Beverage Design Challenge

# Introduction

Although the production of fermented, alcoholic beverages such as wines, beers, and spirits have existed as early as the Neolithic period (c. 10,000 BC) [1], beverages that retain the health benefits [2] and taste of fermented beverage but are alcohol free have not been readily available. Indeed, non-alcoholic brew is a small, but growing segment in the fermented beverage market [3] with one third of the worldwide sales to the Middle East [4]. A quick search on Amazon.com for non-alcoholic beer and wine reveals that these beverages in general receive low ratings from consumers either because the products are very expensive and/or the taste is very poor [5].

For this challenge, you will work in a team of five or six students to design a product that meets the consumer demand of high quality and low alcoholic content fermented beverages.

At the heart of the production of non-alcoholic fermented beverages are separation processes, which filter and clarify the fermented product as well as remove alcohol content of the beverages. Distillation is the process of separating components from a liquid mixture by boiling and condensation. The use of the technique dates back to at least the 1st century A.D. and by the 11th century, batch distillation was used to produce alcoholic beverages [6]. Currently, multistage and largely continuous distillation is the most widely used industrial method for separating chemical mixtures, despite the fact that it can be very energy intensive.

**Your challenge is to design a separation process to produce a high quality and low alcoholic content fermented beverage.** Your effort, which will be guided, will span the early phases of product development, including opportunity identification, generating ideas, gathering customer and market data, selecting ideas, devise concepts and building sketch models, and deliver your value proposition to potential investors.

In this design challenge, you will learn about **creativity**, product design, **teamwork** in a unifying engineering experience. The experience is designed to emulate what engineers might experience as part of a design team in a modern product development firm.

# Student Learning Outcomes

After completing this design challenge, students will be able to:

1. Identify, formulate, and solve complex separation problems by applying mass transfer, thermodynamics, and multi-stage separations principles.
2. Apply engineering design to produce solutions that meet specified consumer needs with consideration of cultural, social, environmental and economic factors.
3. Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
4. Develop effective written and oral communication skills.

# Project Roles *(Adopted from Team Roles, 2.009! product engineering processes, MIT)*

All members of the team are ultimately responsible for identifying a product direction and designing a distillation process in a manner consistent with course learning objectives, using their course instructor(s) and peer learning facilitators (PLFs) as resources. All team members should actively share ideas, information, and feedback. A team owns and drives its process and product development and the vision of the product. The team creates and coordinates an internal structure, develops and follows a schedule for the project, and submits deliverables for the design challenge project. The full team is needed to tackle the problem of developing the product concept and designing the separation process. However, it is rare that all members will be simultaneously working together on the same thing.

To work effectively to realize a team’s goals, team members should discuss, organize, and specialize into “team roles”. Below is one set of suggested roles. Some teams may wish to have two members with the same specialization and some members may wish to assume more than one role. Note that these team roles are not necessarily organized by “tasks” or “deliverables”. Rather, they facilitate effective team dynamics, management, and consensus building, which are all key ingredients of good teamwork.

**Systems Integrator (SI):** Coordinates weekly meetings, agendas and goals. Assumes a number of coordination and integration functions during the design challenge project, from both a project management and technical design viewpoint. While the SI is not the owner of the design vision (the team is), the SI is a hub of team communication. Responsible for developing a group action plan and keeping the group on task. Organizes and submits deliverables. Monitors the shared understanding of the project by the team.

**Market & Sustainability Guru**: Oversees market research to identify products. Studies the impact of the product production and waste/side products on natural and human resources. Coordinates with team members to ensure that they have the product information and specifications they need to be effective in their roles.

**Separation Geek:** Designs and develops the separation process to produce products, including design and modeling of the distillation process (for example, using Aspen Plus) as well as additional separation processes that are needed to meet product specifications. Responsible for providing a final technical design for the products.

**Yoda Officer:** Monitors work distribution, individual engagement, and team dynamics. Acts as a mediator or an active listener, and as a team resource for any interpersonal conflicts while being sensitive to any imbalance due to team member identity such as gender, race, and religion. The Yoda’s ultimate purposes are to promote balance and productive engagement within the team and to assist members in reaching their full potential.

