

How to use PharmaHUB

www.PharmaHUB.org

A source for supplemental pharmaceutical course material

C. Stewart Slater and Mariano J. Savelski

Rowan University

Glassboro, NJ

Contributors:

David Hitchcock, Alexander Jannini, Michael Terkhanian, William Wilkins

2012 ASEE Summer School for Chemical Engineering Faculty

Orono, ME

July 2012

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PHARMAHUB

COLLABORATION FOR PHARMACEUTICAL ENGINEERING AND SCIENCE

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HOPPER FLOW DISCHARGE

Hoppers are commonly used devices for handling and storing granular materials. Despite their common use and deceptively simple design...

Learn more



Find Resources

Keyword or phrase:

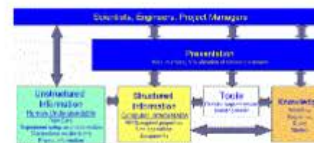
Search

- Popular Tags:
- Knowledge-based systems
 - Discrete element model (DEM)
 - Qbd presentation
 - Van der waals force
 - Particle adhesion
 - Process modeling
 - Hamaker constants
 - Particle-based computations
 - Roller compaction

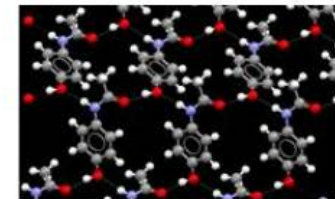
featured pharmaHUB online tools and resources



Visualization of Particle-Based Computer Data



Pharmaceutical Informatics



Computational Methods for Molecular Crystals

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Letters not clear?
[Click to renew CAPTCHA.](#)

Please enter the following characters you see into the textbox below.

- To access the materials available on PharmaHUB, move mouse over “Resources” in the main toolbar

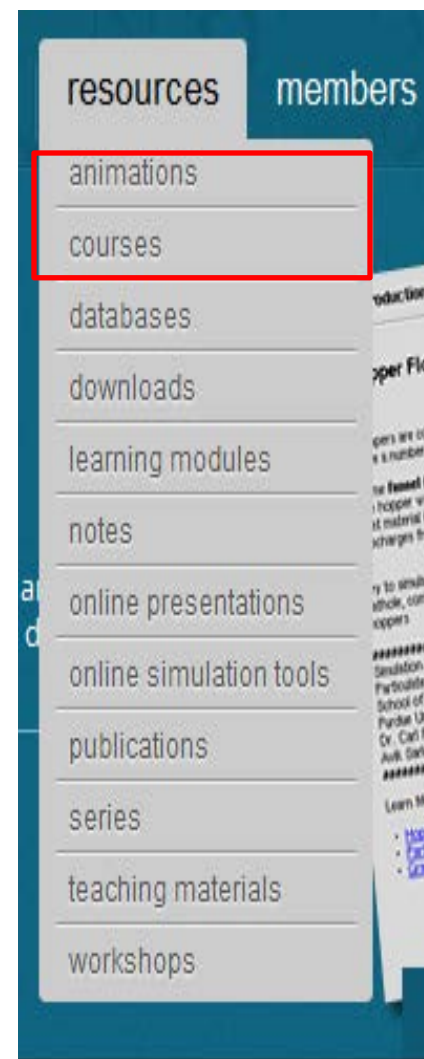
- Here you can access all of the resources available on PharmaHUB

- Each of the links provides access to different resources

The screenshot displays the PharmaHUB website interface. At the top left is the PharmaHUB logo, which includes a stylized molecular structure and a pill. To the right of the logo is the text "COLLABORATION FOR PHARMACEUTICAL ENGINEERING AND SCIENCE". Below this is a navigation bar with links for "home", "resources", "members", "partners", and "about". The "resources" link is highlighted, and a dropdown menu is open, listing various resource categories: "animations", "courses", "databases", "downloads", "learning modules", "notes", "online presentations", "online simulation tools", "publications", "series", "teaching materials", and "workshops". The main content area features a large heading "HOPPER FLOW DISCHARGE" and a sub-heading "HOPPER FLOWS". Below this is a paragraph of text: "Hoppers are commonly used devices for handling granular materials. Despite their common use and simple design...". A "Learn more" link is provided. On the right side of the page, there is a preview of a simulation titled "Hopper Flows" which includes a 3D model of a hopper and a graph showing "Mass remaining in hopper vs. time". The graph shows a curve that starts at a high value and decreases over time, leveling off towards the end.

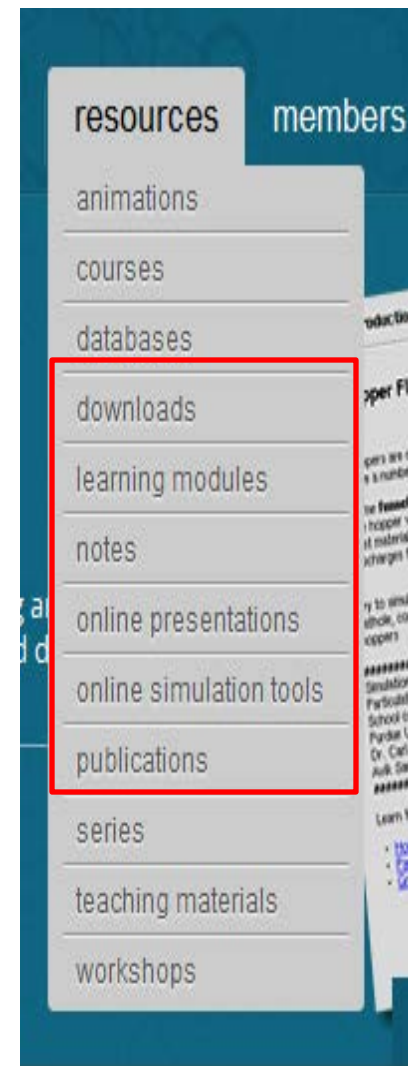
Resources

- Animations
 - Animations for visualizing particle motion
 - A video lecture on soft particle discrete element method of modeling
- Courses
 - Introduction to API process development
 - Graduate level computation methods for molecular crystals
 - An introduction to the discrete element method of modeling
 - Building statistical models and applying this to various experiments



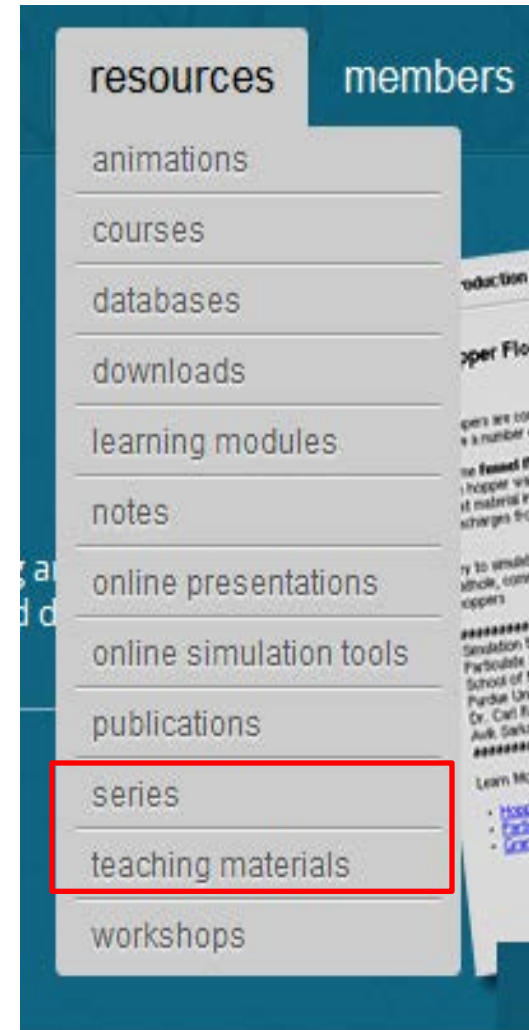
Resources

- Downloads
 - Web browser plug-in for uploading presentations
 - ParticleVis: software for visualizing particle motion
 - A tablet compaction scale-up program
 - ViewStruct: software for visualizing crystal structures
- Online Presentations
 - Presentations uploaded for a class or project
 - Some presentations can be viewed online with a presenter and are timed
 - Others can be downloaded as a Powerpoint or pdf
- Learning Modules
 - None available at this time
- Publications
 - Journal articles
 - Presentations
 - General information



