Applicant: Your Company Name: Catalysta Industries

Inventors: Names in the order of contribution (highest contributor's name will be first. Author's must be listed under the EHS division)

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Chemical Product Formula: CH18N2O5

Chemical Product Name: Aspartame

Process Title: Production of Aspartame through enzymatic and chemical synthesis

(a). List of the intermediates generated in the production of aspartame through enzymatic and chemical synthesis:

Methylation of Aspartic Acid (Asp):

- Partially methylated aspartic acid derivatives
- Hydrolyzed products of methyl ester or peptide bonds in aspartic acid

Enzymatic Condensation of Asp-(OMe)2 with Phenylalanine (Phe):

- Partially acylated intermediates containing aspartic acid, phenylalanine, and methyl ester groups
- Unreacted starting materials, such as residual aspartic acid or phenylalanine
- Hydrolyzed products of ester or peptide bonds

Spontaneous Transfer of Methyl Ester:

- Minor hydrolyzed products or side reactions may occur.

Crystallization of Aspartame Hydrochloride:

- Presence of impurities, including residual starting materials, partially reacted intermediates, or side products from previous steps.

Neutralization Step Using Sodium Hydroxide:

- Byproducts or wastes from neutralization, depending on the specific reaction products formed.

Waste:

1. Impurity generated after washing process (containing some amount of aspartame crystals)

Waste quantity = 478.93 kg (as given in flow diagram of production done by tech team).

2. Acidic water generation after methylation

Current Regulations for Waste Materials

- Hazardous Waste Management Regulations: Most countries have regulations governing the management of hazardous waste, which includes byproducts generated during chemical synthesis processes. For example, in the United States, the Resource Conservation and Recovery Act (RCRA) regulates the generation, transportation, treatment, storage, and disposal of hazardous waste. Facilities producing aspartame would need to comply with these regulations, which may involve obtaining permits, properly labeling waste containers, and adhering to storage and disposal requirements.
- Environmental Protection Regulations: Environmental agencies set standards for emissions to air, water, and soil to protect human health and the environment. Byproducts emitted during aspartame production, such as carbon dioxide and organic substances, would be subject to limits established by these regulations. For instance, the Clean Air Act in the United States sets emission standards for pollutants released into the atmosphere.
- Permit Requirements: Facilities involved in chemical production often require permits from regulatory authorities. These permits outline specific requirements for waste management, emissions control, and environmental monitoring. Regulatory agencies may conduct inspections to ensure compliance with permit conditions.
- Recycling and Resource Recovery Initiatives: Governments may implement programs to promote recycling and recovery of waste materials from industrial processes. In some cases, facilities may be required to implement measures to minimize waste generation and maximize resource recovery. For example, the European Union's Waste Framework Directive sets targets for recycling and recovery of certain waste streams.
- Risk Assessment and Management: Regulatory agencies may require facilities to conduct risk assessments to evaluate the potential environmental and health impacts associated with aspartame production and its byproducts. Based on the findings of these assessments, measures may be mandated to mitigate identified risks, such as implementing pollution prevention measures or installing pollution control technologies.
- International Standards and Guidelines: Some countries adopt international standards and guidelines developed by organizations like the International Organization for Standardization (ISO) or the United Nations Environment Programme (UNEP). These standards provide guidance on waste management practices, environmental performance, and sustainability.

Specific Limits for Disposal:

Specific limits for the disposal of waste and byproducts from aspartame production would depend on factors such as the toxicity of the materials, their potential to harm the environment, and local regulatory requirements. For example:

Limits on Emissions: Regulatory agencies may set maximum allowable concentrations for pollutants emitted into the air, water, or soil. Facilities must monitor emissions and ensure they comply with these limits.

Waste Disposal Criteria: Hazardous waste generated during the production process may need to be treated, stored, or disposed of at authorized facilities in accordance with regulatory criteria. These criteria may include requirements for containerization, labeling, and transportation of hazardous waste.