# References

[1]. Charles H, Patrick; Durham, NC (1952). Alcohol, Culture, and Society. Duke University Press (reprint edition by AMS Press, New York, 1970). pp. 26–27. [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number) [*9780404049065*](https://en.wikipedia.org/wiki/Special%3ABookSources/9780404049065).

[2]. Maria L. Marco et al., Health Benefits of Fermented Foods: microbiota and beyond (2017), Current Opinion in Biotechnology, **44**:94-102.

[3]. Ivana Kottasová, “Forget craft beer. The next craze is non-alcoholic brews”, published February 9, 2018, <http://money.cnn.com/2018/02/09/news/beer-non-alcoholic/index.html> (Accessed 3/20/2018)

[4]. E.H. the Economist explains., “Why are sales of non-alcoholic beer booming?”, published August 12, 2013, <https://www.economist.com/blogs/economist-explains/2013/08/economist-explains-3> (Accessed 3/26/2018)

[5]. Amazon.com home page, https://www.amazon.com/ref=nav\_logo (accessed 3/20/2018)

[6] Patrick E. McGovern, Armen Mirzoian, Gretchen R. Hall (2008). Ancient Egyptian herbal wines, Proceedings of the National Academy of Sciences. 106(8): 7361-7366. doi: 10.1073/pnas.0811578106

# Deliverables

\**More information to come for worksheets, report, and pitch deliverables.*

|  |  |  |
| --- | --- | --- |
| Deliverables | Points | Due Date |
| Team Formation Memo* Team members identified
* Team roles assigned
* Project outline reviewed and tasks assigned
 | 5 |  |
| Worksheet 1: Defining the problem  | 10 |  |
| Worksheet 2: Designing a solution  | 10 |  |
| Worksheet 3: Technical design of separation process | 25 |  |
| Short Technical Report | 50 |  |
| Pitch Video due  | 50 |  |
| **TOTAL** |  **150** |  |

# Beverage Design Challenge: Team-Formation Activity

*complete as a team*

Tasks 1 and 2 (this page) due by:

Task 3 and Team Formation Memo due by:

|  |
| --- |
| Team Number / Name:  |
| Team Member Names:System Integrator: Market and Sustainability Guru: Separation Geek(s): Team Yoda:  |

**Task #1:** Share contact information with your team mates. **What is the best way to get in touch with each other?**

**Task #2:** The next deliverable, Worksheet 1 – Defining the Problem, will be due Friday March 27th. The team will need to meet, plan, distribute the workload, and meet again to work on it together. **Set a time to meet before the next class**. Write the date, time, and location below.

**Task #3: Look ahead at Worksheet 1 due in two weeks. Decide on team roles and detail the responsibilities and tasks for each team member.**

You have already reviewed the design brief and assigned team roles in the team formation memo submitted last Friday. To design a product that meets the consumer demand of high quality and low alcoholic content fermented beverages, your team first needs to understand and define the problem. Worksheet 1 will guide your team to do this by conducting research on several relevant topics.

Review Worksheet 1 (posted on Learn) and detail the responsibilities for each team member. Tasks for completing Worksheet 1 include, but are not limited to,

* set deadlines
* find at least 9 sources
* determine the relevance and usefulness of the sources
* review, summarize and answer questions about each source
* review and edit the completed Worksheet 1
* submit completed Worksheet 1

|  |  |
| --- | --- |
| **Team member name** | **Tasks** |
| **Systems Integrator:** |  |
| **Market and Sustainability Guru:** |  |
| **Separation Geek(s):** |  |
| **Team Yoda:** |  |

Other notes:

**Task 4: Write a short, up to 1-page Team Formation Memo** that summarizes the activities completed on this worksheet, including identify team members, assigned team roles, and a short description of the tasks associated with the project.

Distillation Design Challenge: Worksheet 1 - Defining the Problem

*complete as a team*

Due by 11am on:

|  |
| --- |
| Team Number / Name:   |
| Team Member Names. Include also descriptions of the tasks completed by each team member.System Integrator: Market and Sustainability Guru: Separation Geek(s): Team Yoda:  |

**Defining the problem**

As chemical engineers, you can help to design processes that turn a readily available product into one that is currently hard to obtain. Your team’s challenge is to design a product that meets the consumer demand of high quality and low alcoholic content fermented beverages.

