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Grau en Enginyeria Química

Treball Final de Grau

Preliminary design of a batch process for the oxolamine citrate.
Diseño preliminar de un proceso de producción en discontinuo de citrato de oxolamina.

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UNIVERSITAT DE BARCELONA

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El camino del progreso no es ni rápido ni fácil.

Marie Curie

Agradecer a mi familia todo el apoyo incondicional durante estos años y por hacer que las cosas sean más fáciles.

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SUMMARY

Oxolamine Citrate is an active ingredient of many antitussive pharmaceutical drugs. Last years, its demand has increased significantly, what has caused the necessity to increase its production.

For that, it was studied experimentally the way to optimize the process that was conducting a company to produce the drug back then, determining the critical points and suggesting improvements. Through the laboratory research and implementing many modifications, it was achieved the way to increase its yield from 24% to 64%, thanks to the identification of impurities in the Oxolamine Citrate synthesis.

For this reason, in this project is going to be studied how to transfer this optimized process to industrial scale. It is going to work in discontinuous mode.

The process can be divided in two phases: Oxolamine Citrate synthesis and its purification. It is going to be studied the most feasible method to the synthesis phase, even if it is going to take into account the purification phase to know the batch time and the time that will take to obtain the requested production. The production that has to be satisfied is 100 tones per year.

In order to achieve this quantity, it has been searched the way to get a balance between the production time and the minimum number of equipment required. Consequently, the equipment will be flexible, so when it is finished the annual production of Oxolamine Citrate, they will be able to be adapted to future processes.

The equipment used is: for the synthesis phase, 4 vessels, all of them provided of a half-pipe jacket, an agitator and a condenser to assure the reflux of the liquid that could evaporate. Anyway, the capacities of these vessels are not the same, and in them are carried out different operations as can be reactions, extractions or crystallizations. In the case of the purification phase, it would be provided of a centrifuge, a rotary dryer and two micronization mills.

It has been scheduled the production process, and has been dimensioned the equipment involved in the synthesis phase, apart from the control and automation system with its P&ID.

Lastly, it has been achieved to produce the annual requirement of 100 tones, through the production of 46 batches of 2180 kg in a period of 8 weeks.

Keywords: oxolamine citrate, active ingredient, batch production, basic design.

RESUMEN

El Citrato de Oxolamina es un principio activo de fármacos antitusivos y antiinflamatorios. En los últimos años ha aumentado su demanda considerablemente, hecho que ha provocado la necesidad de un aumento de producción.

Para ello, se estudió experimentalmente el modo de optimizar el proceso que se llevaba a cabo en una empresa, determinando os puntos críticos y planteando mejoras. Mediante el estudio a escala de laboratorio de todo el proceso, e implantando diversas modificaciones, se consiguió aumentar el rendimiento de un 24% a un 64% gracias a la identificación de las impurezas en la síntesis del compuesto.

Es por eso que en este proyecto se ha decidido llevar a cabo dicho proceso optimizado de producción de Citrato de Oxolamina a escala industrial. Se trabajará en discontinuo (en lotes).

El proceso puede dividirse en dos etapas: la síntesis del Citrato de Oxolamina y su purificación. A continuación se estudiará la metodología más factible para la etapa de síntesis, aunque se deberá tener en cuenta la etapa de purificación con tal de saber el tiempo de batch y el tiempo que llevará obtener la producción requerida. La producción que debe satisfacerse es de 100 toneladas anuales.

Con tal de obtener dicha cantidad, se ha buscado conseguir un equilibrio entre el tiempo de producción y el mínimo de equipos posibles. Es por ello que a menudo se llevarán a cabo varias etapas en un mismo equipo. De esta manera, los equipos que se utilizarán serán flexibles, y al finalizar la producción anual requerida éstos podrán adaptarse a posibles procesos futuros de la planta.

Los equipos utilizados son: para la etapa de síntesis, 4 reactores, todos ellos provistos de una media caña, un agitador, y un condensador a reflujo total para no perder la materia que pudiera evaporarse. De todas formas, los tamaños de éstos son diferentes, y en todos ellos se llevan a cabo operaciones diferentes así como reacciones, extracciones o cristalizaciones. En cuanto a la etapa de purificación, constaría de una centrífuga, un secador rotatorio por vacío y dos molinos micronizadores.

Se ha planificado el tiempo del proceso productivo, y se han dimensionado los equipos implicados en la etapa de síntesis, además del sistema de control y automatización con el P&ID correspondiente.

Finalmente, se ha conseguido producir la demanda de 100 toneladas anuales, mediante 46 lotes de 2180 kg, en un periodo de 8 semanas.

Palabras clave: citrato de oxolamina, principio activo, producción en discontinuo, diseño básico.

1. INTRODUCTION

Pharmacology is a fundamental part of medicine, since pharmaceutical drugs are used to cure, prevent or treat health diseases. In this case, Oxolamine Citrate (COX), an active ingredient that is found in many cough syrups, is used because of its anti-inflammatory effects and antitussive action. (1)

This active ingredient is sold in a lot of countries, since many pharmaceutical companies use them as one of its raw materials to produce the cough medicines, mainly in South America, where it has a big market. (2)

Due to the increase of its demand, it was studied experimentally how to optimize the production process of COX that was conducting a company back then, determining the critical points and studying the formation of impurities in order to reduce them. Trough many modifications, it was achieved to increase the yield of the process from 24% to 64%. (3)

For this reason, down below has been studied the way to transfer this optimized process to industrial scale, working in batch mode.

Working in discontinuous mode allows being more flexible with the equipment. That kind of working mode is very common in pharmaceutical industry, because the volumes are not so high. As it works on campaigns, whose time depends on the process and on the product, the equipment used for a specific process would not be working for a big part of the year. This is why it is tried to design the equipment the most adaptable way possible, which allows the consecutive production of different compounds using the same installations.