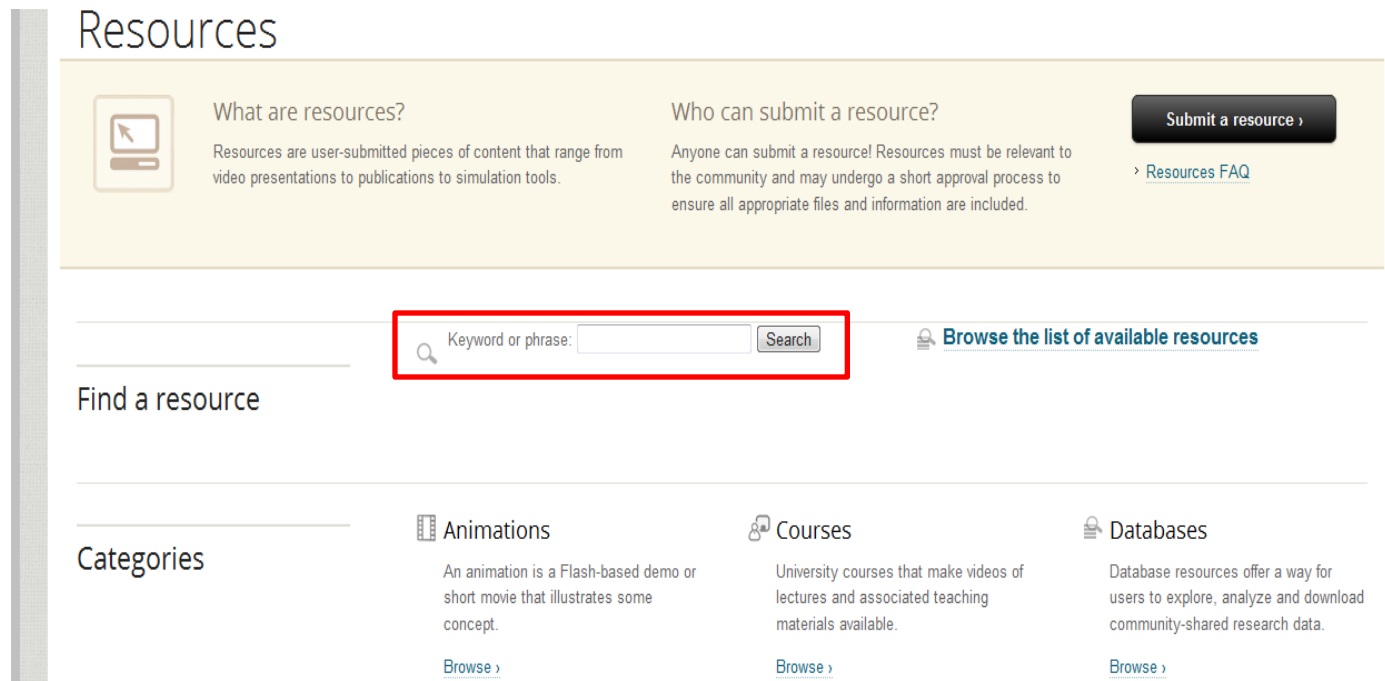
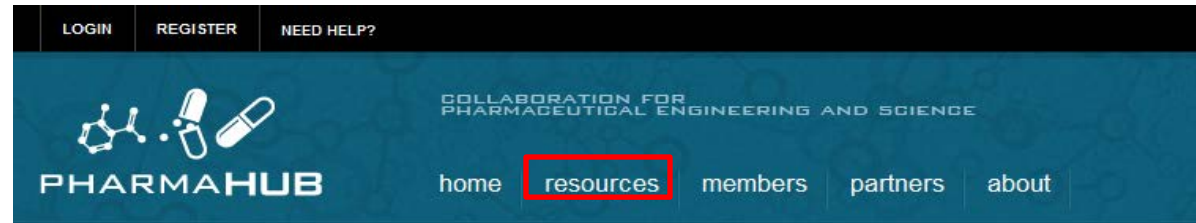
Resources

- Series
 - These series contain all resources on PharmaHUB related to specialized topics
 - Particle and thin film adhesion
 - Pharmaceutical informatics
 - Purdue ontology for pharmaceutical engineering
 - The body of pharmaceutical data generated by Purdue
 - Visualization of particle-based computer data
- Teaching Materials
 - Various teaching materials used in:
 - Courses
 - Series
- Workshops
 - None available at this time



Accessing Resources

- Left click on “Resources”
- Search for resources or select from the different “Categories”



Another Way to Access Resources

- On home page, lower left hand corner has a small resource section
- Search for resources, select a topic in popular tags, or select a category

PHARMAHUB home

Find Resources

Keyword or phrase:

Search

Popular Tags

- Knowledge-based systems
- Discrete element model (DEM)
- QbD presentation
- Van der waals force
- Particle adhesion
- Process modeling
- Hamaker constants
- Roller compaction
- Particle-based computations
- Johanson's model
- Statistical model building
- Molecular modeling
- Visualization
- Dry granulation
- Excipients
- Database
- Active pharmaceutical ingredient (API)
- Thin films
- Fast fourier transform
- Crystal graph
- Surface roughness
- Surface forces
- Filtration
- Expert system
- Hopper flow
- Pharmaceutical concepts into introductory ChE courses
- Pharmaceutical manufacturing
- NIPTE
- Product development
- Solid-liquid separation
- Particle modeling
- Compartment model
- Modeling
- Dissolution
- Recipe representation
- Micromanufacturing
- Drop formation
- Protege
- Individualized dosage regimen
- Scheduling optimization
- More tags >

[Animations](#), [Courses](#), [Databases](#), [Downloads](#), [Learning Modules](#), [Notes](#), [Online Presentations](#), [Publications](#), [Series](#), [Teaching Materials](#), [Tools](#), [Workshops](#), [All Categories >](#)

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Another Way to Access Resources

- Items in the “Tag” box refer to various categories
- Items in the “Resources” box refer to different topics within each category

Another Way to Access Resources

- Select an item under “Tag”
- Select an item under “Resources”
- You will be able to access the material by clicking the “Download” link

PHARMAHUB COLLABORATION FOR PHARMACEUTICAL ENGINEERING AND SCIENCE

home resources members partners about

You are here: Resources > Teaching Materials

Resources: Teaching Materials

Teaching Materials

Tag Resources

[All] Applications: Solvent Switching

Active pharmaceutical ingredient (API) (4)

Batch reaction (1)

Bayesian modeling (1)

Colloids and surfactants (1)

Discrete element model (DEM) (8)

Dissolution (1)

Distillation (1)

Drop penetration time (1)

Drug delivery (1)

ERC (1)

Filtration (1)

Granulation (1)

Individualized dosage regimen (1)

Induction (1)

life cycle analysis (1)

Mixing (2)

Molecular modeling (1)

Batch Distillation Basics

Introduction to API Process Simulation

Solid-Liquid Separations

Applications: Solvent Switching

This module presents an application of a simulation model in API process development and design. The application involves the use of a simulation model to compare feed profiles for solvent switching in a batch vessel. ERC for Structured Organic Particulate Systems [Learn more >](#)

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184 users

Another Way to Access Resources

- Can access certain resources through podcasts
 - Video podcasts
 - Audio podcasts

The screenshot shows the PHARMAHUB website header with the logo and navigation menu. The main content area displays the course title 'Pharmaceutical API Process Development and Design' by Kamal Kuriyan from Purdue University. A 'View Course Lectures' button is present, along with a list of resource types: 'Audio podcast', 'Video podcast', and 'Slides/Notes podcast'. The 'Audio podcast' and 'Video podcast' items are highlighted with a red box. On the right side, there are options for '0 wish(es)', '0 questions', social sharing, and 'Add to your favorites!'.

PHARMAHUB COLLABORATION FOR PHARMACEUTICAL ENGINEERING AND SCIENCE

home resources members partners about

You are here: resources > Courses > Pharmaceutical API Process Development and Design > About

Pharmaceutical API Process Development and Design

By Kamal Kuriyan
Purdue University

View Course Lectures

- Audio podcast
- Video podcast
- Slides/Notes podcast

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Another Way to Access Resources

- When selecting podcasts, must subscribe to content



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[Video] Pharmaceutical API Process Development and Design

API process development involves selection, preliminary design and scale-up of the equipment used to carry out the recipe for producing the desired form of the drug substance. This course will cover selected topics in API process development. Operations studied include batch reaction, evaporation, crystallization and filtration. The material is organized into two parallel tracks. One track introduces the basic concepts, equipment types and modes of operation for common API unit operations. The ...

- When subscribed, the you will be able to access content in the Bookmarks Toolbar



ost Visited Getting Started Latest Headlines [Video] Pharmaceutica... [Video] Discrete Eleme... [Audio] Discrete Eleme...

- All checked podcasts are empty at the moment

Course Materials

- Mass & Energy Balances
- Fluid Transport
- Heat Transfer
- Thermodynamics
- Kinetics & Reaction Engineering
- Separations
- Process Design
- Introduction to Pharmaceutical Engineering
- Pharmaceutical Engineering Unit Operations
- Crystallization
- Particulate Processing

Course Materials

| | Intro Chem Eng. | Fluid Transport | Unit Ops. | Seps. | Intro to Pharma | Heat Transfer | Crystallization | Advanced Topics | Design | Statistical Model Building | Kinetics and Reaction Engineering | Thermo |
|---|-----------------|-----------------|-----------|-------|-----------------|---------------|-----------------|-----------------|--------|----------------------------|-----------------------------------|--------|
| Integrating Pharmaceutical Concepts into Introductory Chemical Engineering Courses - Part I | ✓ | | | | | | | | | | | |
| Introduction to Mixing Equipment and Processes in Pharmaceutical Operations | | | ✓ | | ✓ | | | | | | | |
| ERC-SOPS Educational Modules | ✓ | ✓ | ✓ | | ✓ | | | | | | | |
| Introduction to API Process Simulation | ✓ | | | | ✓ | ✓ | | | | | ✓ | |
| Pharmaceutical Bulk Drug Production | ✓ | | | | ✓ | | | | ✓ | | | |
| Solid-Liquid Separations | | | | ✓ | | | | | | | | |
| Batch Distillation Basics | ✓ | | | ✓ | | | | | | | | ✓ |
| Particle Processing and Modeling in the Pharmaceutical Industry | | | ✓ | | | | ✓ | ✓ | | | | |
| Review of Statistics | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | | |

Note: Only representative Teaching Materials included

Mass & Energy Balances

- Integrating Pharmaceutical Concepts into ChE courses (Word document - Compendium of Problem Sets, Farrell, Savelski, Slater, Rowan University, 2010)
 - Location:
 - Search “Mass and Energy Balances”
 - 3 problem sets with numerous problems integrating pharmaceutical concepts into ChE curriculum
 - Unit conversions
 - Balances on reactive/non-reactive processes
 - Process variables
 - Overall mass and energy balances

C. Stewart Slater (2010), "Integrating Pharmaceutical Concepts into Introductory Chemical Engineering Courses - Part I," <https://pharmahub.org/resources/360>. (C. Stewart Slater – Rowan University)

Mass & Energy Balances

F&R 4.3c TB1.16e (Powder blending calculations)

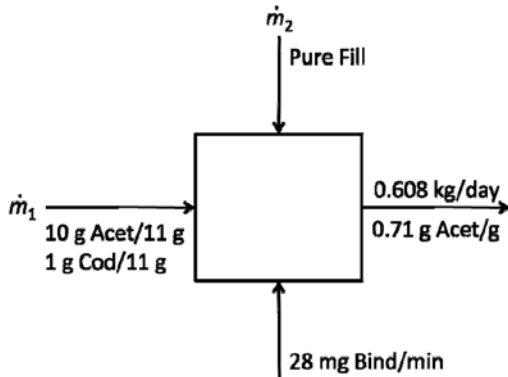
One of the unit operations in the pharmaceutical engineering is **powder blending** in which multiple powders are mixed together to give a uniform product. In the production of a tablet, **binders** (effectively glue for powders), **fillers** (for dilution) and the **active pharmaceutical ingredients** (APIs) are blended. In a lab blender being tested, 10 parts acetaminophen to one part codeine are being fed as API. Pure starch enters at 28 mg/min along with a pure stream of microcrystalline cellulose (MCC) filler. The mixer is run continuously in order to produce 3.04 kg in 5 days at 71 wt% acetaminophen. Draw and label a flowchart and determine all mass flow rates and compositions.