Your first task is to understand and define the problem. This worksheet will guide your team to do this by conducting research on several relevant topics.

**Gather information**

In order to understand the problem, do some research to investigate the following:

* Health benefits of fermented beverages **(at least 2 sources)**
* Reasons why there is a demand for reduced or non-alcoholic beverages **(at least 2 sources)**
* Current alcohol-reducing technologies **(at least 3 sources)**
* Problems with currently available reduced or non-alcoholic beverages **(at least 2 sources)**

**Source 1: Health benefits of fermented beverages**

*Make sure you can describe the health benefits of fermented beverages, what the fermentation process is, and what is known about the fermentation-derived compounds that give rise to the health benefits.*

Citation (in Chemical Engineering Progress (CEP) style):

Notes:

**Source 2: Health benefits of fermented beverages**

*Make sure you can describe the health benefits of fermented beverages, what the fermentation process is, and what is known about the fermentation-derived compounds that give rise to the health benefits.*

Citation (in CEP style):

Notes:

**Source 3: Reasons why there is a demand for reduced or non-alcoholic beverages**

*Make sure you can explain the reasons why some consumers choose to drink non-alcoholic fermented beverages over the more common alcoholic beverages.*

Citation (in CEP style):

Notes:

**Source 4: Reasons why there is a demand for reduced or non-alcoholic beverages**

*Make sure you can explain the reasons why some consumers choose to drink non-alcoholic fermented beverages over the more common alcoholic beverages.*

Citation (in CEP style):

Notes:

**Source 5: Current alcohol-reducing technologies**

*Your design must include a distillation process by which the alcohol content of an available beverage is reduced. First, search for information on strategies / technologies that are in use for reducing alcohol content. Make sure you can explain how the technology works. What are the pros and cons of this technology? Consider including a schematic or an image.*

Citation (in CEP style):

Notes:

Paste figure here:

**Figure/Image 1**

Citation (follow guidelines here: <http://www.15minutemondays.com/2014/03/10/give-photo-credit-credit-due/>).

**Source 6: Current alcohol-reducing technologies**

*Your design must include a distillation process by which the alcohol content of an available beverage is reduced. First, search for information on strategies / technologies that are in use for reducing alcohol content. Make sure you can explain how the technology works. What are the pros and cons of this technology? Consider including a schematic or an image.*

Citation (in CEP style):

Notes:

Paste figure here:

**Figure/Image 2**

Citation (follow guidelines here: <http://www.15minutemondays.com/2014/03/10/give-photo-credit-credit-due/>.

**Source 7: Current alcohol-reducing technologies**

*Your design must include a distillation process by which the alcohol content of an available beverage is reduced. First, search for information on strategies / technologies that are in use for reducing alcohol content. Make sure you can explain how the technology works. What are the pros and cons of this technology? Consider including a schematic or an image.*

Citation (in CEP style):

Notes:

Paste figure here:

**Figure/Image 3**

Citation (follow guidelines here: <http://www.15minutemondays.com/2014/03/10/give-photo-credit-credit-due/>.

**Source 8: Problems with currently available reduced or non-alcoholic beverages**

Investigate currently available products. Compare their costs, taste, and content (for example, beneficial compounds identified in previous sources) with their alcohol containing counterparts.

Citation (in CEP style):

Notes:

**Source 9: Problems with currently available reduced or non-alcoholic beverages**

Investigate currently available products. Compare their costs, taste, and content (for example, beneficial compounds identified in previous sources) with their alcohol containing counterparts.

Citation (in CEP style):

Notes:

Distillation Design Challenge: Worksheet 2 – Designing a Solution

*complete as a team*

Due by 11am on:

|  |
| --- |
| Team Number / Name:   |
| Team Member Names. Include also descriptions of the tasks completed by each team member.System Integrator: Market and Sustainability Guru: Separation Geek(s): Team Yoda:  |

**Worksheet 2: Design Solution**

As chemical engineers, you can help to design processes that turn a readily available product into one that is currently hard to obtain. Your team’s challenge is to design a product that meets the consumer demand of high quality and low alcoholic content fermented beverages.

