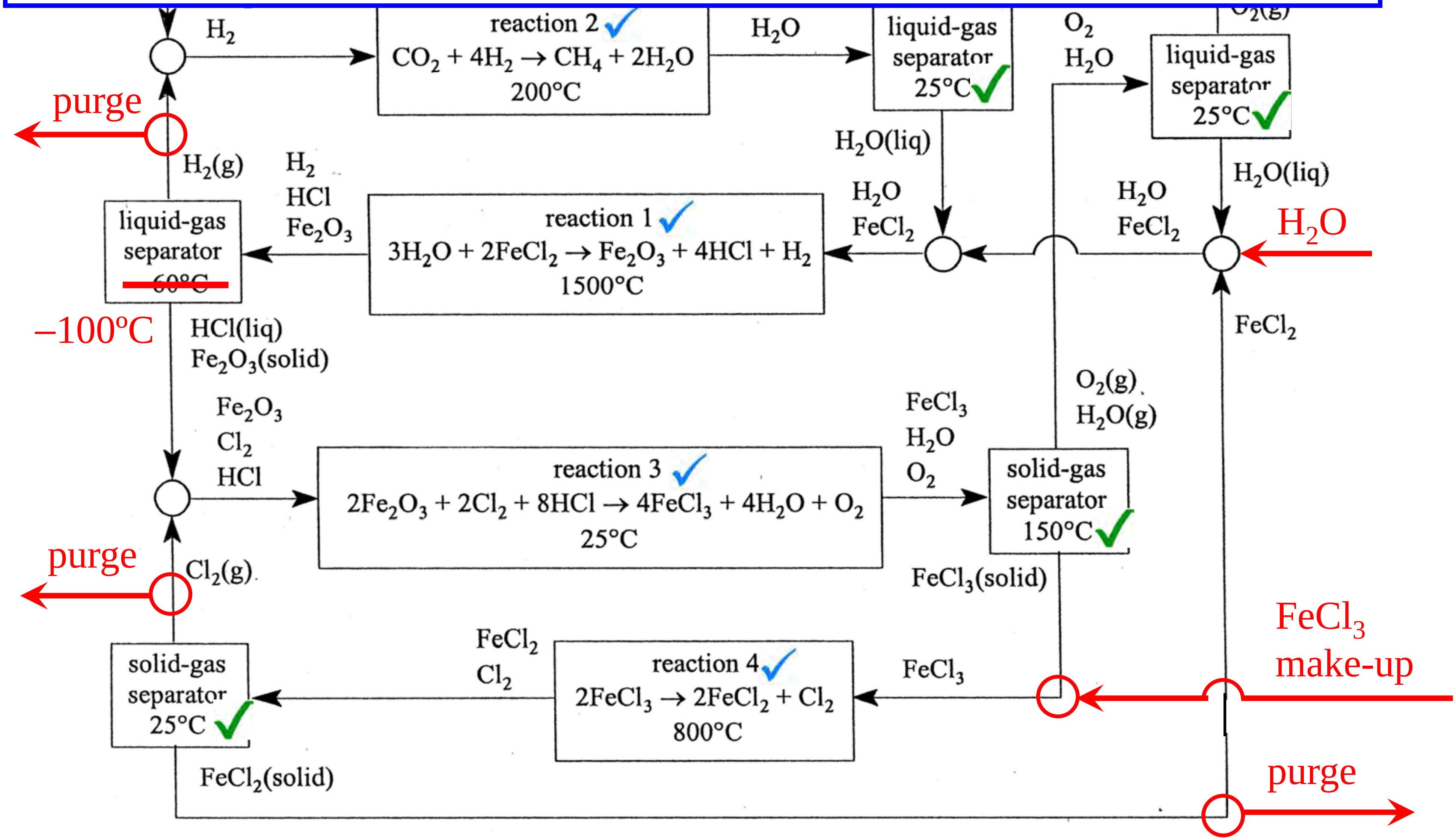


1. ... rator ... es

Why do we need a $FeCl_3$ make-up input?