Environmental Impact Assessments: Facilities may be required to conduct environmental impact assessments to evaluate the potential effects of waste disposal on surrounding ecosystems. Limits for disposal may be established based on the findings of these assessments to prevent adverse environmental impacts.

Table 3. Life cycle inventory data for production of 1 kg Aspartame.

Aspartame synthesis			
Inputs	**Inputs per 1 kg**	**Outputs per 1 kg**	**Notes**
Z-Asp acid	1118.75 g		
L-PheMEHCl	940.80 g		
Acetic anhydride	467.40 g	14.56 g	
Ethyl acetate	1033.20 g	1033.20 g	
Sodium bicarbonate	386.58 g	15.38 g	
Palladium	1.49×10^{-2} g		Proxy for Pd on activated carbon.
Hydrogen	8.39 g		
Methanol	249.20 g		
Water	5656.2 g	5735.88 g	Includes by-product water.
Factory	3.38×10^{-11} units		
Heating	11.06 kWh		
Electricity	4.31×10^{-2} kWh		
Carbon dioxide		194.70 g	
Acetic acid		503.87 g	
Organic substance		32.58 g	Proxy for L-PheME.
Benzyl acetate		569.99 g	Proxy used for benzyl methanoate.
Sodium chloride		258.60 g	
Aspartame		234.60 g	Proxy for beta-aspartame.

(C)1. In a **zero liquid discharge (ZLD)** plant for the production of aspartame through enzymatic and chemical synthesis, the treatment procedure for wastes can be outlined in a block diagram as follows:

1.Waste Generation: Wastes are generated from various stages of the production process, including cleaning, synthesis, and purification steps.

2.Evaporation: The liquid phase, containing water and soluble impurities, is sent to an evaporation system.

3.Multiple Effect Evaporation (MEE): The evaporator uses multiple stages of evaporation to concentrate the liquid waste. Steam from the process is used as a heating medium in each effect, and the vapor generated is condensed and collected as distilled water.

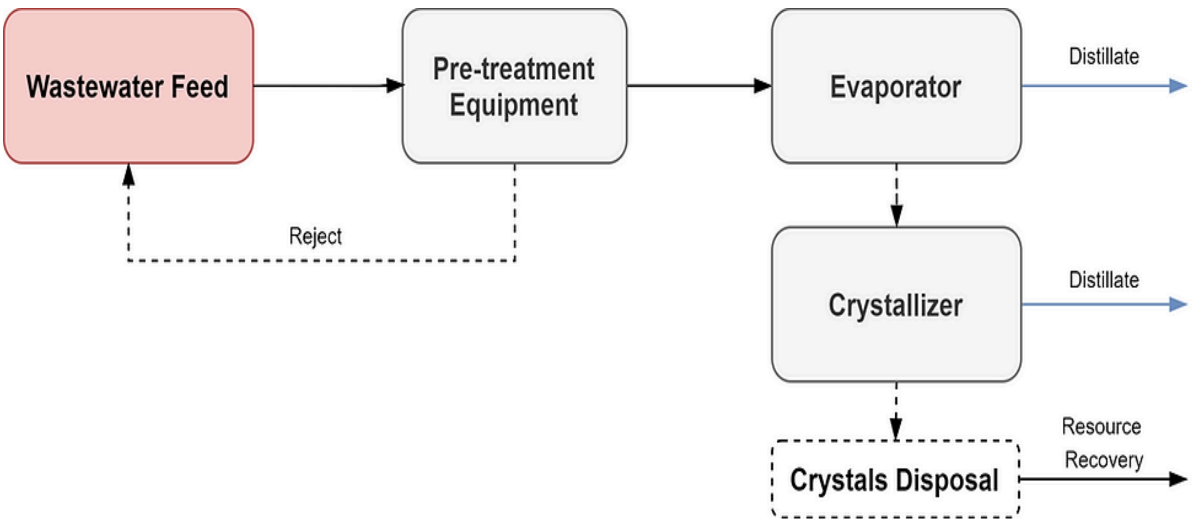
4.Crystallization: The concentrated solution from the evaporator is then processed through crystallization to separate the aspartame from the remaining impurities. Crystallization is achieved by cooling the solution..