C. Stewart Slater (2010), "Integrating Pharmaceutical Concepts into Introductory Chemical Engineering Courses - Part I," <https://pharmahub.org/resources/360>. (C. Stewart Slater – Rowan University)

Mass & Energy Balances

Solution

We begin with our flowchart:



Note the conversion of the awkward kg/5 days to kg/day.

At this point, we may examine the diagram to see where best to start. We are given enough data to solve an equation on acetaminophen ("Acet" in the figure).

$$\sum_{\text{in}} \dot{m} = \sum_{\text{out}} \dot{m}$$

$$\dot{m}_1 \times \frac{10 \text{ g Acet}}{11 \text{ g}} = 0.71 \frac{\text{g Acet}}{\text{g}} \times 0.608 \frac{\text{kg}}{\text{day}}$$

$$\dot{m}_1 = 0.475 \frac{\text{kg}}{\text{day}} \times 1000 \frac{\text{g}}{\text{kg}} \times \frac{1 \text{ day}}{24 \text{ h}} \times \frac{1 \text{ h}}{60 \text{ min}} = 0.330 \frac{\text{g}}{\text{min}}$$

From this the total flow may be determined

$$\sum_{\text{in}} \dot{m} = \sum_{\text{out}} \dot{m}$$

$$0.330 \frac{\text{g}}{\text{min}} + \dot{m}_2 + 28 \frac{\text{mg}}{\text{min}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 0.608 \frac{\text{kg}}{\text{day}} \times 1000 \frac{\text{g}}{\text{kg}} \times \frac{1 \text{ day}}{24 \text{ h}} \times \frac{1 \text{ h}}{60 \text{ min}}$$

$$\dot{m}_2 = [0.422 - (0.330 + 0.028)] \frac{\text{g}}{\text{min}}$$

$$\dot{m}_2 = 0.064 \frac{\text{g}}{\text{min}}$$

Now, since the problem asked for everything specified, this is best answered as a table:

| | | Mass flows (g/min) | | | |
|----------------|----------------|--------------------|-------|-------|--------|
| | | m1 | m2 | Bind | Out |
| | | 0.330 | 0.064 | 0.028 | 0.422 |
| Mass fractions | x _A | 0.909 | 0 | 0 | 0.7109 |
| | x _C | 0.091 | 0 | 0 | 0.071 |
| | x _B | 0 | 0 | 1 | 0.066 |
| | x _F | 0 | 1 | 0 | 0.152 |

Fluid Transport

- Introduction to Mixing Equipment and Processes in Pharmaceutical Operations (Powerpoint lecture slides, Armenante, Rutgers University, 2009)
 - Location:
 - Teaching Materials → Mixing
 - Apply mixing principles to pharmaceutical processes
 - Single and multiphase mixing in pharmaceutical processes
 - Analyze pharmaceutical processes where mixing is important
 - Tools to conduct process design analysis and scale-up

Fluid Transport

Objectives

- Become familiar with the principles of single and multiphase mixing in pharmaceutical processes
- Analyze pharmaceutical processes or in which mixing is important
- Provide basic tools to conduct process design analysis and scale-up of processes or in which mixing is important

Piero M. Armenante

ChE702

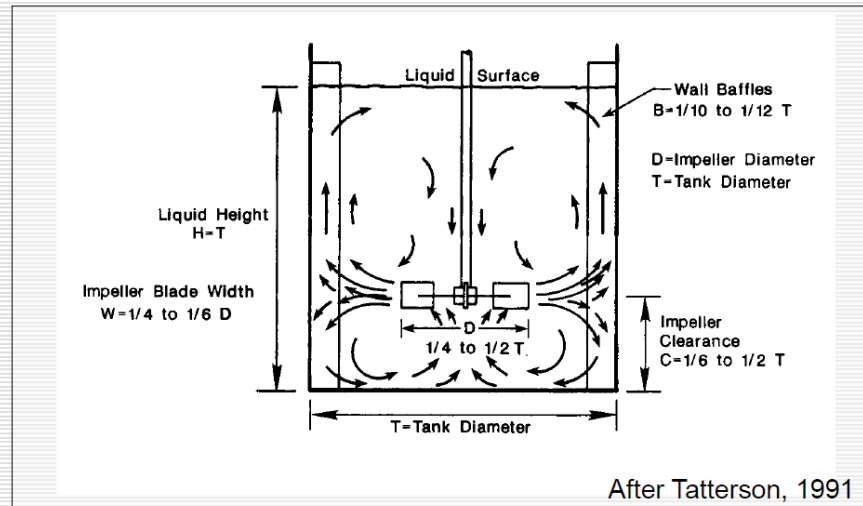
2

Piero Armenante; Henrik Pedersen (2009), "Introduction to Mixing Equipment and Processes in Pharmaceutical Operations," <https://pharmahub.org/resources/292>. (Piero Armenante – Rutgers University)

Fluid Transport

- Impeller influences flow pattern
 - How does this influence process decisions

Flow Generated by a Radial Impeller in a Stirred Tank



Piero M. Armenante

ChE702

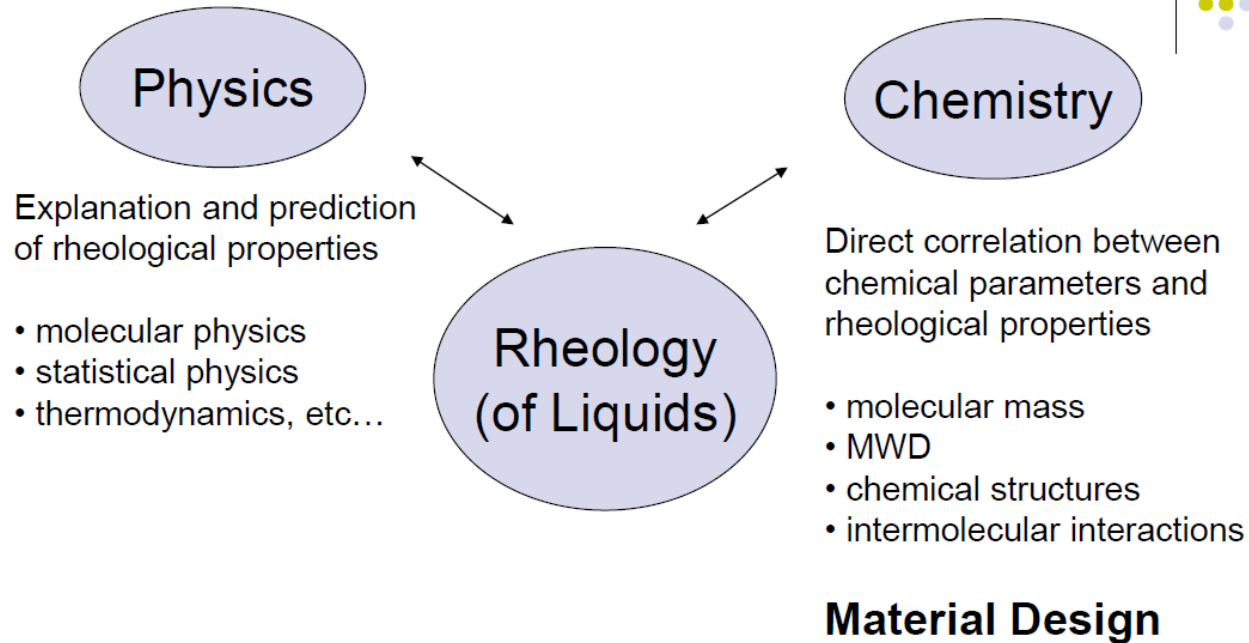
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Fluid Transport

- Introduction to the Rheology of Complex Fluids (Powerpoint lecture slides, Acevedo, Pederson, Rutgers University, 2010)
 - Location:
 - Teaching Materials → Rheology
 - Lecture
 - Mathematics behind complex fluid transport
 - Stress
 - Viscosity
 - Viscoelastic Modulus
 - Mathematical modeling approaches

Fluid Transport

Rheology as an Interdisciplinary Science



Dr. Aldo Acevedo - ERC SOPS

10

Fluid Transport

Modeling of Shear Thinning and Thickening

- Carreau-Yasuda Model

$$\frac{\eta(\dot{\gamma}) - \eta_{\infty}}{\eta_0 - \eta_{\infty}} = [1 + (\dot{\gamma}\lambda)^a]^{\frac{n-1}{a}}$$

a – affects the shape of the transition region

λ – time constant determines where it changes from constant to power law

n – describes the slope of the power law

η_0, η_{∞} - describe plateau viscosities

- Advantages: fits most data
- Disadvantages: contains 5 parameters, do not give molecular insight into polymer behavior

Heat Transfer

- Introduction to API Process Simulation (Powerpoint lecture slides, Kuriyan, Purdue University, 2009)
 - Location:
 - Teaching Materials → Active Pharmaceutical Ingredient (API)
 - Presentation presenting methods to model heat transfer in pharmaceutical process
 - Heat or cool a phase with a jacket (flow)
 - Heat exchange between phases
 - Heat duty