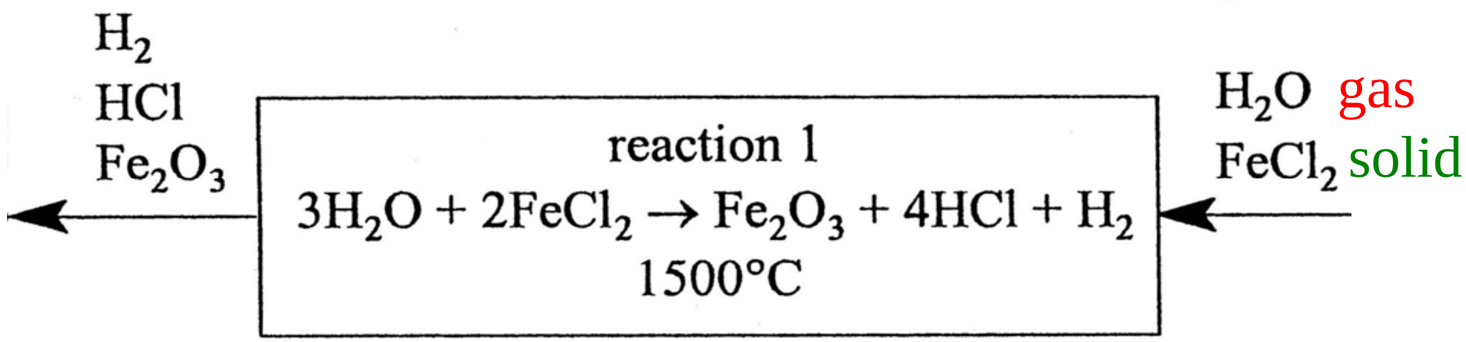
2. Check reactor — 4. Recycle loops

Draw borders around the entire process. Fe atoms leave in the $FeCl_2$ purge. Eventually there would be no Fe in the process.



Engineering Details: Transporting Solids

Consider reaction 1.



Problem: Devise a means to transport a mixture of solids and gases into, through, and out of a reactor.

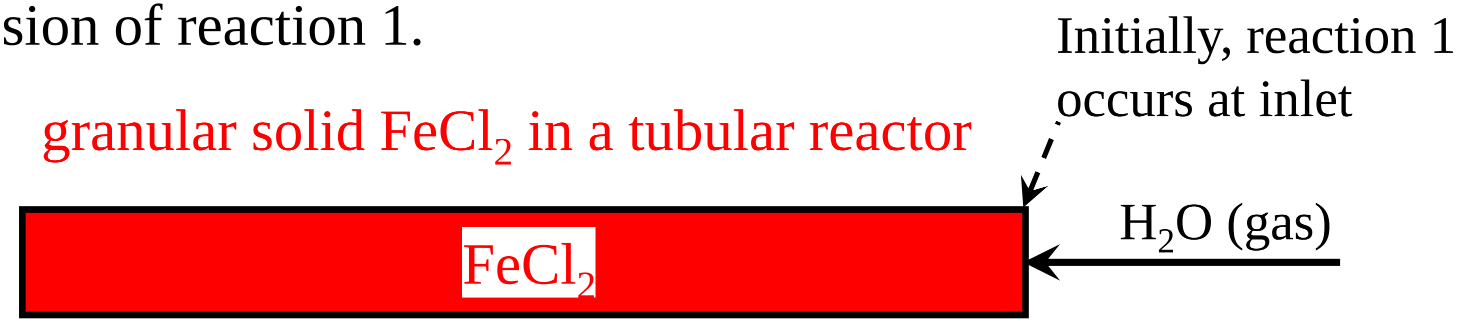
Input must be an exact ratio of 3 mols H_2O to 2 mols $FeCl_2$.

Real Problem: Convert H_2O to H_2, convert solid $FeCl_2$ to solid Fe_2O_3.

Bring solids to the reaction? No. Bring the reaction to the solids.

Consider the progression of reaction 1.

Initially …

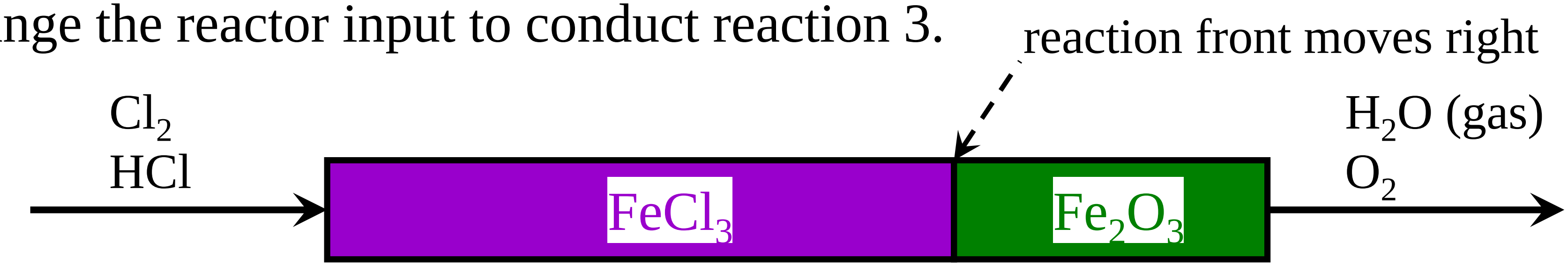


$$3H_2O + 2FeCl_2 \rightarrow Fe_2O_3 + 4HCl + H_2$$

Later …

Eventually reactant gases are detected in the reactor effluent.

