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Submitted to:

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Subject:

Process Analysis & Optimization

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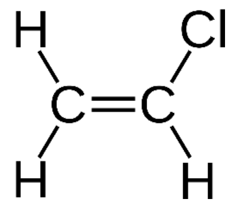
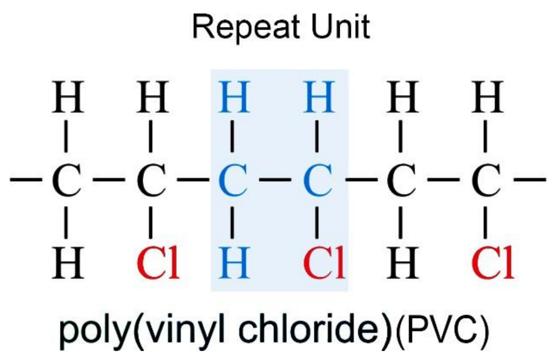
Contents

Vinyl Chloride Manufacture Information Gathering

Consider the need to manufacture vinyl chloride.



A monomer intermediate for the production of polyvinylchloride,



An important polymer (usually referred to just as vinyl) that is widely used for rigid plastic piping, fittings, and similar products. Over the years, large commercial plants have been built, some of which produce over1billionlb⁄yr. Hence, polyvinyl chloride and the monomer from which it is derived are referred to commonly as commodity chemicals that are produced continuously, rather than in batch, virtually everywhere. Historically, vinyl chloride was discovered in1835 in the laboratory of the French chemist Regnault, and the first practical method for polymerizing vinyl chloride was developed in 1917 by the German chemists Klatte and Rollett (Leonard,1971).Vinyl chloride is an extremely toxic substance and, therefore, industrial plants that manufacture it or process it must be designed carefully to satisfy government health and safety regulations. An opportunity has arisen to satisfy and, on the order of 800 million pounds per year, for vinyl-chloride monomer in petrochemical complex on the Gulf Coast of the United State, given that an existing plant owned by the company produces1billionlb⁄yr of this commodity chemical. At this point, a design team has been formulated,

Alternative1:
A competitor's vinyl chloride plant, which produces 2 billion pounds (2 MMM lb/yr) of vinyl chloride annually and is located about 100 miles away, might be expanded to produce the required amount. The vinyl chloride could be shipped by truck or rail in tank car quantities. In this case, the design team would project the purchase price and design appropriate storage facilities. This might be the simplest solution to provide the monomer required to expand the local PVC plant.

Alternative2:
Chlorine from the electrolysis of NaCl solution could be processed and shipped by pipeline from a nearby plant. Then, the chlorine could be reacted with in-house ethylene to produce the monomer (vinyl chloride), with HCl as a byproduct.

Alternative3:
Because the existing company petrochemical complex produces HCl as a byproduct in many processes (e.g., in chloroform and carbon tetrachloride manufacture), and since HCl is normally available at low prices due to large production quantities, it can be utilized efficiently. Reactions of HCl with acetylene—or with ethylene and oxygen—could produce 1,2-dichloroethane, an intermediate that can be cracked to produce vinyl chloride.

Alternative4:
Design an electrolysis plant to produce chlorine. One possibility is to electrolyze the HCl, available from within the petrochemical complex, to obtain H_2 and Cl_2. Then, chlorine could be reacted according to Alternative 2. Elsewhere in the petrochemical complex, hydrogen could be reacted with nitrogen to form ammonia, or with carbon monoxide (CO) to produce methanol.

These are typical of the alternatives that might be selected from a large number of ideas that serve as a base on which to begin the process design. For this example, it is sufficient to consider only the production of the monomer, with a focus on **Alternatives 2 and 3**.

Data from chemistry laboratories focus on several promising chemical reactions involving the chemicals in **Table 2.1**. Thermophysical property data (e.g., normal boiling points, vapor pressures, heat Here is the grammatically correct and properly punctuated continuation of the paragraph capacities, latent heats of vaporization, heats of formation, and liquid densities) for these (and many other similar chemicals) are available in extensive databases and, when not available, can be estimated fairly reliably. The availability of toxicity, safety, and purchase price data is discussed following this example.

Answer:

☑ **Best Alternative: Alternative 3**

Use of HCl as a byproduct and reaction with acetylene and oxygen to produce vinyl chloride

Justification: Why Alternative 3 is the best

1. Economic Advantage

- **HCl is already available** as a byproduct from the existing petrochemical processes (like chloroform or tetrachloroethane manufacture).
- HCl is generally sold at **low prices**, and **internal utilization** removes the need to purchase or transport raw materials like Cl_2 or ethylene.
- The overall process leverages **existing plant streams**, reducing capital investment.

2. Process Integration

- Utilizing byproducts is a **hallmark of efficient process design** in integrated petrochemical complexes.
- The plant gains **circular economy benefits**, improving sustainability and resource efficiency.

3. Environmental Benefit

- Reduces emissions and waste disposal associated with HCl, which is **corrosive and hazardous**.
- Minimizes the need to handle and store large quantities of chlorine gas, which poses **major health and safety risks**.

4. Technical Maturity

- The reaction between **acetylene and HCl** (hydrochlorination) is a well-known industrial method to produce vinyl chloride:

$$C_2H_2 + HCl \rightarrow C_2H_3Cl$$

- The process is **thermodynamically favorable** and has been practiced globally for decades.

5. Capital Cost Advantage

- Because HCl is already present and **no need for electrolyzes or expansion of Cl_2 production**, the capital cost is lower compared to Alternative 2 or 4.
- Acetylene is also commercially available and relatively inexpensive compared to ethylene.

Drawbacks of Other Alternatives

❌ Alternative 1: Expand existing VC plant 1000 miles away

- **Transportation costs** of vinyl chloride monomer (VCM) are high and pose **severe safety risks** (VC is highly toxic and flammable).
- Requires **new transport and storage infrastructure** (rail cars, pipelines, refrigeration).
- Least sustainable; **no process integration** at the new site.

❌ Alternative 2: Use Cl_2 from electrolysis and react with in-house ethylene

- Requires **installation or upgrade of Cl_2 handling facilities**—chlorine is toxic and needs special containment.
- Ethylene must be sourced and may not be readily available.
- Produces **HCl as a byproduct**, which will need to be neutralized or sold—a **reverse situation** of Alternative 3.

❌ Alternative 4: Electrolyze HCl to produce Cl_2 and react with ethylene

- Involves **high electricity consumption** (HCl electrolysis is energy intensive).

- A **multi-step process** that is **less efficient** and requires large capital for the electrolier and separation units.
- Not optimal unless **cheap electricity** and **no direct acetylene source** is available.

Summary Comparison Table

Criteria	**Alt 1: Existing Plant**	**Alt 2: Cl_2 + Ethylene**	**Alt 3: HCl + Acetylene**	**Alt 4: Electrolyze HCl**
Raw Material Availability	Medium	Medium	**High (HCl already available)**	High (requires HCl, electricity)
Economic Feasibility	Low	Medium	**High**	Low
Safety	**Low** (VC transport)	Medium	**High** (uses internal HCl)	Medium
Process Complexity	High	Medium	**Low**	High
Environmental Impact	High	Medium	**Low**	Medium
Capital Investment	High	High	**Low**	Very High

Conclusion: Choose Alternative 3

Alternative 3 offers the **best balance of cost, integration, safety, and environmental sustainability.** It utilizes an already existing byproduct (HCl), which reduces both **raw material costs** and **waste**, and avoids the complexities of chlorine or long-distance transport of hazardous chemicals. It is a proven route and aligns with **modern chemical plant integration philosophies**.