1.1. OXOLAMINE CITRATE PRODUCTION PHASES

The process of COX production can be divided in two main phases: synthesis and purification. This project is focused on the synthesis phase, even if it has been taken into account the time that would take the purification, so it has been possible to know the production schedule.

1.1.1. PHASE OF SYNTHESIS

As it has been said before, one of the main phases of the process is the synthesis of COX. During this phase, it is possible to obtain the COX before purification. The row materials are principally benzonitrile, sodium carbonate and hydroxylamine hydrochloride.

The fact of working with the optimized process studied in the past, allows the formation of fewer impurities and helps to form the final products needed. These modifications differ from the original process in the formation of Oxolamine and in the crystallization. From now on, we will talk about this optimized process. (3)

The chemical reactions that take place are the ones that can be seen on the next figure:

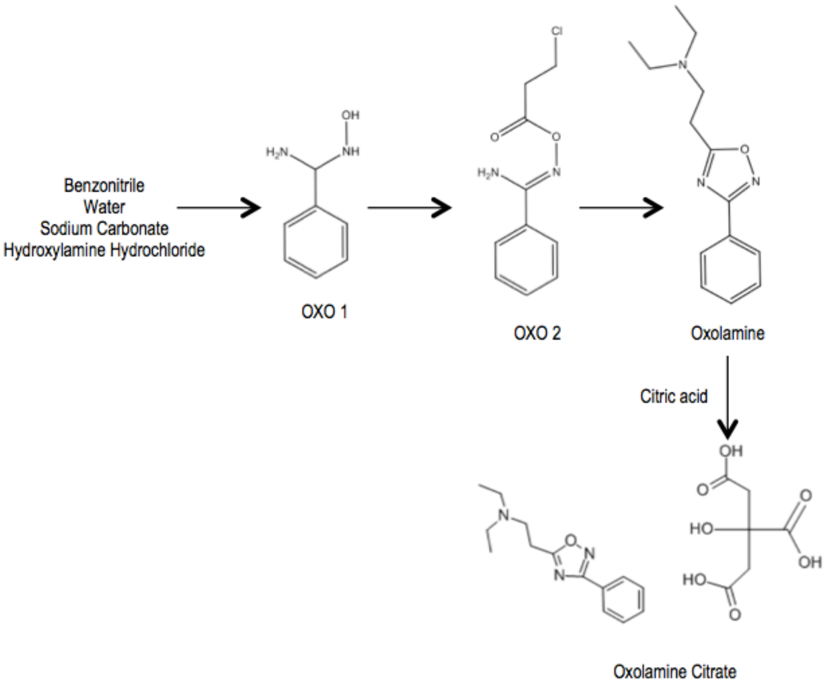


Figure 1. Oxolamine Citrate forming reactions

As it is seen in the reaction, COX is produced by many phases, and many secondary reactions take place. First of all, are added benzonitrile (which is the limiting reagent), water, sodium carbonate and hydroxylamine hydrochloride. The first product that is formed is a secondary one, which has been called OXO1. After that, are added anhydrous sodium sulfate, triethylamine (TEA) and 3-chloropropionyl chloride (3-CC) to form another secondary product, which has been called OXO2. The next substance that is added is diethylamine (DEA) to form Oxolamine. Once oxolamine is formed, is added citric acid monohydrate to form the final product, COX.

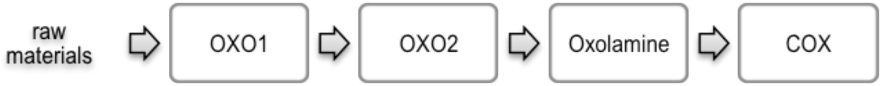


Figure 2. Oxolamine citrate synthesis

1.1.2. PHASE OF PURIFICATION

Purification phase comes after the formation of COX, in other words, when it has been obtained the final product but it is wet already. The first step to do is to centrifuge the wet COX to separate the solid COX from the liquids that rest on the final step of the synthesis, even if it is not possible to separate completely all the liquid. COX will have approximately a 10% of humidity, so on the next step it has to be dried. After that, the product has to be milled to reduce the size of the particles. The last step would be packing the COX for selling it.

Figure 3. Oxolamine citrate purification

2. OBJECTIVES

The main objective of this project is to do the preliminary design of an industrial plant to produce 100 tones per year of Oxolamine Citrate, taking into account many modifications studied experimentally to optimize the process.

To achieve this production, it is necessary to satisfy the next tasks:

- Select how would have to be the necessary equipment to acquire the production proposed.
- Study all the phases of the project, deciding where to execute them and the time they will take.
- Design the diagrams to develop the project: block, process and services.
- Select the batch size and batch time, as well as the production schedule.
- Study the automation of the process and design the piping and instrumentation diagram (P&ID).

The project covers the design, the diagrams and the automation of the synthesis phase, until obtaining the Oxolamine Citrate. The purification process until having the product in the optimal conditions in order to sell it, has been taken into account but not studied insightfully.

3. PRODUCTION PROCESS

COX production is the result of numerous operations. As it has been said before, the process can be divided in two general phases, synthesis and purification, even if each of them can be divided in different stages too. To specify the process better, along this section it is going to be explained each stage individually.

First of all, it is necessary to make a general vision of the process. For that, on this section there is a block diagram where it is possible to see the different stages of the synthesis phase. After that, it is going to be explained the recipe, to understand the sequence of the operations in each stage. Once the process is explained, it is going to be selected the equipment necessary to perform the different stages.

It should be reminded that this process works in discontinuous mode, so it is necessary to understand that one operation starts when finishes the preceding, remaining that preceding equipment empty (unless it is used for the next batch, if it is possible). It is going be another diagram to see the position of the solution along the process, since some equipment works more than one time in one batch.

Finally, it will be shown a process diagram with all the equipment chosen represented, apart from the macroscopic mass balance, both global and individual.