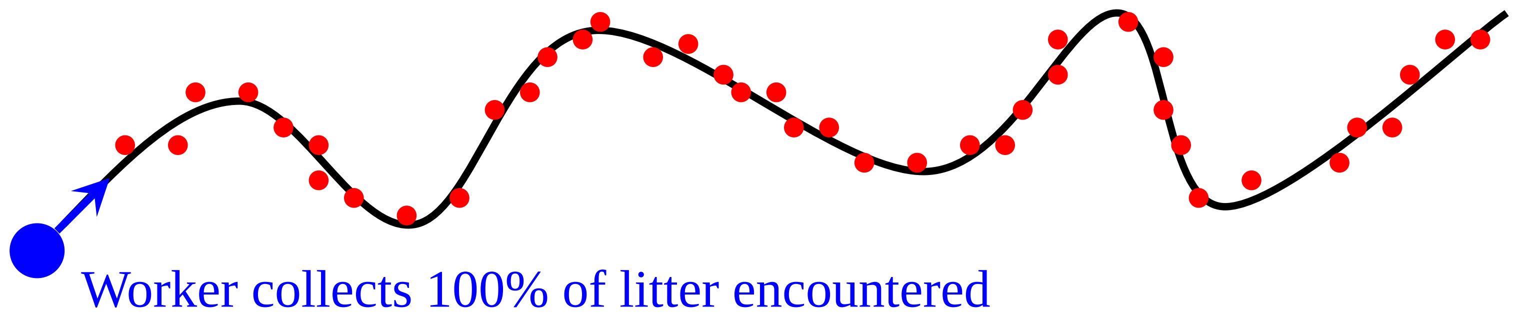
Change the reactor input to conduct reaction 3.



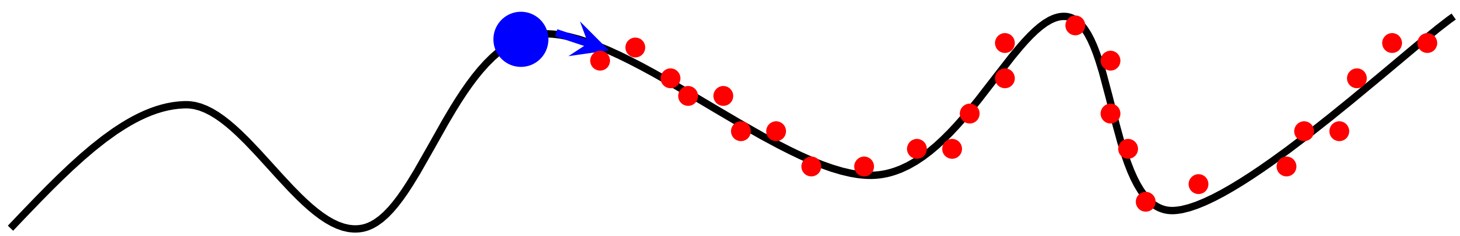
$$2Fe_2O_3 + 2Cl_2 + 8HCl \rightarrow 4FeCl_3 + 4H_2O + O_2$$

A moving reaction front allows for a lower reaction temperature and a lower conversion.

Analogy: Consider a hiking trail littered with trash.