Heat Transfer

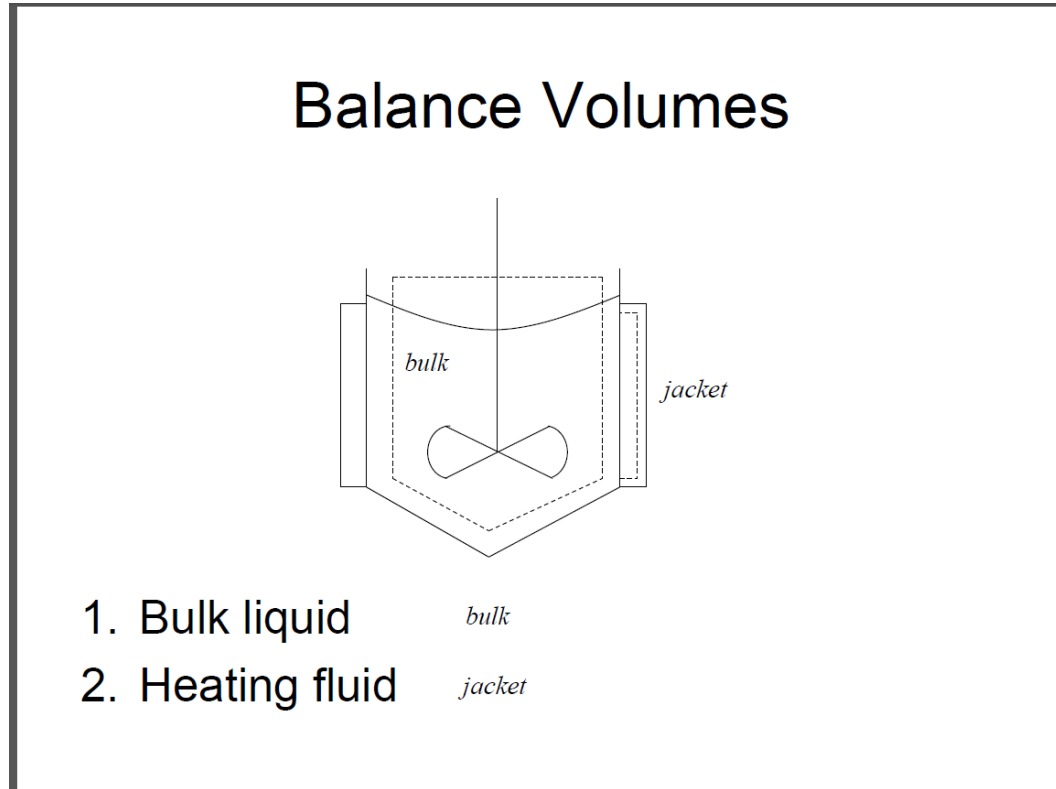
Module Structure

- Process modeling basics
 - Model applications
 - Model types
 - Modeling procedure
- Simulation packages
 - DynoChem
- Examples
 - Heat transfer
 - Batch reactor with accumulation effects

Kamal Kuriyan (2009), "Introduction to API Process Simulation," <https://pharmahub.org/resources/319>.
(Kamal Kuriyan – Purdue University)

Heat Transfer

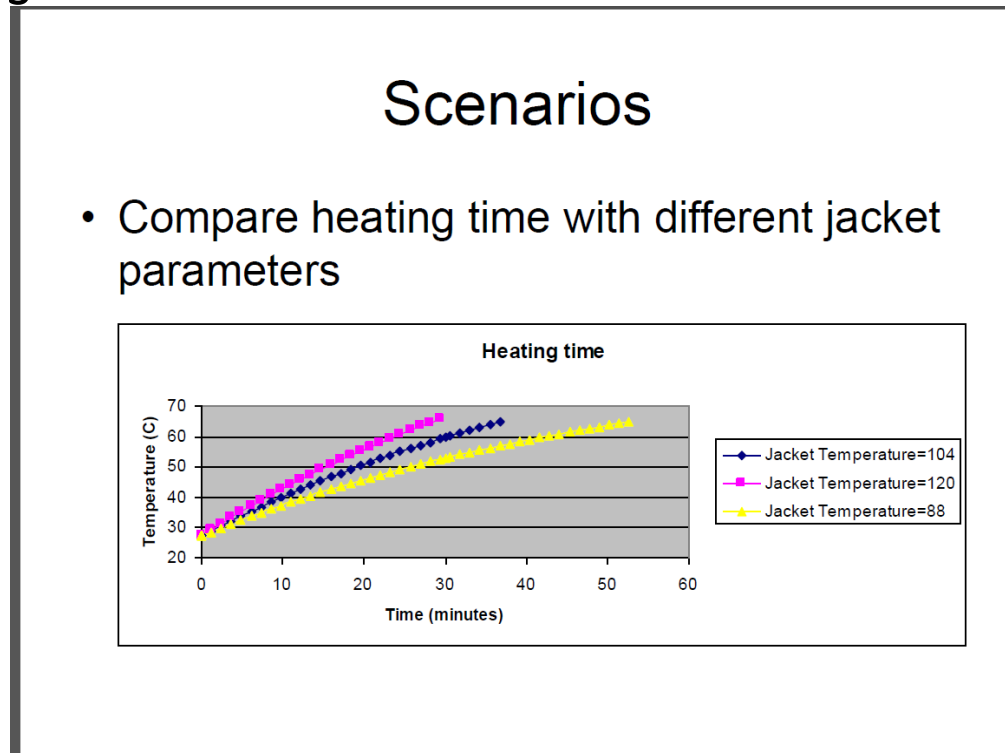
- Modeling example for heat transfer through a jacket



Kamal Kuriyan (2009), "Introduction to API Process Simulation," <https://pharmahub.org/resources/319>.
(Kamal Kuriyan – Purdue University)

Heat Transfer

- Comparison of heating time using different heat transfer parameters



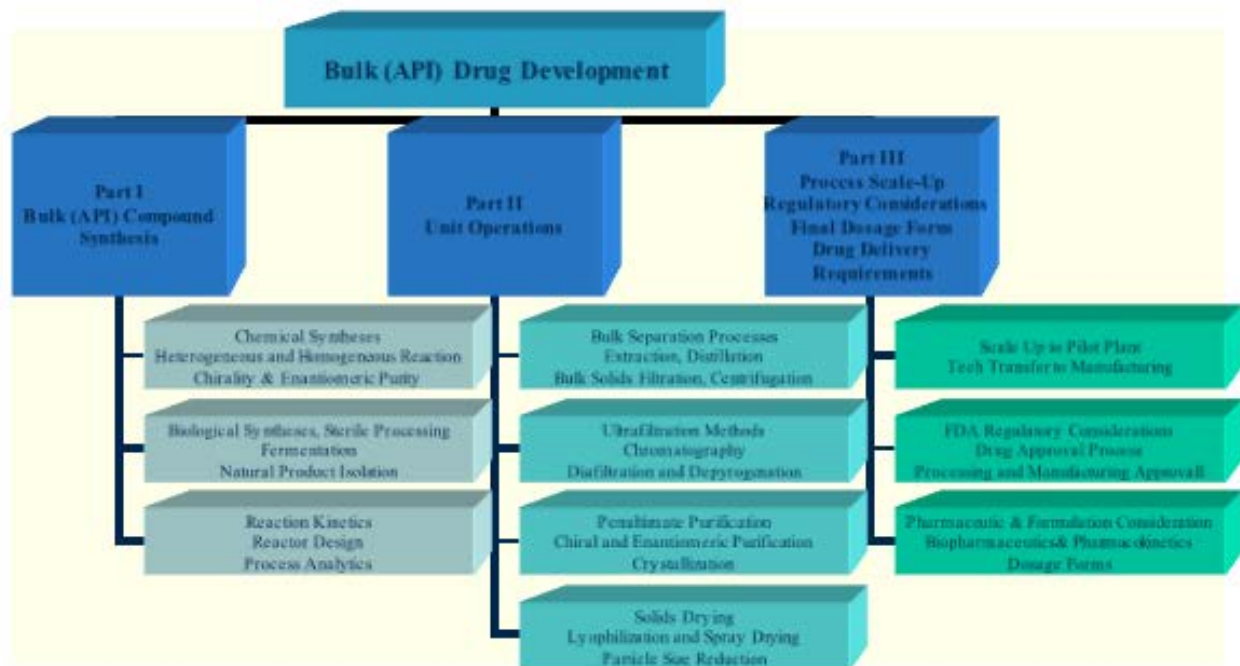
Kamal Kuriyan (2009), "Introduction to API Process Simulation," <https://pharmahub.org/resources/319>.
(Kamal Kuriyan – Purdue University)

Process Design

- Pharmaceutical Bulk Drug Production (Powerpoint lecture slides, Glaser, Rutgers University, 2009)
 - Location:
 - Teaching Materials → Pharmaceutical Manufacturing
 - Two part presentation on pharmaceutical manufacturing
 - Pharmaceutical market
 - Introduction to pharmaceutical engineering
 - API synthesis
 - Process development
 - Scale-up