3.1. BLOCK DIAGRAM

Hereunder, it is shown a basic representation of the process where it can be easily understood the method that it follows.

The colored blocks correspond to the different stages within the synthesis phase. The stages differentiated are: the formation of OXO1, the formation of OXO2, the formation of Oxolamine and lastly the formation of COX. They are easily identifiable because of the different colors and the legend map shown below. The last block, non-colored, correspond to the purification.

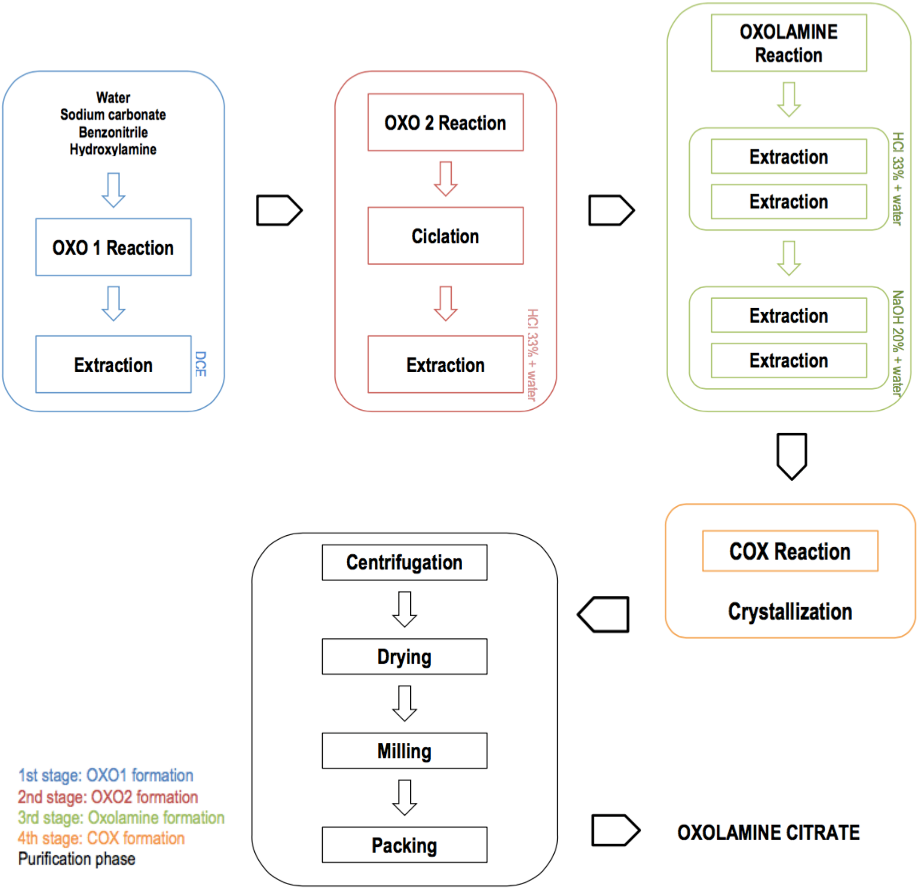


Figure 4. Block diagram

As we can see in the block diagram, in each stage is not only conducted a chemical reaction, but also one or more extractions in order to take the organic phase and separate the aqueous phase. All of them work diversely, since not is always used the same dissolvent. In the fourth stage, instead of extractions, there will be crystallization once the COX is formed, to solidify it. After that, it has to be conditioned on the purification phase.

It is important to specify that not necessarily each stage must be carried out in only one equipment, and not necessarily each equipment will take part in only one stage.

3.2. RECIPE

Once the process has been represented by its different stages, it is going to be described each one of these stages in more detail in order to clarify all the operations accomplished.

3.2.1. OXO 1 FORMATION (1st STAGE)

The first step is the formation of the secondary product designated OXO1. This stage comprises a chemical reaction, which is the formation of OXO1, and an extraction.

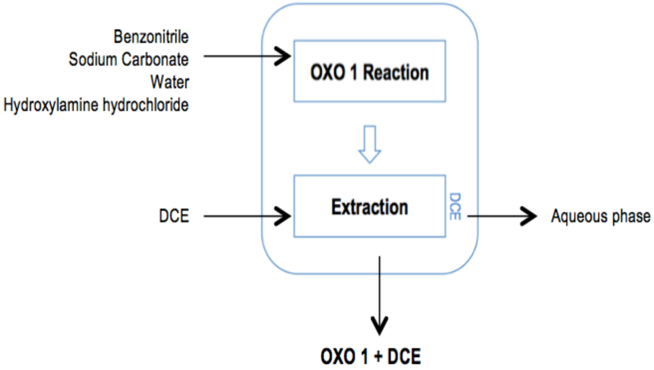


Figure 5. OXO1 formation

OXO 1 is formed by the raw materials previously appointed, water, sodium carbonate, benzonitrile (that is the limiting reagent), and hydroxylamine hydrochloride. The reactants are introduced in this order inside the reactor, as the sodium carbonate, that is a solid and has to be introduced manually, can be dissolved in water. At the beginning, the reactants are at ambient temperature. Once inside the vessel, the reaction lasts 5 hours and has to take place at the temperature of 75ºC. For that, it has been necessary to implant a heating system. This system is a heating jacket. After that time, the temperature has to decrease to ambient temperature again in order to perform the extraction.

The purpose of the extraction is to eliminate the water inside the reactor, because the next reaction (OXO2 reaction) needs a non-aqueous medium as the 3-CC is discomposed in hydrochloric acid (HCl). This is why it is introduced 1,2-dichloroethane (DCE), an organic dissolvent that has a very low solubility in water. This way, the organic phase, formed by OXO1 (the product) and DCE will be separated from the aqueous phase, which will be water and impurities. The aqueous phase is eliminated by now (it is going to be treated with other effluents), and the organic phase continuous to form another secondary product, the OXO2.