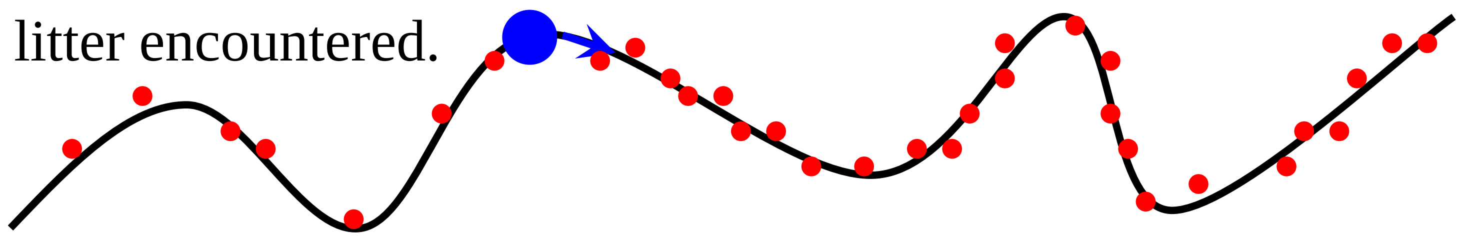


Later …

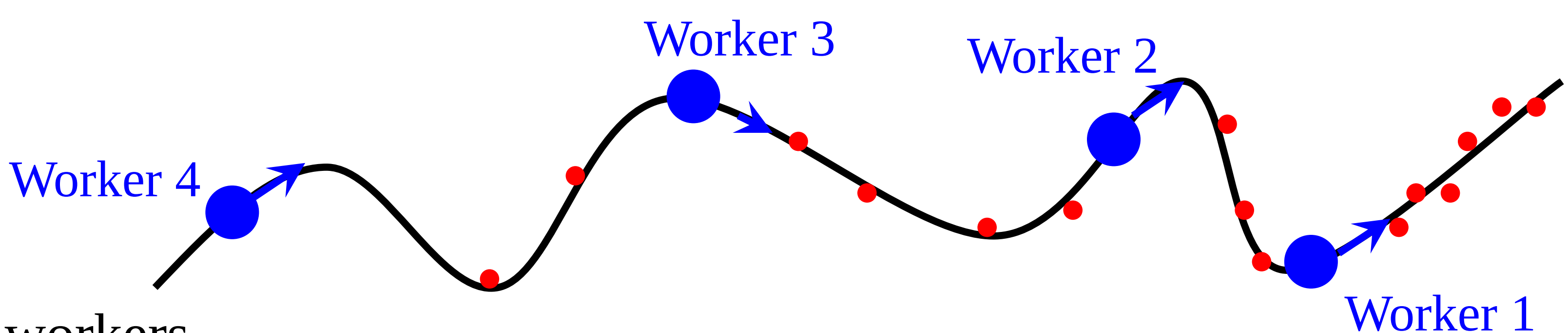


Consider a series of workers.

Each collects 50% of litter encountered.



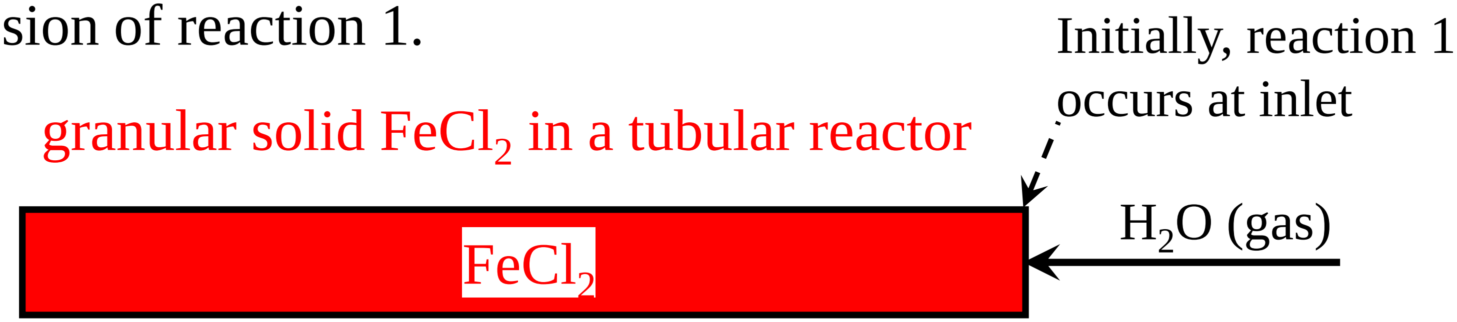
Later …



Imagine 10^{23} workers.

Consider the progression of reaction 1.