Take the research you have done for the last worksheet and design a solution. This worksheet will guide you to generate ideas and evaluate how well your ideas meet the needs you identified. You will present your technical design in a report (due 5/4) and your solution in a pitch (5/9).

**Product Market Research:** List and describe at least two products in your target area (for example, non-alcoholic beer or wine) currently on the market.

How are they similar to and different from yours?

Who is currently buying those products?

How much do these products cost?

Are consumers happy with these products?

Product 1:

Product 2:

**Customer Market Research:**

What is the target customer market for your product?

What are the reasons for this market segment for non-alcoholic fermented beverage?

Are there particular criteria that your product needs to meet, for example, level of alcohol or content of particular ingredients, in order to be a viable / desirable product for this market segment?

How big is this market and what is the estimated demand for your product?

Is there a secondary market for your product (or byproducts)?

**Product Ideas**: Describe at least two products your design team wishes to produce. How are they similar to or different compared to existing products?

Product 1:

Product 2:

**Generate ideas for alcohol removal**

Identify at least 3 different methods currently used to reduce alcohol content in fermented beverages. You have already done this for Worksheet 1. Now, you will look more closely at these of methods.

**Method #1 name (include citations):**

|  |  |
| --- | --- |
| Describe how the method works.  |  |
| What are some pros/benefits for this method? |  |
| What are some cons/problems for this method? |  |

**Method #2 name (include citations):**

|  |  |
| --- | --- |
| Describe how the method works.  |  |
| What are some pros/benefits for this method? |  |
| What are some cons/problems for this method? |  |

**Method #3 name (include citations):**

|  |  |
| --- | --- |
| Describe how the approach works.  |  |
| What are some pros/benefits for this method? |  |
| What are some cons/problems for this method? |  |

For your design, distillation will be a part of your product production process. Fill in the table below about distillation.

|  |  |
| --- | --- |
| Describe how the method works.  |  |
| What are some pros/benefits for this method? |  |
| What are some cons/problems for this method? |  |

**Innovate:** Your product will cost more, compared to alcoholic counterparts, because of the additional separation processes.

What can you do to your design to minimize this difference?

Can you justify the added cost to your customers?

How will you show that your product is better in some way, compared to existing products? Consider, for instance, benefits to the customer and technical improvements over current products that make your product competitive or more appealing.

Distillation Design Challenge: Worksheet 3 – Technical Design of the Separation Process

*complete as a team*

Due by 11am on:

|  |
| --- |
| Team Number / Name:   |
| Team Member Names. Include also descriptions of the tasks completed by each team member.System Integrator: Market and Sustainability Guru: Separation Geek(s): Team Yoda:  |

**Design problem, needs and constraints**: Concisely describe the problem your design solution addresses and the design requirements (one paragraph).

**Product design**. Concisely yet thoroughly describe your alcohol removal process. Use process flow diagrams and process simulation outputs to show that your method meets the design requirements. Include supplemental information that supports your technical design of the alcohol removal process, including citations as needed.

Deliverable 5: Short Technical Report

*Complete as a group*

Due by 5pm on:

Short reports are commonly written for the client or investors to provide backing for your design. These can be difficult to write well because engineers must be very selective about what goes in the report. They must have a very clear understanding of the most important things that need to be communicated.

Your report should be **3 - 4 typed pages,** including figures and tables, but excluding reference list and cover sheet. Use a standard font and size, such as Times 12 or Arial 10. Margins should be 1 inch. Writing should be concise, but substantive. Avoid fluff and filler.

Cover Sheet: (single page, does not count in page limit): Includes title, date, and team number/name. Also include your names, roles and work completed by each member.

Introduction: One paragraph that concisely describes the problem your design solution addresses and the design requirements (needs and constraints).

Redesigned product: (no more than 1 page with one figure). Concisely describe your product design. You may include a figure — a design or product schematic with descriptive labels and dimensions — depicting your final design, with an informative caption. Briefly review existing alcohol reducing strategies and how your team decided on your method. Cite references you used.