3.2.2. OXO 2 FORMATION (2nd STAGE)

This step consists mainly on the formation of OXO2, even if there are other operations, so there is a reaction, a ciclation (that is how was called a modification from the optimized process), and an extraction.

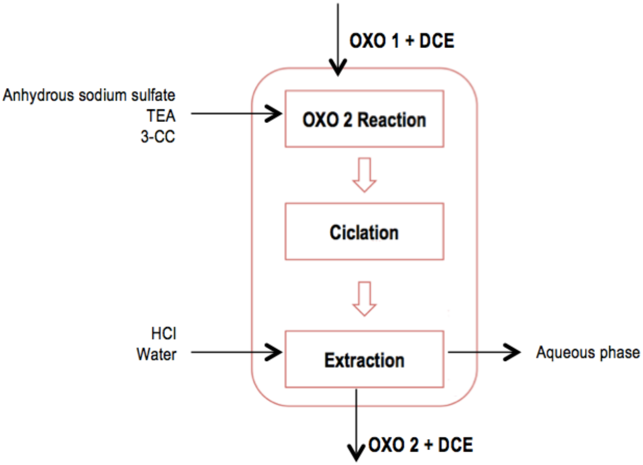


Figure 6. OXO2 formation

First of all, is introduced to the reactor the mix of OXO1 produced in the preceding stage and DCE. After that, it is introduced anhydrous sodium sulfate manually, since it is a solid, TEA and 3-CC. This last substance has to be dissolved previously with DCE, and introduce the mix in 7 steps in order to increase its dilution. The reaction lasts 1 hour and has to take place at the temperature of 10ºC because it is exothermic. The heating system will be a jacket, which like in the previous stage, it will be able to cool and to heat.

Once the reaction has finished, it was studied a chemical method that concludes that an increasing of the temperature to 80ºC at this point, increases the solubility and provokes a higher yield and less formation of impurities. For that, it is used the heating jacket.

The last step before the next reaction is an extraction to separate the TEA that has not reacted. For that, it is introduced water and HCl with a concentration of 33%, to form triethylamine hydrochloride, which is very soluble in water. They form the aqueous phase, which will be treated apart. Meanwhile, OXO2 is very soluble in DCE, so they form the organic phase that will react next to form the Oxolamine.

3.2.3. OXOLAMINE FORMATION (3rd STAGE)

This part of the process is represented by the formation of the Oxolamine. After the reaction, there are four extractions, two with HCl and other two with NaOH.

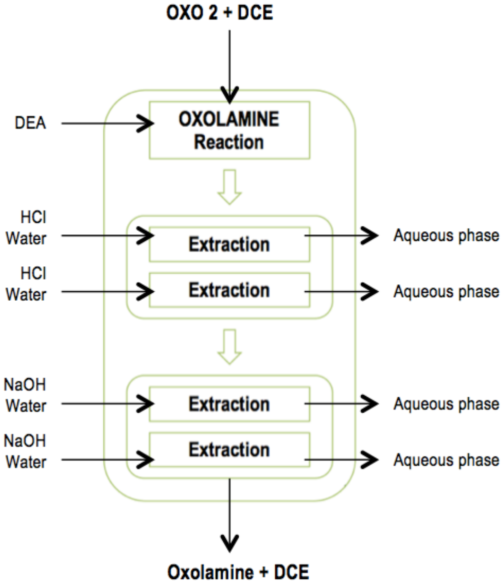


Figure 7. Oxolamine formation

The first step of this stage is the Oxolamine reaction. It is introduced DEA, and the reaction takes place for 1 hour at the temperature of 80ºC. Again, a jacket heating system works to increase the temperature. Once Oxolamine is formed and the reaction has finished, it has to work to decrease the temperature to ambient temperature again in order to carry out the extractions.

Then, there are two acid extractions. Are made two of them to assure that all the impurities are eliminated (also the DEA that has not been reacted). To perform these extractions, first of all are added HCl and water, and then the system, like in the other extractions, is agitated. The aqueous phase is set apart to treat it, and the organic phase, composed of Oxolamine and DCE, is moved to perform the second acid reaction, again with HCl and water. The result will be the same, and the new aqueous phase will eliminate the impurities that could not be eliminated in the previous extraction.

Lastly, there are who basic extractions. These last two extractions with NaOH, are another modification from the original process. This is done because the result of these acid and basic washings is an Oxolamine with less quantity of impurities. As in the extractions above, NaOH and water are introduced, the system is agitated, and there is a separation of the aqueous and the organic phases.

3.2.4. COX FORMATION (4th STAGE)

The last step of the synthesis phase of the process is the formation of COX, the final product. This step is formed by the reaction of COX and a crystallization right after in order to solidify it.

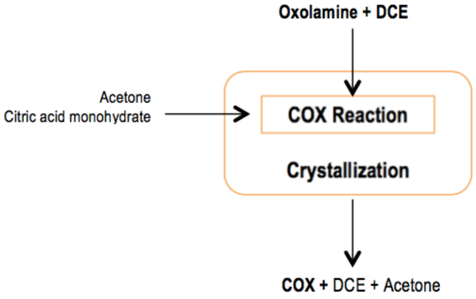


Figure 8. COX formation

After being introduced the previous organic phase, composed by Oxolamine and DCE, are introduced acetone and citric acid monohydrate. There is a reaction where is formed the final product, the Oxolamine Citrate.

Thereafter, is made a crystallization to solidify the COX. After that, the solution contains solid COX, acetone and DCE.

The synthesis phase finishes here because the final product has been obtained. The aim of the purification phase is, first of all, to separate the solid COX from the other substances, which are liquid, through a centrifugation. After that, COX has to be dried and conditioned so it can be packed.

3.3. EQUIPMENT SELECTION

The equipment of this project has been selected taking into account the fact of using the less number of them possible, but taking also into consideration the batch time.