5.Drying: The separated aspartame crystals are dried to remove any remaining moisture, producing a pure aspartame product.

6.Recycle and Reuse: The distilled water from the evaporation process is collected and can be treated further to meet quality standards for reuse in the production process. Any remaining concentrated brine or solid residues can be further processed for disposal or recovery of valuable materials.

7.Zero Liquid Discharge: The ZLD plant ensures that no liquid waste is discharged into the environment, as all liquid waste is either evaporated and recovered as distilled water or further processed for reuse or disposal.

Water treatment block diagram:

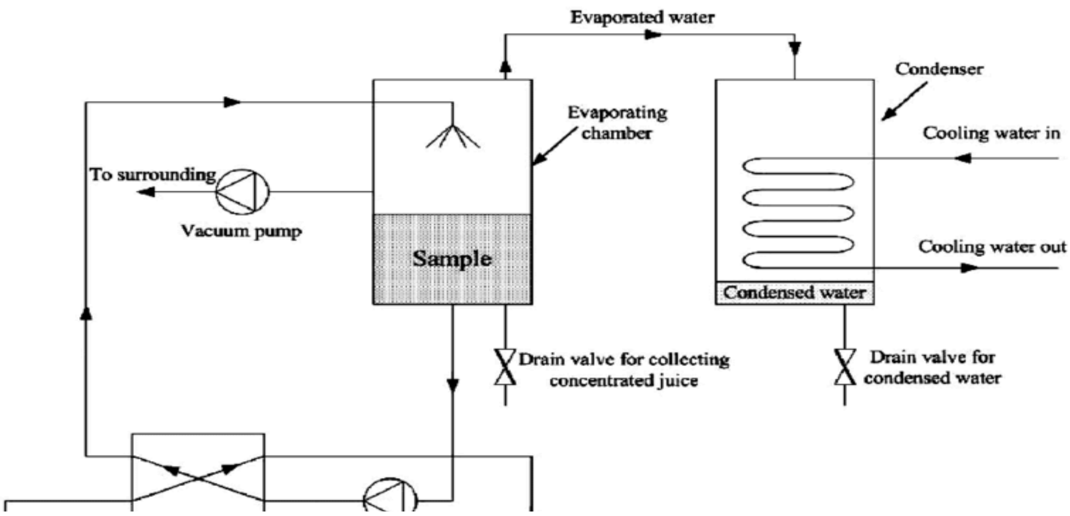


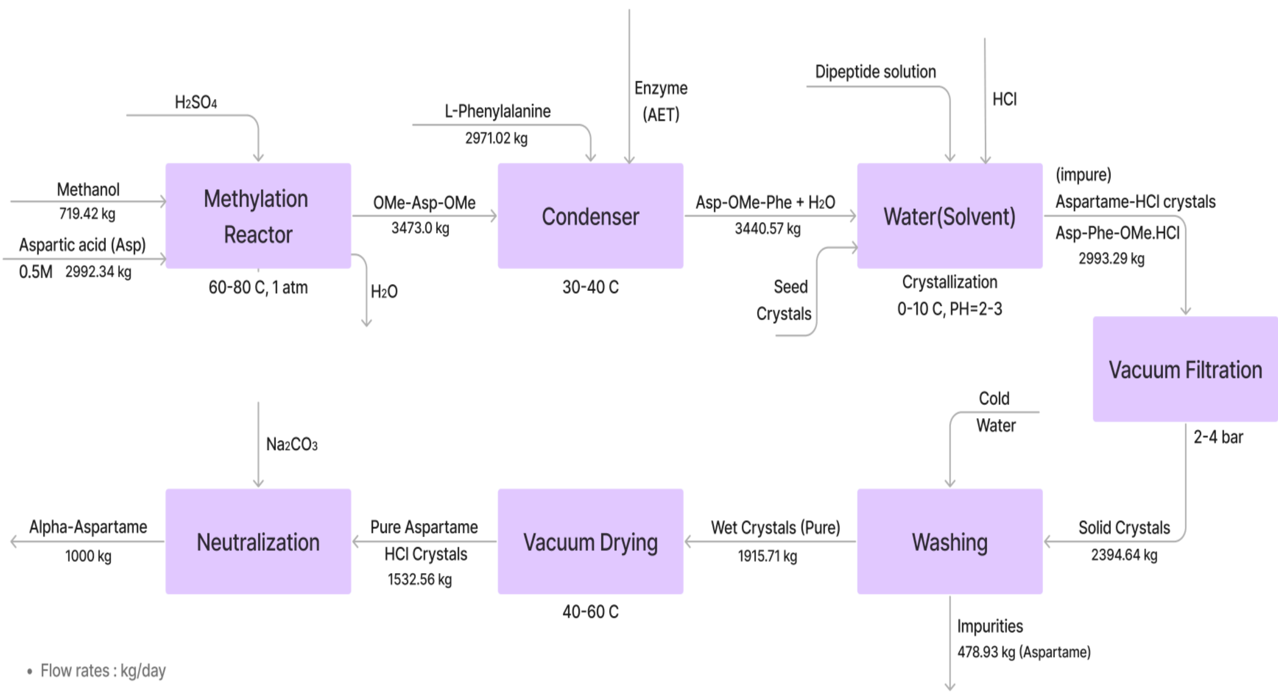
2.**Acidic solution treatment:** In the process H2SO4 is used and it is converted into a dilute acidic solution after the methylation process. So to reuse the acid, concentration of sulfuric acid is achieved through evaporators using a procedure similar to water evaporation.

The concentration of sulfuric acid is achieved in two stages using evaporators:

Vacuum Evaporation: Non-volatile impurities are removed, and the acid is concentrated using vacuum evaporation. This stage lowers the boiling point of the acid, aiding in concentration and preventing rusting. Lower Vacuum Stage: Further concentration is done to reach the desired high-concentration level. Any remaining impurities are removed in this stage. Vapors produced during the process are cleansed in a column above the evaporator. Heating the cold feed with concentrated acid reduces costs. Acid vapors are stored in rust-resistant condensers