Technical design: (1.5 page plus appendices). Concisely and thoroughly describe your alcohol removal process. Use process flow diagrams and process simulation outputs to show that your method meets the design requirements. If necessary, use appendices to provide supplemental information regarding your design.

Conclusions and Recommendations: (½ to 1 page) Explain how well your design meets the needs while not violating constraints. Consider your design in contrast to existing solutions. What makes your design more efficient, in terms of cost or ability to meet the identified needs? What next steps should be taken to improve the performance of your design? What additional testing should be completed? What did you learn from the design process?

References (does not count in page limit): At the end of your report, list the references in numerical order. All references must be complete, and should be cited in the report, using numbers in square brackets.

You are welcome to submit drafts of the report for obtaining feedback from the instructor. To allow for adequate time for feedback and revision, drafts should be submitted to the report submission site no less than 4 days before the due date. Please email the instructors and let us know if you have submitted a draft.

# Infographics Guidelines

*Complete as a group*

Due by 5pm on:

50 points

Your final deliverable for the design challenge will be an **infographic** to communicate your product and/or company value on social media. The purpose of the infographic is to ***market*** and ***launch*** your new product or company by ***visual story telling***. With infographics, you get to both show people what your product looks (graphics) like and tell them how it works (info).

In developing your infographic, consider your product strengths, how your product or company benefits clients and customers, and how your product works. Be creative and have fun! Below are useful websites I found on the blog “Show, don’t tell” about infographic design and data visualization

- <https://www.easel.ly/blog/communicate-business-products-with-infographic/>

- <https://www.easel.ly/blog/visual-storytelling-small-business/>

- <https://www.easel.ly/blog/creative-ways-differentiate-small-business/>

**Feedback:** View and provide feedback to other teams. Focus your feedback on how creative their idea seems and how effectively they communicated their product/company value. ***Feedback due by Monday May 18 by 5 pm.*** You will get points towards class participation for providing feedback.

### Evaluation and Feedback

Each infographic will also be evaluated by a panel using the form below:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *TEAM \_\_\_\_\_\_\_\_\_\_**Please evaluate the students on the following:* | *Strongly agree* | *Agree* | *Neutral* | *Disagree* | *Strongly disagree* |
| 1. The students presented a creative idea  |  |  |  |  |  |
| 2. The students effectively communicated their product/company value  |  |  |  |  |  |
| 3. The infographics provided information about their product(s)/company  |  |  |  |  |  |
| Please provide any comments here: |

# Video Pitch Guidelines

*Completed as a group*

Due by:

Your final deliverable for the design challenge will include a brief video-recorded pitch uploaded to the Learn discussion board. Your pitch should be persuasive and include data about the problem and technical design of your solution.

You pitch should meet the following elements:

**Time:** Your pitch should be no shorter than 3 minutes and no longer than 4 minutes. Keep this in mind when putting your content together.

**Professionalism:** If you are on screen, dress professionally. Voices should be clear. Graphics, if used, should be attractive and relevant, not distracting. Text, if used, should be easy to read.

**The Problem:** Concisely explain the problem and needs addressed by your design.

**Use-case**: A good pitch helps the potential investor envision how the product will be used and how your company will be profitable, not just what the products look like. Sharing a (very) short story about how it will change customers’ lives for the better will help seal the deal. The story should communicate what makes your product better than existing products.

**Creativity:** An idea viewed as novel will be received better than an ordinary one. Your pitch should highlight what makes your product stand out.

**Market potential:** Your pitch should concisely convey the market potential of your product. Clarify what makes your approach feasible.

**Technical content**: Concisely describe the main techniques, including production and separation, you will use to produce your product.

**Feedback:** Watch and provide feedback to at least 5 other teams. Focus your feedback on how (1) creative their idea seems; (2) feasible their approach seems; (3) appropriate their technical content seems.

***Feedback due Thursday May 11 by the end of the day.***

### A few resources on business pitches

1. Twice-a-year UNM student business pitch competition sponsored by LOBO Rainforest and STC.UNM (***YOU are all eligible!***): <https://stc.unm.edu/rainforest-student-pitch-competition-2/>
2. Shark Tank, the TV show on ABC: <http://abc.go.com/shows/shark-tank>
3. Need a place to practice or record? Reserve the Den in Centennial Library: http://libcal.unm.edu/spaces?lid=348&gid=0

### Video Pitch Evaluation and Feedback

Each pitch video will also be evaluated by a panel. Panelists use the form below to evaluate your performance.