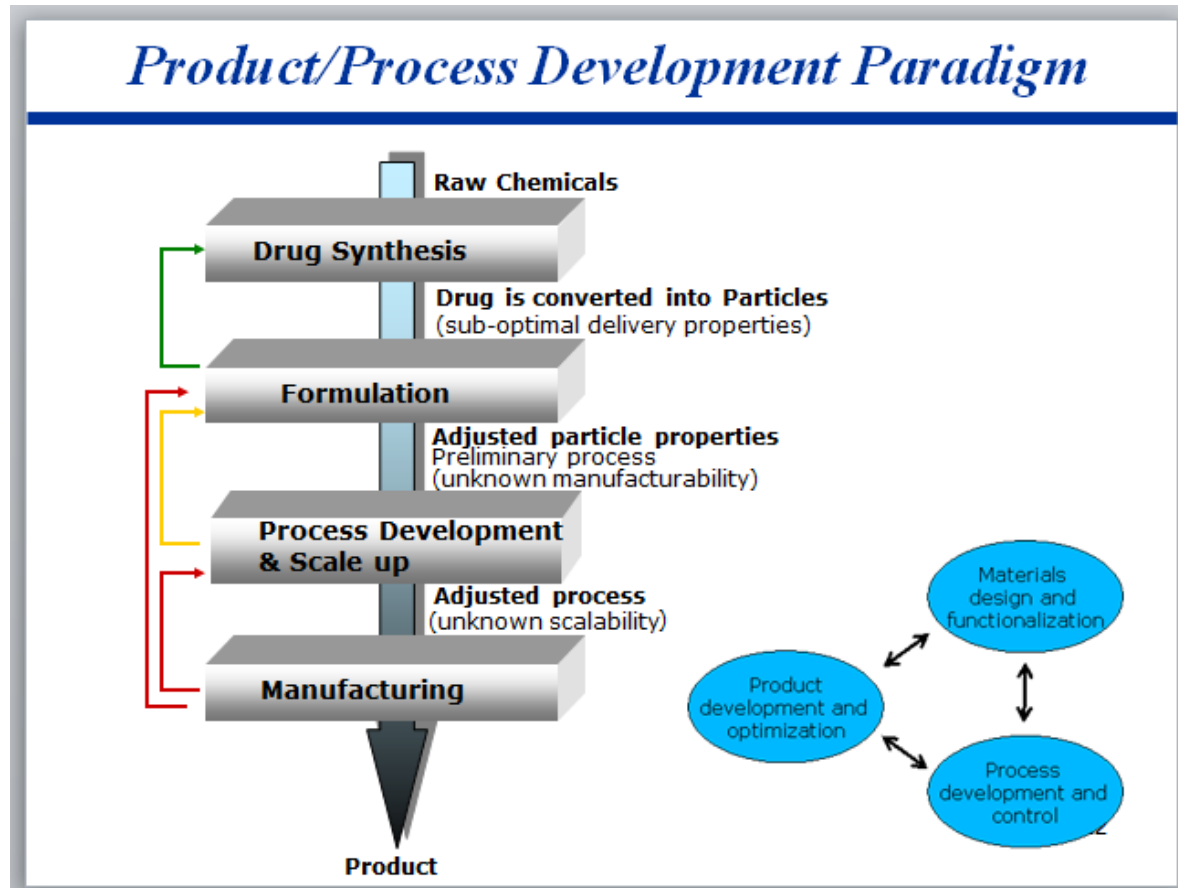
Process Design

Course Overview



2

Process Design



Benjamin Glasser; Henrik Pedersen (2009), "Pharmaceutical Bulk Drug Production,"
<https://pharmahub.org/resources/286>.
(Benjamin Glasser – Rutgers University)

Process Design

Pilot plant objectives

Taken from:

Rosas, C., 2005, Process development in *Active Pharmaceutical Ingredients, Development, Manufacturing and Regulation*, Ed. Nusim, S.H., 2005, Taylor & Francis, New York. (pages 46 & 47)

1. provide ready access to scaled-up processing for the bulk drug preparative effort.
2. give the preparative effort a responsive environment to deal with the vicissitudes of the drug development programs being supported.
3. permit the rapid and convenient evaluation of processes, methods and equipment, as well as the mastery of scale-up.
4. obtain process data to support process design and the development of procedures for the eventual manufacture of the drug.
5. Demonstrate process performance at a scale that minimizes risk and the need to trigger scale-up constraints upon first manufacture.

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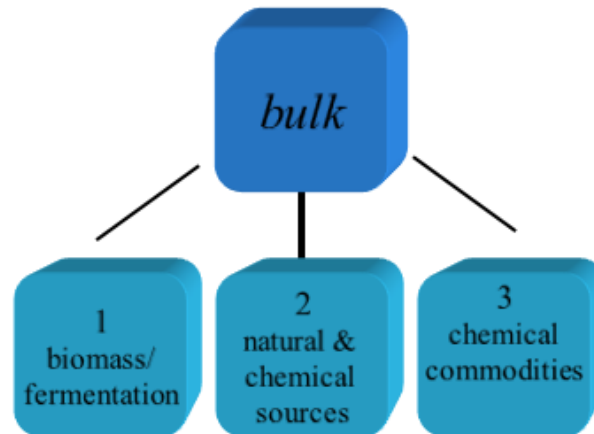
Benjamin Glasser; Henrik Pedersen (2009), "Pharmaceutical Bulk Drug Production," <https://pharmahub.org/resources/286>.
(Benjamin Glasser – Rutgers University)

Process Design

Bulk Drug Synthesis

Bulk drug is obtained via one of the following three chemical processing routes¹

1. *Biosynthetic route* (from biomass or fermentation broth)
2. *Semi-biosynthetic route* with chemical modification (natural & chemical)
3. *Total chemical synthesis* (from chemical commodities and intermediates)



¹Nasim, S., 2005, *Active Pharmaceutical Ingredients*, Taylor & Francis, New York

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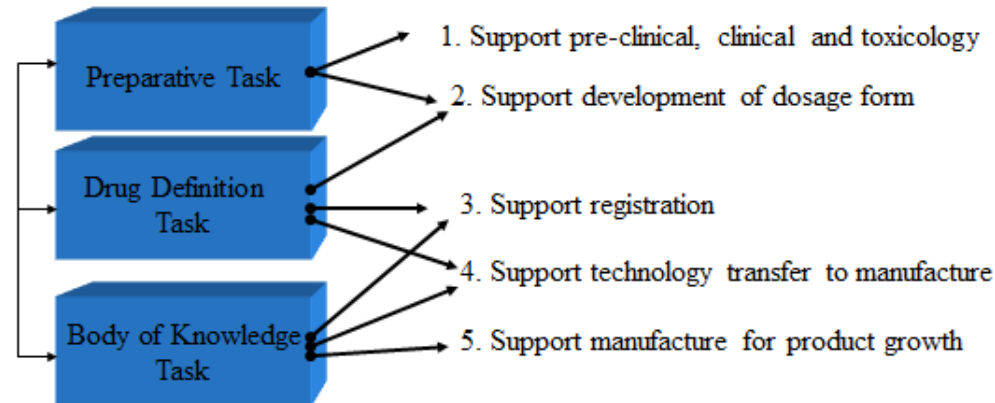
Introduction to Pharmaceutical Engineering

- Pharmaceutical Bulk Drug Production (Powerpoint lecture slides, Glasser, Rutgers University, 2009)
 - Location:
 - Teaching Materials → Pharmaceutical Manufacturing
 - Approval process for drugs
 - Application of chemical engineering principles to pharmaceutical engineering
 - Bulk pharmaceutical manufacturing techniques

Introduction to Pharmaceutical Engineering

Process Development

These stages occur concurrently and must be well managed by a cross-functional development team.



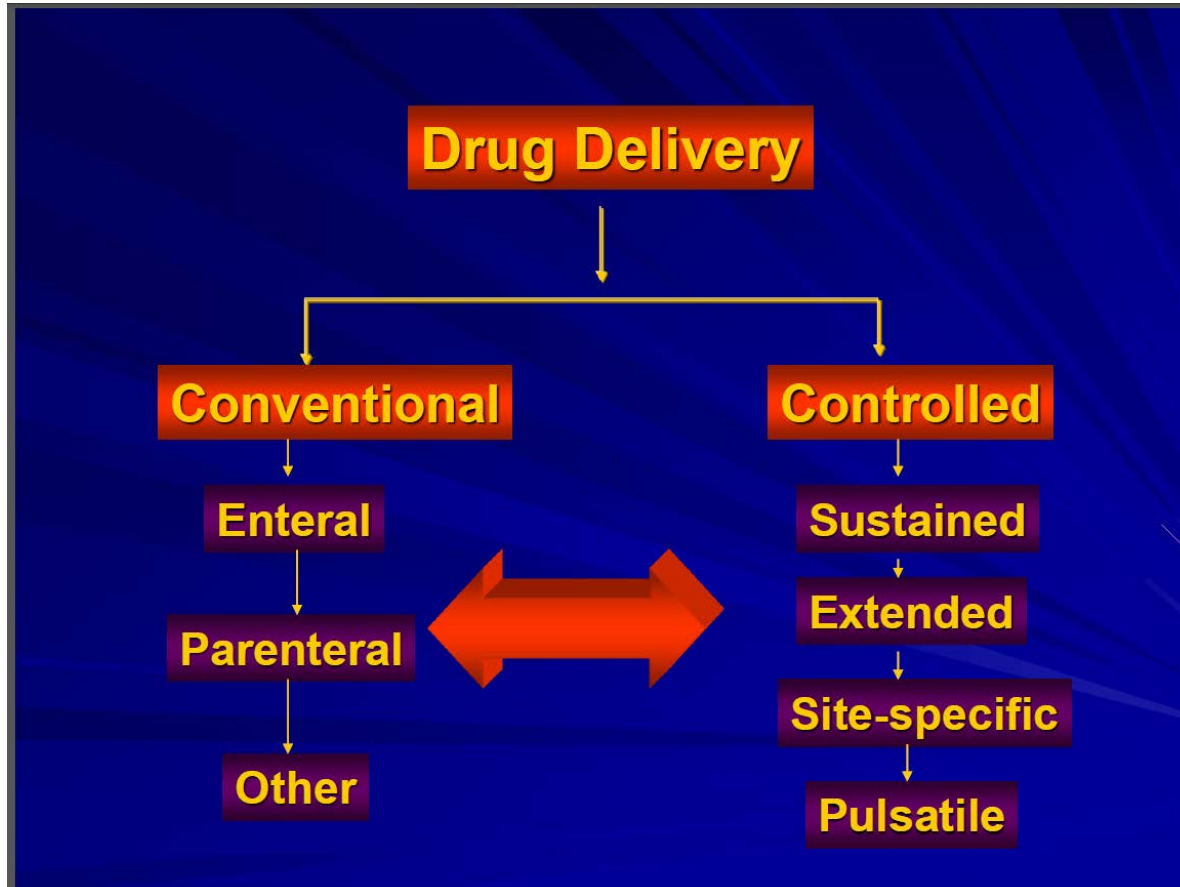
45

Benjamin Glasser; Henrik Pedersen (2009), "Pharmaceutical Bulk Drug Production,"
<https://pharmahub.org/resources/286>.
(Benjamin Glasser – Rutgers University)