Process diagram for concentration of dilute acid (waste):





(d) Yes, there are safety concerns associated with the chemicals used in producing aspartame through enzymatic and chemical synthesis. Some of the chemicals involved may pose health risks if not handled properly. Here are a few key chemicals and their exposure limits:

TWA and STEL data

Substance	CAS number	Workplace exposure limit				Comments
		Long-term exposure limit (8-hr TWA reference period		Short-term exposure limit (15-minute reference period)		The Carc, Sen and Sk notations are not exhaustive. Notations have been applied to substances identified in IOELV Directives
		ppm	$mg.m^{-3}$	ppm	$mg.m^{-3}$	
Methanol	67-56-1	200	266	250	333	Sk
Phenylalanine	-	-	-	-	-	
Sodium Hydroxide	1310-73-2	-	4	-	2	
Aspartame	-	-	-	-	-	

Sk: Can be absorbed through the skin. The assigned substances are those for which there are concerns that dermal absorption will lead to systemic toxicity.

References:

1)https://www.sciencedirect.com/science/article/pii/S0959652623030123

2) https://www.sciencedirect.com/science/article/pii/S0959652623030123

3)https://www.researchgate.net/figure/A-schematic-diagram-of-the-vacuum-evaporation-process_fig1_268355831

List the contributions of each author:

- Authors 1 and 2 made the flow charts and described the process of waste treatment.
- Authors 3 and 4 have worked on the current regulation criterion for waste disposal and optimize the way according to the regulation.

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