3.3.1. SYNTHESIS EQUIPMENT

Since there are carried out many reactions, and other operations like extractions and crystallizations, and they all can be performed in reactors, this is the main equipment of the process, even if not all the operations have the same necessities. This is why, even if there will be many reactors, all of them will be different with each other.

Even though, they all have similar properties. They are all provided of a condenser on it, which uses water at ambient temperature from a cooling tower in order to condense the steam that could evaporate from the reaction (4). Another thing that they have in common is the heating system. They are all provided of a heating jacket with two services. On the one hand, there is the steam in order to increase the temperature of the reactor when it is necessary, and on the other hand there is glycol-water at 50% at the temperature of -20ºC in order to decrease the temperature.(4)

The first stage is all carried out in the first reactor, called R1. This means that it is conducted the OXO1 reaction first, and after that, the extraction. The particular thing of this reactor is that since at the first step (the reaction) the volume of the solution fills only the half part of the capacity of the reactor, and at the second step (the extraction) it takes approximately the 90% of the capacity, the jacket is split at half height. This way, the transfer area will be adequate for each situation.

The second stage is carried out in the second reactor, R2. The capacity of this reactor is the same of R1, and the difference is that the jacket, in that case, will not be split but entire.

The third stage, since it has four extractions, has to be completed in more than one vessel, because after each extraction it has to be separated the aqueous phase from the organic phase. This is why the reaction and the first extraction are carried out in a third reactor, R3. The next extraction will be conducted in a fourth reactor, R4. The two basic extractions with NaOH are accomplished in reactors R2 and R3, respectively. R3 is very similar to R2; they have the same capacity and the same heating system, even if obviously they do not have the same inputs and outputs. In the case of R4, it is bigger because later on is needed more capacity on the formation of COX.

Finally, the fourth stage, composed by the COX reaction and crystallization, is carried out in reactor R4.

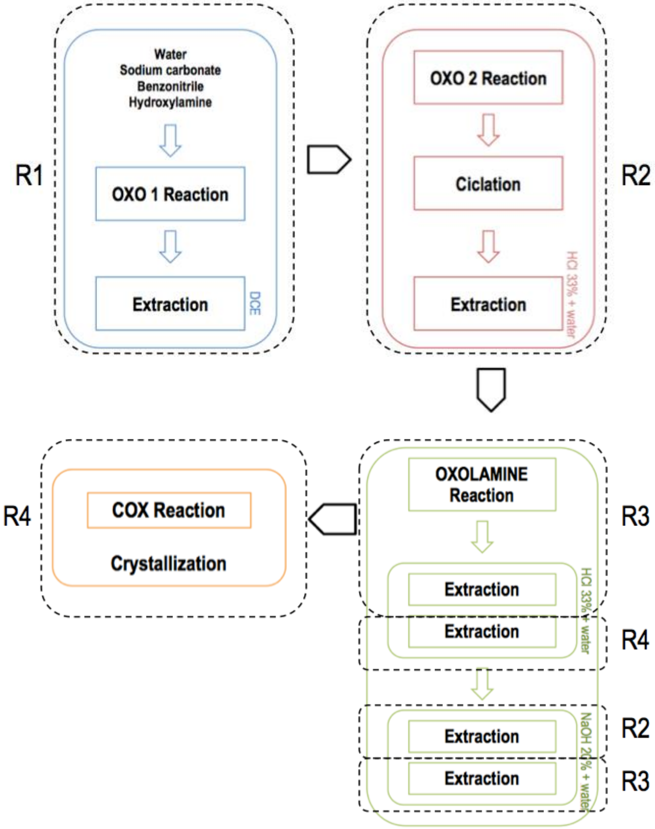


Figure 9. Equipment distribution

As it can be seen, are used four reactors, and all of them except R1 are used more than once in every batch. This equipment has been dimensioned and the results will be exposed further on.

3.3.2. PURIFICATION EQUIPMENT

Even if the phase of purification has not been dimensioned, talking about the size of the equipment, if has been chosen which will be used taking into consideration the necessities both of capacities and batch time.

The output of the previous step, the fourth stage of the synthesis phase, was a mix of COX, DCE and Acetone. It has to centrifuge, even if the volume of R4 is much bigger than the volume of the centrifuge. This is why it is necessary to move the solution from R4 to the centrifuge in 7 steps because of the size of the centrifuge. While each of these 7 parts is centrifuging, the reminder that has not transferred yet stays in R4.

After centrifuge, the 90% of the liquid has been separated and is obtained wet COX. To dry it is used a rotary vacuum dryer. Once COX is dried also in 7 steps, it has to be milled. It is milled in continuous, right after the drying operation. For it, are used two micronizer mills because its capacity is small. Right after, COX is packed.

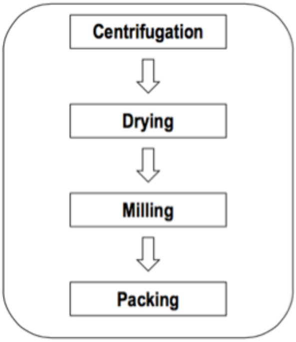


Figure 10. Purification stages

3.4. PROCESS DIAGRAM

Shown below is represented the process diagram where are seen all the equipment and the inputs and outputs of the synthesis phase.

Can be also seen the plant services, which are:

- Cooling water at ambient temperature used for the condensers, which is refrigerated in a cooling tower.
- Water steam to heat the reactors through the jacket, which leaves the jacket as condensate.
- Water-glycol mixture at 50%, at the temperature of -20ºC, to cool the reactors through the jacket.