Introduction to Pharmaceutical Engineering

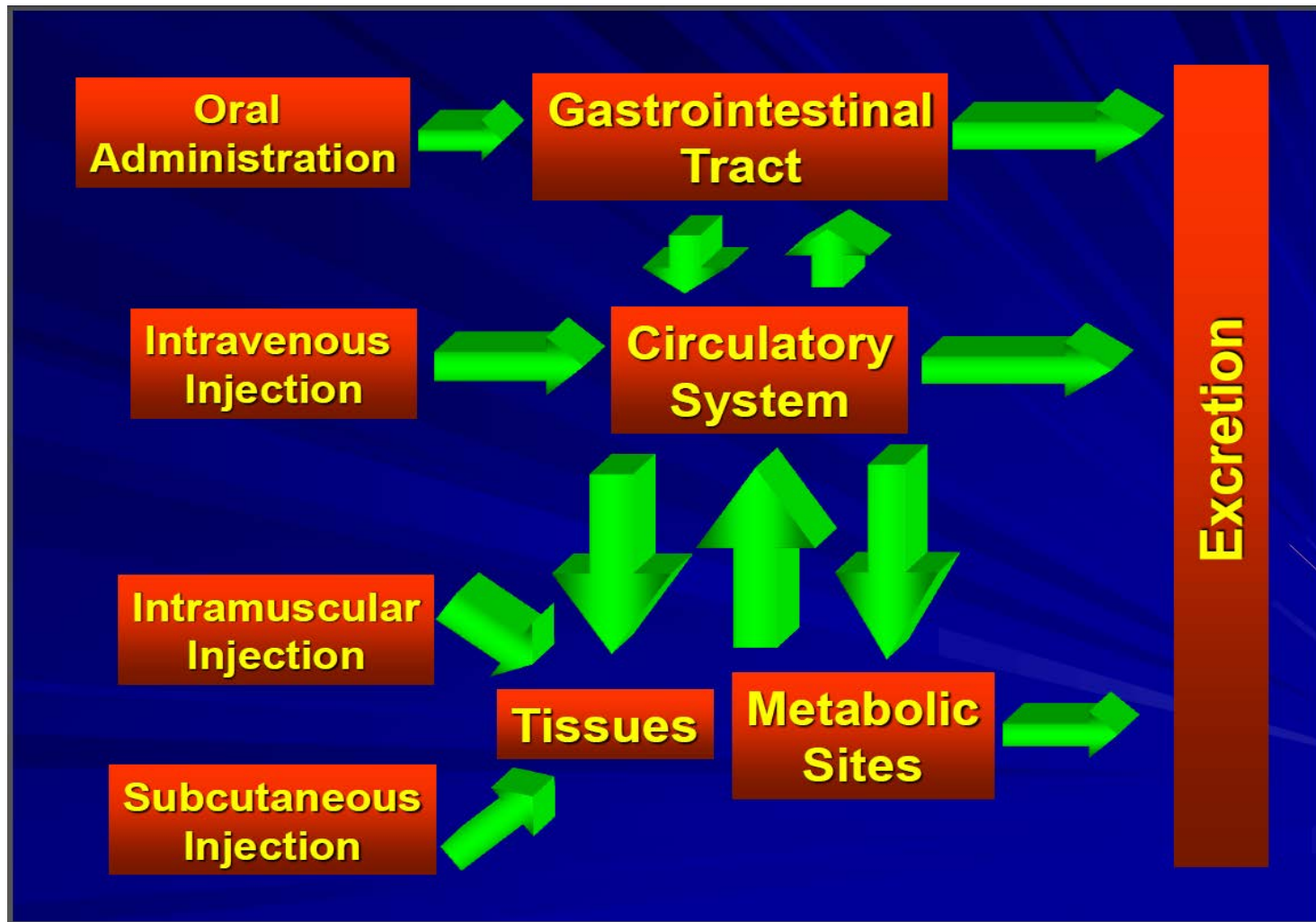
- Application of Chemical Engineering Principles to Drug Delivery (Powerpoint lecture slides, Torres-Lugo, Pederson, Rutgers University, 2010)
 - Location:
 - Teaching Materials → Drug Delivery
 - Types of drug delivery
 - Oral, buccal, subcutaneous, etc
 - Use of chemical engineering principles when selecting drug delivery route
 - Body's response to drugs
 - Mathematical modeling

Introduction to Pharmaceutical Engineering



Madeline Torres-Lugo; Henrik Pedersen (2010), "Application of Chemical Engineering Principles to Drug Delivery," <https://pharmahub.org/resources/339>. (Madeline Torres-Lugo – Rutgers University)

Introduction to Pharmaceutical Engineering



Introduction to Pharmaceutical Engineering

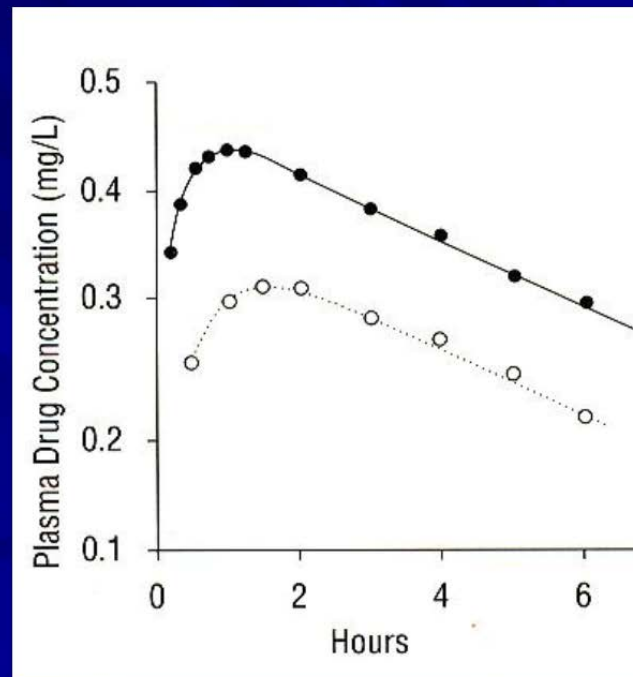
Absorption of drugs could vary within different administration routes

■ 500 mg dose given

- ● intramuscularly
- ○ orally

**to the same subject on separate occasions

■ Biological barriers greatly affect the extent of drug absorption



Separations

- Solid-Liquid Separations (Powerpoint lecture slides, Kuriyan, Purdue University, 2009)
 - Location:
 - Teaching Materials → Active pharmaceutical ingredient (API)
 - Solid-Liquid separation techniques for pharmaceutical processes
 - Cake filtration
 - Centrifugation
 - Deliquoring
 - Washing

Kamal Kuriyan (2009), "Solid-Liquid Separations," <https://pharmahub.org/resources/322>. (Kamal Kuriyan – Purdue University)

Separations

Solid-Liquid Separations

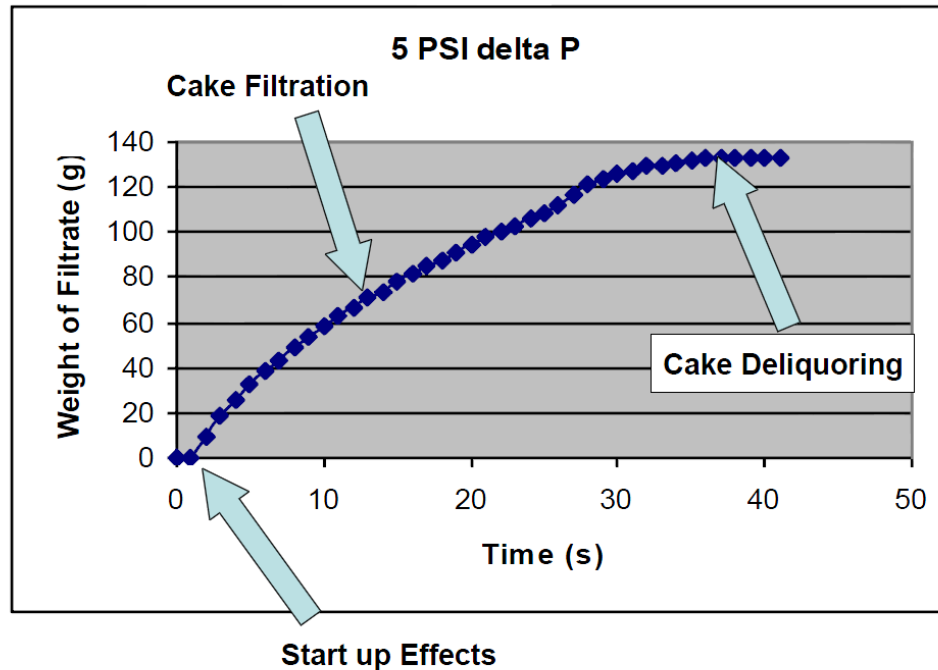
- Filtration Analysis
 - Flow in packed beds
 - Cake Filtration
 - Centrifuges
 - Deliquoring
 - Washing
- Examples
 - Cake compressibility
 - Cycle time calculations

Kamal Kuriyan (2009), "Solid-Liquid Separations," <https://pharmahub.org/resources/322>. (Kamal Kuriyan – Purdue University)

Separations

Filtration Analysis

Example



Separations

- Batch Distillation (Powerpoint lecture slides, Kuriyan, Purdue University, 2009)
 - Location:
 - Teaching Materials → Distillation
 - Vapor-Liquid equilibrium
 - Batch evaporation
 - Column configurations
 - Advantages of batch distillation
 - Process simulation