Initially …

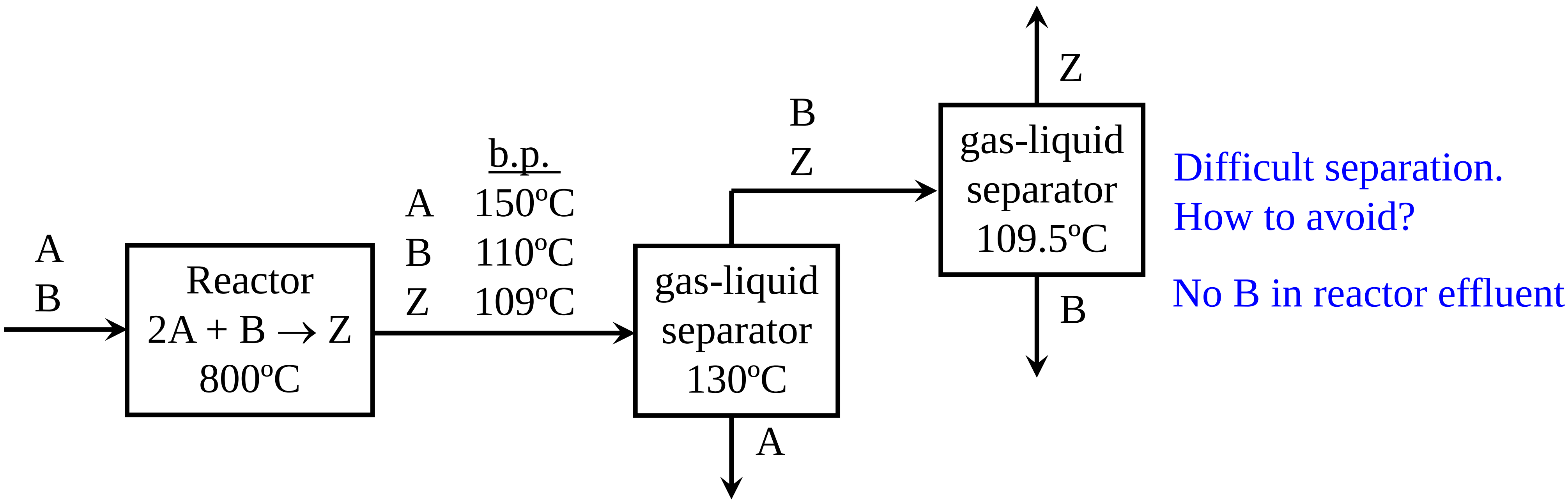


$$3H_2O + 2FeCl_2 \rightarrow Fe_2O_3 + 4HCl + H_2$$

Later …

Strategies for reactions with <100% conversion

Excess reactants



Strategy: Use excess reactant A to deplete co-reactant B in reactor effluent.

In general $e^{-\Delta G / RT} \propto \dfrac{\text{(products)}}{\text{(reactants)}}$ at equilibrium

In this case, at 800ºC $10 = \dfrac{a_Z^1}{a_A^2 a_B^1}$

~90% conversion

stoichiometric coefficient

a = chemical activity

for liquids and solids, $a \approx 1$

$$10 = \frac{P_Z}{P_A^2 P_B}$$

for gases, $a \approx$ (partial pressure)/(1 bar)

Strategies for reactions with <100% conversion

Excess reactants

$$2A + B \rightarrow Z$$

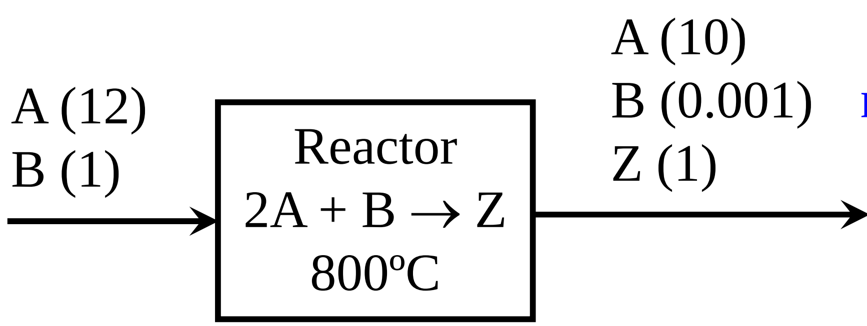
$$e^{-\Delta G/RT} \propto \frac{\text{(products)}}{\text{(reactants)}}$$

$$10 = \frac{P_Z}{P_A^2 P_B}$$ assume P_Z = 1 bar ≈ 1 atm

$$10 = \frac{1}{P_A^2 P_B} \quad \Rightarrow \quad P_A^2 P_B = 0.1 \text{ in reactor effluent}$$

Example: set P_A = 10 atm in reactor effluent. $\Rightarrow \quad 10^2 P_B = 0.1$

$$P_B = 0.001 \text{ atm}$$



negligible? If not, increase A in input