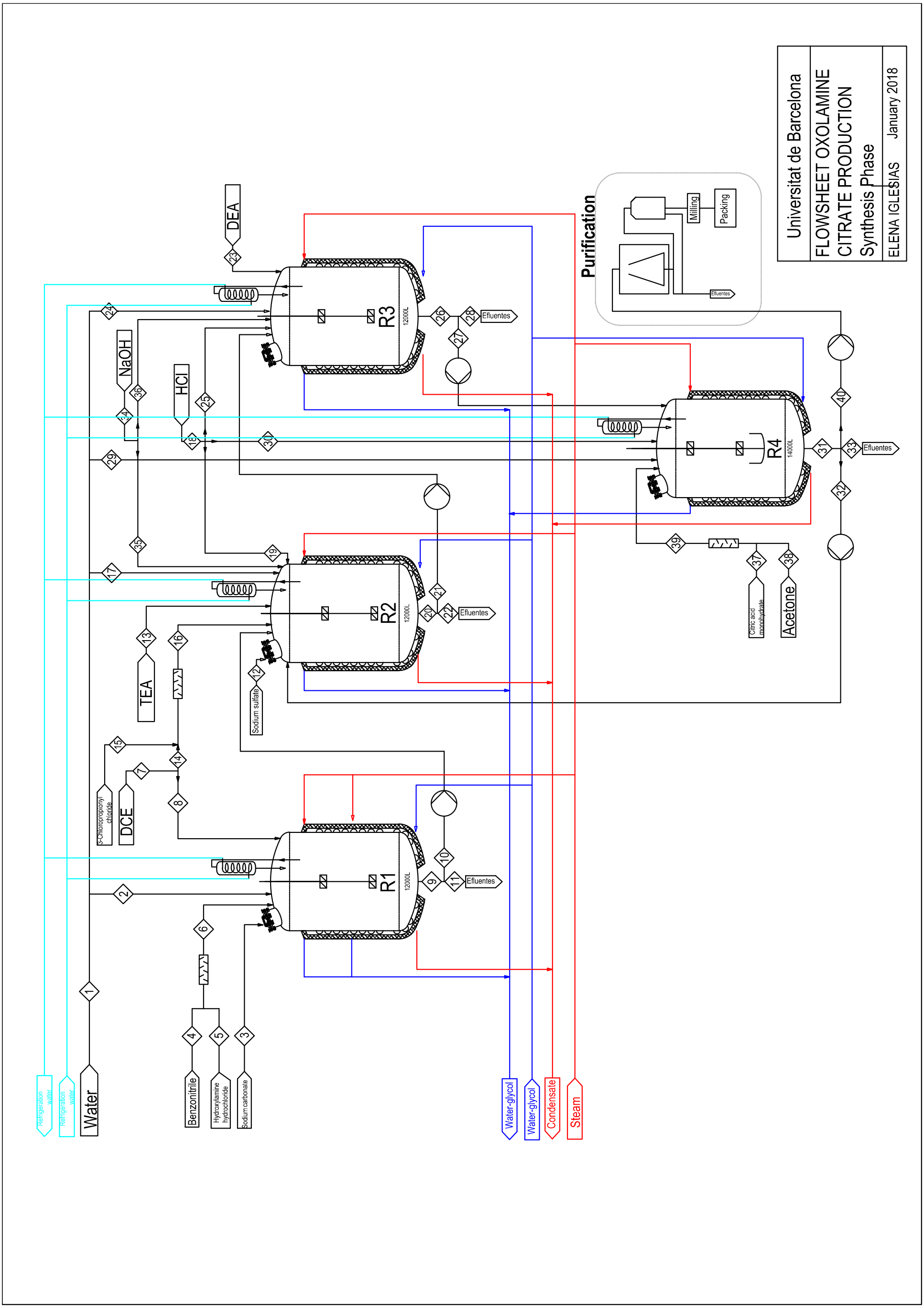


Figure 11. Process diagram

3.5. MASS BALANCE

Down below are written the design bases and the mass balances of the process, both global and individual of every reactor.

3.5.1. DESIGN BASES

One of the bases of the project is that it works in discontinuous, so not all the equipment is working all the time.

The mainly aim of the process is producing the quantity of 100 tons per year of COX. This is the calculation base of the production process. In every batch are produced 2180 kg of COX, which means that it should be produced 46 batch/year.

In the original process the quantity obtained in each batch was the half part, but as it was said before, the production had to increase. Even though, it is known the amount of raw materials that were used, as well as the yield of the operations. This way it was possible to calculate the quantity of product obtained in the operations involved in the process.

	kg/batch
Benzonitrile	800
OXO 1	952
OXO 2	1,488
Oxolamine	1,708
COX before purification	2,508
COX obtained	**2,180**

Table 1. Base calculation

3.5.2. MASS BALANCES

Down below there is a table where can be seen the inputs and the outputs in each equipment step by step. Until the R4 there are the quantities per batch. From there, there are the quantities of every load (taking into account that every batch is divided in 7 loads).

	IN	OUT	
R1	9,656	9,656	kg/batch
R2	9,516	9,516	
R3	10,340	10,340	
R4	9,112	9,112	
R2	11,244	11,244	
R3	11,244	11,244	
R4	12,744	12,744	
Centrifuge	1,778	1,778	kg/load
Dryer	353	353	
Mills	315	315	

Table 2. Inputs and outputs

In order to see it more clearly, the increase of the mass in each batch with the time can be seen in the Figure 16 (chapter 6.2).