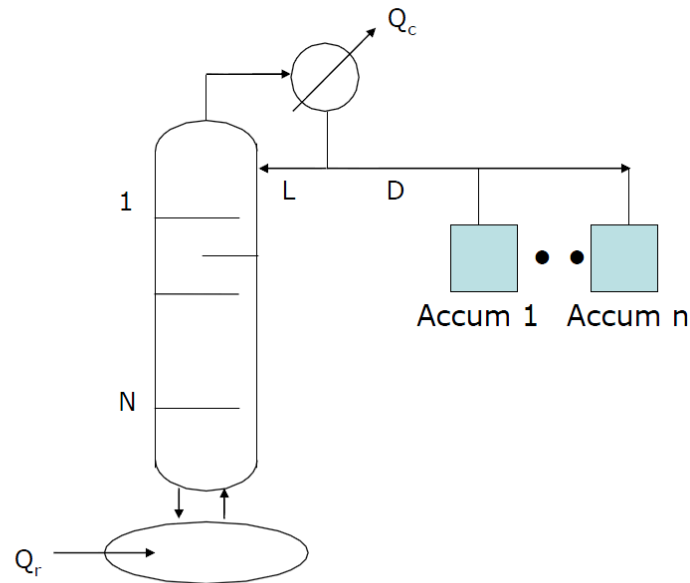
Separations

Module Structure

- Vapor Liquid Equilibrium Curves
- Rayleigh Distillation
- Column Configurations
- Column Operation
- Simulation
- Design of Batch Columns

Separations

Conventional Batch Distillation Column



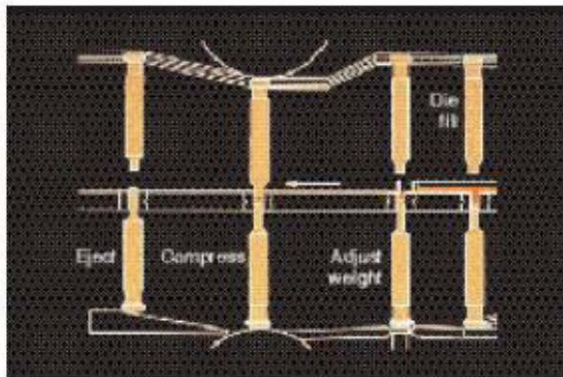
Pharmaceutical Engineering Unit Operations

- Particle Processing and Modeling in the Pharmaceutical Industry (Powerpoint lecture slides, Glasser, Rutgers University, 2010)
 - Location:
 - Teaching Materials → Particle Modeling
 - Detailed descriptions of pharmaceutical unit operations
 - Tableting and coating
 - Particle geometry and granular flow
 - Nanoparticles
 - Drug delivery

Pharmaceutical Engineering Unit Operations

Tableting Machines

Four main stages for tableting : Die fill, weight adjustment, compression, and ejection

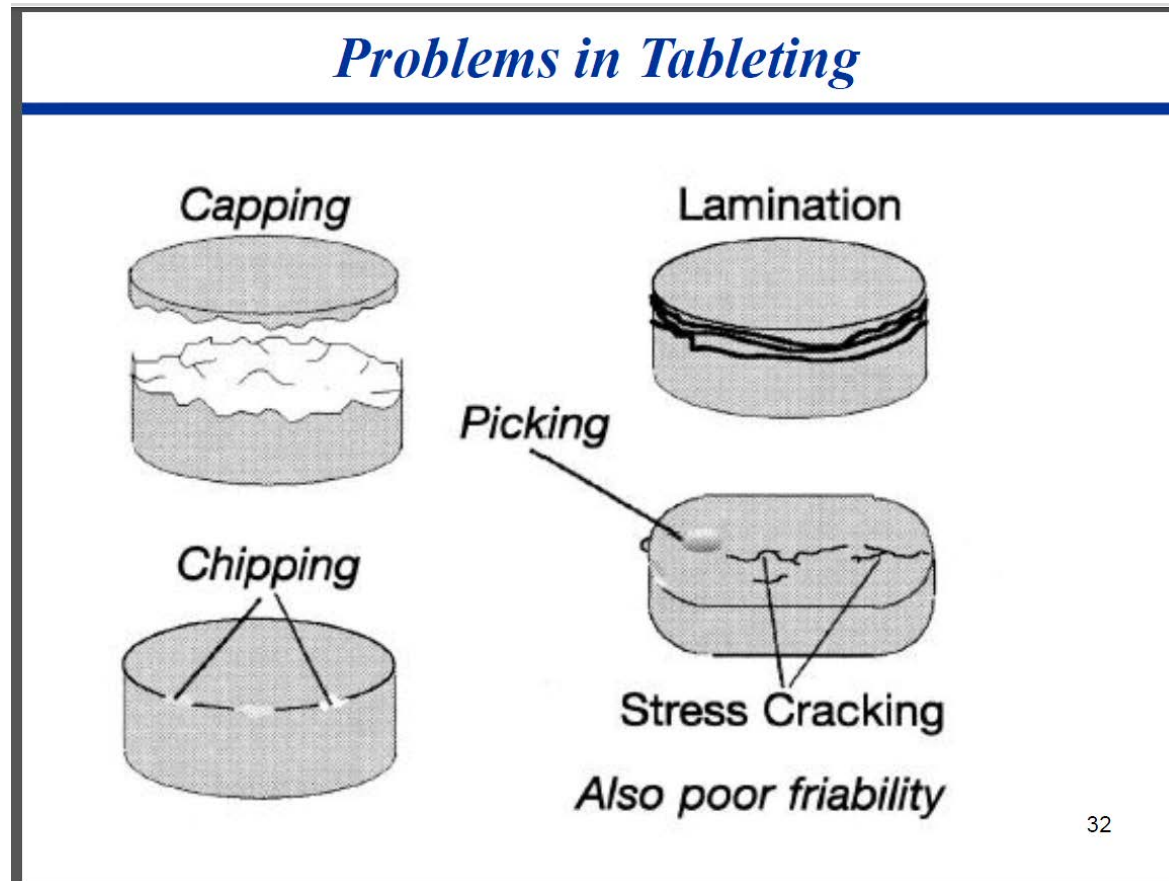


Rotary tablet presses

<http://www.capsule-filling-machine.com/rimages/131/tablet-h03.jpg>

Benjamin Glasser; Henrik Pedersen (2010), "Particle Processing and Modeling in the Pharmaceutical Industry," <https://pharmahub.org/resources/356>. (Benjamin Glasser – Rutgers University)

Pharmaceutical Engineering Unit Operations



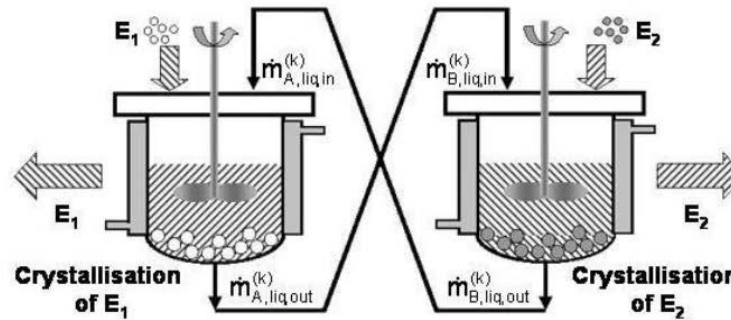
Benjamin Glasser; Henrik Pedersen (2010), "Particle Processing and Modeling in the Pharmaceutical Industry," <https://pharmahub.org/resources/356>. (Benjamin Glasser – Rutgers University)

Crystallization

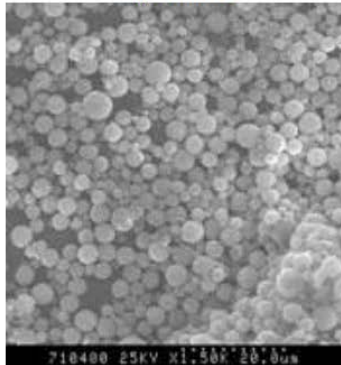
- Particle Processing and Modeling in the Pharmaceutical Industry (Powerpoint lecture slides, Glasser, Rutgers University, 2010)
 - Location:
 - Teaching Materials → Particle Modeling
 - Crystal Formation
 - Crystal morphology
 - Processing of crystals
 - Drying
 - Transport
 - Crystal/granular transport devices

Crystallization

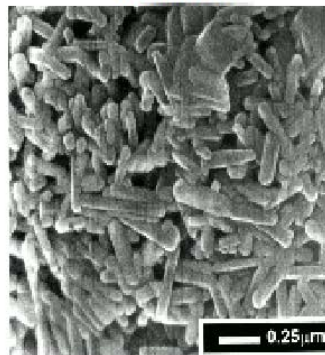
Crystallization



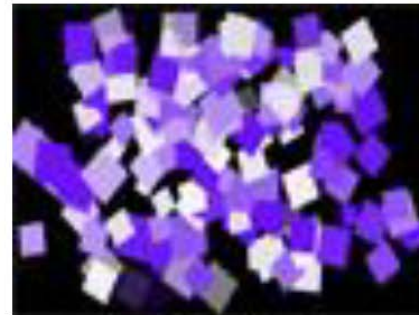
Spheres



Needles



Cubes

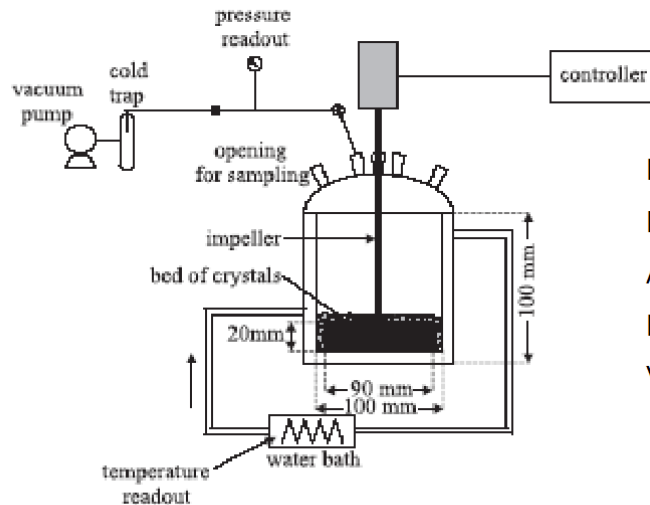


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<http://aiche.confex.com/aiche/2005/techprogram/images/21810-0.jpg>

Crystallization

Agitated Drying of Crystals



Drying Parameters:
Drying Temperature
Agitation Speed
Drying time
Vacuum

Crystal Size Distribution:
Attrition decreases the size.
Agglomeration increases the size.