***PANELIST***: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***TEAM*** *\_\_\_\_\_\_\_\_\_\_**Please evaluate the students on the following:* | *Strongly agree* | *Agree* | *Neutral* | *Disagree* | *Strongly disagree* |
| 1. The students presented confidently  |  |  |  |  |  |
| 2. The students concisely explained the problem and needs addressed by their design |  |  |  |  |  |
| 3. The pitch conveys the market potential of their product  |  |  |  |  |  |
| 4. The pitch helps clarify their target market and what makes their product better than existing products |  |  |  |  |  |
| 5. The idea presented is creative |  |  |  |  |  |
| 6. The technical solution presented has rigor |  |  |  |  |  |
| 7. The design is feasible |  |  |  |  |  |
| Please provide any comments here: |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***TEAM*** *\_\_\_\_\_\_\_\_\_\_**Please evaluate the students on the following:* | *Strongly agree* | *Agree* | *Neutral* | *Disagree* | *Strongly disagree* |
| 1. The students presented confidently  |  |  |  |  |  |
| 2. The students concisely explained the problem and needs addressed by their design |  |  |  |  |  |
| 3. The pitch conveys the market potential of their product  |  |  |  |  |  |
| 4. The pitch helps clarify their target market and what makes their product better than existing products |  |  |  |  |  |
| 5. The idea presented is creative |  |  |  |  |  |
| 6. The technical solution presented has rigor |  |  |  |  |  |
| 7. The design is feasible |  |  |  |  |  |
| Please provide any comments here: |

### Report Teamwork Contributions

The survey below will provide meaningful input to the instructor on the contributions of team members on activities related the report. The instructor may choose to factor this input into individual grades for the report and/or the overall course grade. This survey also helps us document teamwork elements related to our program accreditation. Your participation is very much appreciated.

Rate each team member, including yourself, on the following elements related to contributions towards the full laboratory report according to the following metrics. Please consider each element independent of the others.

* **Unacceptable (U):** little or no effort to participate or contribute.
* **Marginal (M):** some contribution/effort, but significantly less, or lower in quality or importance, than most members of the team.
* **Good (G):** significant and important contributions roughly comparable to most members of the team.
* **Outstanding (O):** significantly higher or more important contribution than other members of the team.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Team members  | **Name 1**(yourself) | **Name 2** | **Name 3** | **Name 4**  |
| **1. Participation in lab activities, meetings, discussions, and other team activities related to the work product.** |  |  |  |  |
| **2. Overall level of effort contributed toward the final product. This should include contributions of all sorts.**  |  |  |  |  |
| **3. Quality and importance of contributions to the final product.**  |  |  |  |  |
| **4. Communication with the team, and timely completion of commitments.**  |  |  |  |  |

Comments:

**Molecular Diffusion “Random Walk” In-class Activity**

We will conduct an activity today to illustrate molecular diffusion. We will form two groups in the front of the classroom (species A and species B). The groups are separated by an arbitrary line on the floor. Each student will now turn to face a random direction. Start walking at a steady pace. Once you run into someone, change direction and keep walking at the same pace.

**Part A: Prediction**

1. What do you think will happen to the distribution of the two groups once “diffusion” starts? Describe what you expect to see a short time and a long time after diffusion starts.
2. Now that you’ve described your prediction in words, let’s translate it into “concentration profiles”. Let’s first sketch what you expect the concentration to be at t=0, that is, before diffusion started. Label your x-axis and y-axis, then sketch the concentration profiles of species A (*C*A), species B, (*C*B) and total concentration (*C*). On the right-hand side, sketch what you expect the concentration profiles to be at a long time later t = ∞.

 t = 0 t = ∞

 

1. Now, if the desks are distributed throughout the room with the diffusing students, what effects will they have on diffusion? When you run into either another person or a desk, change direction and keep walking.