	MASS BALANCE (kg/batch)																														
Line	**2**	**3**	**6**	**8**	**10**	**11**	**12**	**13**	**16**	**17**	**19**	**21**	**22**	**23**	**24**	**25**	**27**	**28**	**29**	**30**	**32**	**33**	**17**	**35**	**21**	**22**	**24**	**36**	**27**	**28**	**39**	**40**
Water	2800	0	0	0	0	3524	0	0	0	687	0	0	1050	0	1600	0	0	1600	1600	0	0	1600	3000	0	0	3000	3000	0	0	3000	0	0
Sodium carbonate	0	492	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benzonitrile	0	0	800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydroxylamine hydrochloride	0	0	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dichloroethane	0	0	0	5000	5000	0	0	0	436	0	0	5436	0	0	0	0	5436	0	0	0	5436	0	0	0	5436	0	0	0	5436	0	0	0
OXO 1	0	0	0	0	952	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anhydrous sodium sulfate	0	0	0	0	0	0	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triethylamine	0	0	0	0	0	0	0	1260	0	0	0	0	1260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-Chloropropionyl chloride	0	0	0	0	0	0	0	0	875	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrochloric acid	0	0	0	0	0	0	0	0	0	0	233	0	233	0	0	128	0	128	0	113	0	113	0	0	0	0	0	0	0	0	0	0
OXO 2	0	0	0	0	0	0	0	0	0	0	0	1488	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diethylamine	0	0	0	0	0	0	0	0	0	0	0	0	0	1688	0	0	255	783	0	0	0	255	0	0	0	0	0	0	0	0	0	0
OXOLAMINE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1708	0	0	0
Sodium hydroxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1100	0	1100	0	1100	0	1100	0	0
Acetone	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4000	9686
Citric acid monohydrate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1600	0
OXOLAMINE CITRATE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2258
Impurities	0	0	0	0	0	180	0	0	0	0	0	0	49	0	0	0	0	430	0	0	0	0	0	0	0	0	0	0	0	0	0	500
TOTAL	2800	492	1364	5000	5952	3704	73	1260	1311	687	233	6924	2592	1688	1600	128	5691	2941	1600	113	5436	1968	3000	1100	5436	4100	3000	1100	7144	4100	5600	12444

Table 3. Mass balance

3.6. ENVIRONMENTAL FACTORS

Nowadays, it is important more than ever taking into consideration the environmental factors that have a connection with the process.

It has to be complied with governmental regulations. For that, it is important to consider many aspects as: the residues generated in the process, the wastewater and its possible segregation and final management, the air emissions, the noise emissions if it is alerted that they could be high, the energy demand of the installation and the possibility of minimize it and the consume and amount of water to use also the possibility of minimizing.(6)

Furthermore, it has to be studied the exploitation of the raw materials, that not will only help the environment but also will decrease the cost of the production.(7) For that, there is an installation to treat the aqueous phases that go out of the many extractions, and also a recirculation system of the solvents that have been separated during the process. Even if they have not been dimensioned on this preliminary design, they are explained down below.

Aqueous phases of extractions:

In total, there are six extractions. On them, it has been separated the organic phase (that was the useful because it contained the product), of the aqueous phase. This aqueous phases have to be treated because they have impurities so can't be segregated to the environment. All of them excepting of one, are all sent to a sewage treatment plant, in order to purify them so they can be segregated. The other one is the aqueous phase coming from the second stage, after the OXO2 formation. This phase contains TEA that has not reaction, so is treated to recover it.

Solvents recuperation:

The solvents recuperation takes part on the purification phase. Once DCE and Acetone are mixed before the crystallization in R4, they will remain in the solution until arriving to the centrifuge, where the liquid part and de solid COX are separated. Is there when DCE and Acetone are removed. After that, they are treated to separate them, so they can be exploited.

4. PROJECT SPECIFICATIONS

In this section, are going to be explained the project specifications. It includes the specifications of the equipment, the auxiliary equipment of the plant services, the pipes, valves and pumps, and an explanation of its distribution in the plant.

4.1. REACTORS

The equipment used in the synthesis phase of the process is formed mainly for four reactors. They are all similar, since they have the same heating system and auxiliary equipment, but not equals.

Reactors R1, R2 and R3 have the same volume, and R4 is bigger. Furthermore, the agitation system of the first three reactors is the same and the one for R4 is different. This is why this point is divided in two sections, first are going to be dimensioned the first three reactors and then the last one. Their specifications sheets can be found on Appendix 2.

The dimensions have been calculated according to the necessities, so the next step would be choosing the reactors that suit these necessities best, once it has been talked to the supplier and has been made the comparison between the offers.

4.1.1. REACTORS R1, R2 AND R3

Even if R1, R2 and R3 are not used for the same operations and either for containing the same solution, they have the same size so they can be more flexible and accordingly more useful if they are ever needed for another process when COX production is not carried out in the plant. Their sizing has been established taking into account the substances properties that take place in the process.(5)

Thereunder, there are the general specifications of these reactors:

Diameter [m]	2.2
Section [m^2]	3.8
Height [m]	3.2
Wall thickness [m]	0.01
Volume [m^3]	12

Table 4. Size of R1, R2 and R3

Apart of the sizing, other properties are shown below:

	R1	R2	R3
Position	Vertical	Vertical	Vertical
Material	AISI 316L	AISI 316L	AISI 316L
Working Temperature [ºC]	+25/+80	+10/+80	+25/+80
Working Pressure [bar]	1	1	1

Table 5. R1, R2 and R3 general properties

After having seen the general considerations of the three reactors, it is going to be contemplated what is the auxiliary equipment required for the correct running of them. All of them are mentioned and explained here below.

Half-Pipe Jackets

The heating system of all the reactors is a half-pipe jacket, which guarantees a good area transfer between the solution inside the reactor and the fluid inside the jacket. This half-pipe jacket is provided by two plant services, since its function is both heating and cooling.(8)

When it has to be heated, it is used water steam at 120ºC, which condensates inside of the jacket and goes out of it as condensate. This condensate is treated in the plant to turn back to vapor steam, so it can be used again on all the processes carried out apart from this one.

When it is necessary to cool the solution inside the reactor, it is used a water-glycol mixture of 50%. The reason for it is that the cooling liquid has to be at a lower temperature than 0ºC, since one of the reactions of the process has to take place at 10ºC because it is very exothermic. If the cooling liquid temperature was higher, the temperature gradient between them would not be high enough. This is why it is used the water-glycol mixture of 50%, which has enough ethylene glycol to decrease its melting point. This cooling liquid goes into the reactor at the temperature of -20ºC.