Lekhal et al. *Powder Technology* (2003)

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Benjamin Glasser; Henrik Pedersen (2010), "Particle Processing and Modeling in the Pharmaceutical Industry," <https://pharmahub.org/resources/356>. (Benjamin Glasser – Rutgers University)

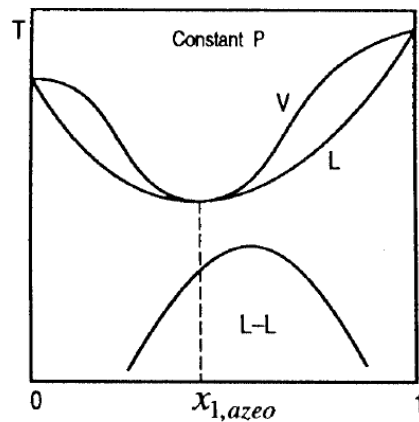
Thermodynamics

- Batch Distillation (Powerpoint lecture slides, Kuriyan, Purdue University, 2009)
 - Location:
 - Teaching Materials → Distillation
 - Vapor-Liquid equilibrium
 - Bubble point/dew point
 - Azeotropes
 - Homogeneous
 - Heterogeneous

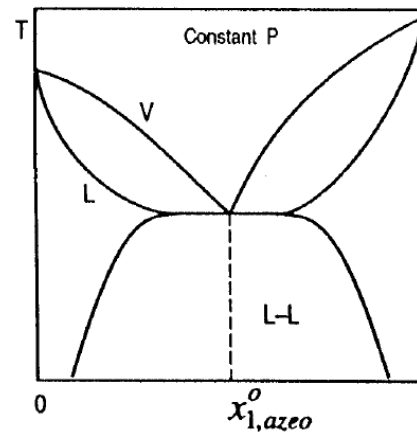
Thermodynamics

Heterogeneous Azeotropes

For a minimum-boiling azeotrope with large deviation from Raoult's law ($\gamma_i \gg 1$), phase splitting may occur and a minimum-boiling heterogeneous azeotrope forms, having a vapor phase in equilibrium with two liquid phases.



Homogeneous Azeotrope



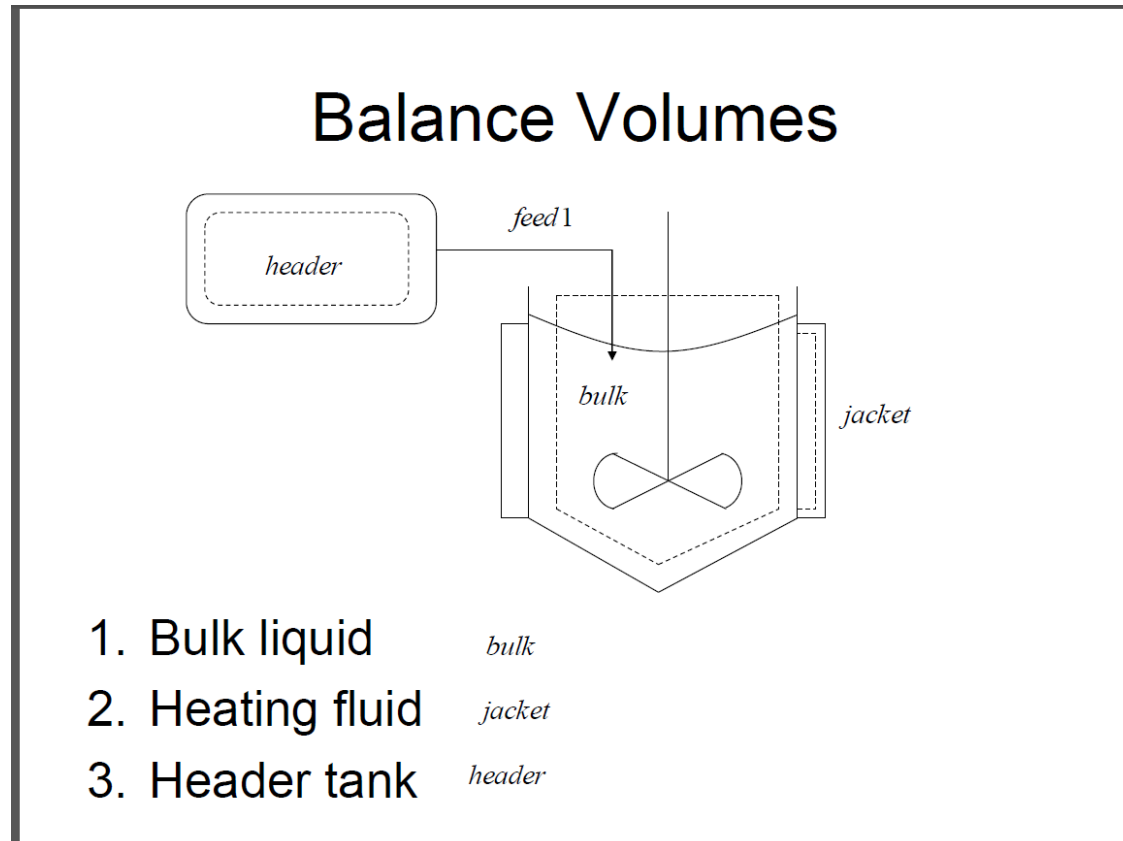
Heterogeneous Azeotrope

Kinetics & Reaction Engineering

- Introduction to API Process Simulation (Powerpoint lecture slides, Kuriyan, Purdue University, 2009)
 - Location:
 - Teaching Materials → Active Pharmaceutical Ingredient (API)
 - Modeling example for fed-batch reaction with safety constraints
 - Reaction kinetics
 - Batch-fed and isothermal reactors
 - Exothermic reactions
 - Different operation scenarios

Kinetics & Reaction Engineering

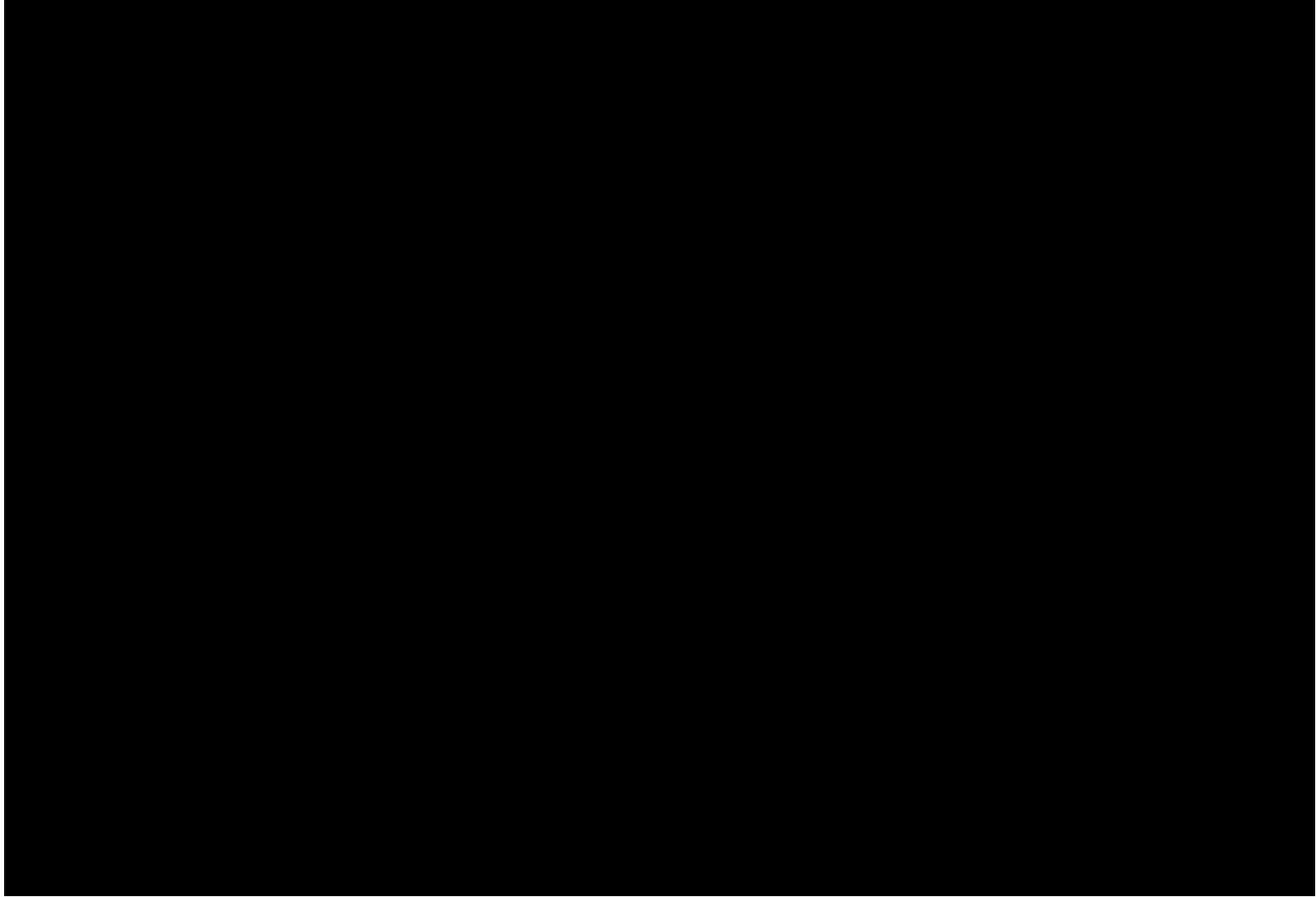
- Fed-batch reaction with safety constraints



Particulate Processing

- 2 Animations demonstrating Particle Processing techniques
 - Location:
 - Video #1: Animations → Particle Modeling → Hopper Segregation (Wassgren, Purdue University, 2007)
 - Particles behavior at hopper outlet
 - Video #2: Animations → Particle Modeling → Inter and Intra Tablet Coating (Wassgren, Purdue University, 2007)
 - Particle behavior in pan coater vortex

Hopper Segregation



Tablet Coating