**Part B: Observations**

Let’s do it! When we perform our diffusion, we will stop a few times to take notice of where species A and B are during diffusion.

 t = 0



 t ~ 3 min free diffusion



Sketch concentration profiles of A and B about 3 min after the start of the diffusion.

 t ~ 3 min after hindered diffusion

 

**Part C: Reflection**

Looking back at the concentration profiles you predicted, how did they differ from your observations?

What was the effect of the desks on your diffusion?

Think back to the factors that we discussed that affect diffusivity, including pressure, temperature, pore size, solvent viscosity, molecular size/molecular weight (think about being wrapped in 6 inches of bubble wrap), intermolecular interactions (attractive or repulsive), write a short reflection on how each of these factors would affect your diffusivity.

Class Activity 2: *Convection in Mass Transfer*

Today we will do an activity to study the effect of fluid flow, or convection, on mass transfer. We will study the mass transfer of dye in water under non-stirring and stirring conditions. We will also use two different types of food dyes, food dye and icing dye.

**Part A: Prediction**

1. Let’s first think about the mass transfer that will take place when we place one drop of food dye or icing dye in a cup of water. What is the species being transferred and what is the medium by which mass transferring is occurring?

What do you think will happen in terms of dye distribution in each of the cups? Describe what you expect to see a short time and a long time after mass transfer starts.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Cup 1:** Food dye, no stir | **Cup 2:** Food dye, stir | **Cup 3:** Icing dye, no stir, then stir |
| 1 minute |  |  |  |
| 10 minutes |  |  |  |
| 1 day |  |  |  |

Explain your answers above. Does amount of time matter? Does dye type matter? Why or why not?

**Part B: Observations**

**Procedure:**

* Form a group of 3-4 students and take 3 clear cups and 2 straws for each group.
* Fill each cup approximately 2/3 full of water.
* In ***Cup 1***, CAREFULLY put one drop of food dye while minimally perturbing the water.
* In ***Cup 2***, put in one drop of food dye and stir the water with a straw 10 times without spilling the water.
* In ***Cup 3***, CAREFULLY put one drop of icing dye into the water. After one minute, stir the water with a straw 10 times without spilling the water.

Record your observation of dye mass transfer in each cup and the time. If desired, you can repeat any of the activity and vary the amount of dye you put in or the number and speed at which you stir the water and record additional observations.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Cup 1:** Food dye, no stir | **Cup 2:** Food dye, stir | **Cup 3:** Icing dye, no stir, then stir |
| Short time:  |  |  |  |
| Long time:  |  |  |  |

**Part C: Reflection**

Looking back at your predictions, how do they differ from your observations? Were there any unexpected observations?

What type of mass transfer occurred in each cup?

If differences were observed between the mass transfer of food dye and icing dye, what’s your explanation for the difference? Feel free to look up information about the products (molecular structures of the dye, formulation (what else is in the product) of the food dye vs. icing dye, etc.)

We have thought extensively about what affects diffusivity (i.e., *D*AB). **Write down 5 factors that influence *D*AB.** Now think about factors that influence the convective mass transfer coefficient (*k*c), the close cousin of *D*AB that is the proportionality constant in convective mass transfer flux, *N*A = *k*c*C*A.

**CLEAN UP!**

Convective Mass Transfer and Phase Partition Activities

We will conduct an activity today to review what we have learned about convective mass transfer. We will additionally think about how solubility and phase partition, two equilibrium concepts, affect mass transfer. You will study the mass transfer of different food coloring dyes in water and oil.

**Part A: Prediction**

1. In this activity, you will add water to a jar and then add food coloring to the water. Oil will then be added to the jar. When you shake the jar, what will happen? In particular, what mass transfer event will happen?
2. Do you think that how you shake the jar, for example, gently vs. vigorously, will make a difference in the rate of mass transfer? Why?
3. Since mass transfer will happen between 2 phases that are immiscible (water and oil), **what impact do the two different phases have on the mass transfer?** Think about which terms in the convective mass transfer flux equation might be affected. Explicitly consider how the solute interacts with each of the phases. Page 5 has some information regarding the dyes.
4. What effect will **the amount of each phase** (ml of water and ml of oil) **have on mass transfer**?

**Part B: Activity and Observations**

1. Form 12 teams.
2. Each team obtain 1 jar with lid and 1 marker. A food coloring will also be given to you. Record food color and team designation (e.g., Red-A)

Team Members:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Food color and team designation: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



1. Mark the jar by ¼ height sections and label the jar (see picture to the right).
2. Fill the jar with water to the height specified (1/4 or 1/2) in the table below according to your team designation.

|  |  |
| --- | --- |
| **Team** | **Fill water to** |
| A | 1/4 |
| B | 1/4 |
| C | 1/2 |
| D | 1/2 |

1. Put 10 drops of food coloring in the water and gently mix by swirling.
2. Pour vegetable oil into the jar and fill it to 3/4 height. Record volume ratio of water to oil: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. Screw the lid securely on. Without shaking the jar, record observations.
4. Shake the jar EITHER gently or vigorously as designated in the table below according to your team designation. Record time when the jar was shaken: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |
| --- | --- |
| **Team** | **Shake** |
| A | Gently |
| B | Vigorously |
| C | Gently |
| D | Vigorously |

1. Place the jar on desk. Record observations, including the appearance of the two phases and the amount of the dye in each phase.

***After 5 min***:

***After 20 min***:

***At the end of class***: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ min. Take a picture of the jar against a light background (e.g., paper towel) and **submit a picture to Learn** by the end of the day. One submission per team.

**Part C: Analysis and Reflection**

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is being transferred from the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ phase to the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ phase.
2. Write the mass transfer equation (*W*A, rate of mass transfer) for the dye from one phase to the other first in terms of flux *N*A, then in terms of concentrations *C*A.
3. What effect did shaking have on mass transfer? Describe what you observed and comment on whether your prediction was correct. Point to the parameter(s) in *W*A equation that shaking affected.
4. Now let’s think about **driving forces, i.e., *C*A, of dye transfer between the two phases**. First indicate on the zoomed in water/oil interface the direction of mass transfer. Then sketch the concentration profiles (*C*A(*x*)) of the dye in both phases at two-time points of observation (e.g., 0 and 20 min after mixing oil and water).

***0 min***:



***20 min***



1. How do you expect the system to look like after a long, i.e., ∞ min, time? Include both flux and concentration profiles. See page 5 for some useful information. What criterion must be satisfied? How is this different from t = 0 min?

***∞ min***



1. Interfacial mass transfer, that is, mass transfer between two different phases (e.g., gas-liquid, liquid-liquid) occurs in a substantial number of industrial operations in which compositions of solutions and mixtures are changed, including absorption, stripping, extraction and leaching (look up these terms).

In this activity, we examined the effects of shaking (i.e., mixing) and the amount of each phase have on mass transfer. **Write a short reflection on how these two factors influence mass transfer rate.**

Moreover, mass transfer driving force is no longer simply CA, that is, concentration different between a high CA somewhere in a control volume and a low CA somewhere in a control volume. **Write a short reflection on what the proper concentration driving force should be for interfacial mass transfer**.

***Some additional information that you might find useful:***

**Red Dye – FD&C Reds 40 and 3**

(By Jü - https://commons.wikimedia.org/wiki/File:Allura\_Red\_AC\_Structural\_Formula\_V1.svg, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=46870820>; Public Domain, https://commons.wikimedia.org/w/index.php?curid=1592752)

 

**Yellow Dye – FD&C Yellow 5**

(By Lukáš Mižoch; later Yikrazuul - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=1005255)



**Blue Dye – FD&C Blue 1 and FD&C Red 40**

(By Shaddack, self-made public Doman https://en.wikipedia.org/wiki/Brilliant\_Blue\_FCF#/media/File:Brilliant\_Blue\_FCF.png)



**Chemical Properties (PubChem)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **FD&C Dye** | **MW****(g/mole)** | **Charge in aqueous solution** | **Polar Surface Area (Å2)** | **Solubility in Water (mg/ml)** | **Solubility in Ethanol (mg/ml)** |
| Red 40 | 496 | -2 | 182 | 27.5 | 0.001 |
| Red 3 | 835 | -2 | 76 |  |  |
| Yellow 5 | 534 | -3 | 228 |  |  |
| Blue 1 | 792 | -3 | 203 | 30 | 3 |