The information above is common for R1, R2 and R3, but there is a difference between them. The R1 is not always full. When it is taking place the reaction, the solution inside fills approximately only the half part of the reactor. This is why the half-pipe jacket of R1 is split at half height. Instead, the half-pipe jackets of R2 and R3 are entire.

Below there are the tables where can be seen its properties:

	R1	
Jacket type	Split half-pipe	
Operation	Heating	Cooling
Fluid	Water Steam	Water-glycol
Exchange area [m^2]	9	9/16
Heating power [kW]	325	140
Fluid flow [m^3/h]	0.6	4.1

Table 6. R1 thermal properties

	R2		
Jacket type	Half-pipe		
Operation	1st Cooling	Heating	2nd Cooling
Fluid	Water-glycol	Water Steam	Water-glycol
Exchange area [m^2]	16	16	16
Heating power [kW]	165	350	220
Fluid flow [m^3/h]	8.6	0.6	6.5

Table 7. R2 thermal properties

	R3	
Jacket type	Half-pipe	
Operation	Heating	Cooling
Fluid	Water Steam	Water-glycol
Exchange area [m^2]	16	16
Heating power [kW]	330	220
Fluid flow [m^3/h]	0.6	6.5

Table 8. R3 thermal properties

Condensers

Each reactor is provided of a condenser on it in order to condense the vapors that could evaporate from the reaction. It works at total reflux, so all the condensate returns to the reactor. The type is a coil condenser. The cooling water goes through the coil and the vapors evaporated through the area between the coil and the casing.

Their properties are shown below:

Type	Coil
Cooling fluid	Water
Exchange area [m^2]	1.5
Fluid flow [kg/h]	30

Table 9. Condensers properties

Agitation system

The agitation system of R1, R2 and R3 is the same. It consists of a vertical agitator located in the center of the reactor. This agitator is consists of two paddle impellers with four pitched blades. The two impellers are located in the same axis but at different heights.

The general properties of the agitators are below: type, size (having into consideration that the diameter of the impeller is approximately 1/3 of the diameter of the vessel), material, and the rotational speed. (11) Taking into account these properties it should be chosen the agitator that best fits from the suppliers' offers, considering its mechanical properties too.

Type	Paddle agitator
Number of axes	1
Number of impellers	2
Impeller shape	4 pitched blades
Material	Contact: AISI 316L
	No-contact: AISI 304
Diameter [m]	0.7
Height [m]	1.25
	2.25
Rotational speed [rpm]	80

Table 10. R1, R2 and R3 agitation properties

4.1.2. REACTOR R4

R4 is slightly different to the others, since it is bigger and inside it is carried out another operation apart from the chemical reaction and an extraction: a crystallization.

Due to all the operations that are performed in it, it has different conditions apart from the size. On the one hand, the heating system will be the same to the other reactors (but bigger, because the contact area has a larger size), and the agitation system has to be different too because all the operations don't need the same agitation speed nor the same agitator type.

On the other hand, many properties are the same, as the fluids used to heat and to cool, the position of the reactor, the material or the working pressure.

As it has been done with the other reactors, below there is a table with the general properties of R4.

Diameter [m]	2.3
Section [m^2]	4.2
Height [m]	3.4
Wall thickness [m]	0.01
Volume [m^3]	14

Table 11. Size of R4

	R4
Position	Vertical
Material	AISI 316L
Working Temperature [ºC]	+10/+25
Working Pressure [bar]	1

Table 12. R4 general properties

Half-Pipe Jacket

The half-pipe jacket is similar to the ones of the other reactors, but it is bigger, so it is R4. In that case the jacket is entire (not split as in R1).

It has the main function of cooling in order to crystallize the COX once the product is formed. This is why the temperature will decrease significantly.

	R4
Jacket type	Half-pipe
Operation	Cooling
Fluid	Water-glycol
Exchange area [m2]	18
Heating power [kW]	130
Fluid flow [m3/h]	6.8

Table 13. R4 thermal properties

Condenser

The condenser used in this reactor has exactly the same function to the others, and the properties are the same. The four condensers used on the synthesis phase of the process are equal.

Agitation system

In the case of R4, the agitator is different since it has to be used for more operations. In the case of the reaction and the extraction, the agitator system requires the same functions as the reactors in the other three vessels.

In respect of the crystallization, it requires a lower rotational speed since COX must crystallize. This agitation has to be energetic enough to maintain the crystals on suspension but gentle enough to do not break them. It must be a multi-position agitator, so it will be possible to change its rotational speed depending on the operation carried out at every moment.

Therefore, it has been chosen an agitator with a single axis with 3 spellers: an anchor at the bottom, and two paddle impellers similar to the chosen before.

Type	Paddle agitator	Anchor agitator
Number of axes	1 (both in the same axis)	
Number of impellers	2	1
Impeller shape	4 pitched blades	U-shaped
Material	Contact: AISI 316L	
	No-contact: AISI 304	
Diameter [m]	0.7	2.25
Height [m]	1.5	Bottom of the vessel
	2.5	
Rotational speed [rpm]	80	20

Table 14. R4 agitation properties

4.2. RAW MATERIALS STORAGE

Reagents are stored in different kind of equipment depending on its use and the quantity necessary to complete each process.

The plant will be provided with tanks to store reagents that are used in big quantities, like DCE, TEA, NaOH, DEA, Acetone and Citric Acid Monohydrate.

By contrast, the reagents that are not used in big quantities will be taken from IBC. It is the case of the Benzonitrile, Hydroxilamine hydrochloride, 3-CC and HCl. If any of them were used in another process in the same plant, would be the possibility of having them into tanks, in order to use them for more than one process.

4.3. PIPING

In this chapter is going to be talked about the pipelines specifications. To calculate the nominal diameter, it has been imposed the fluid velocity as 2m/s, and it also depends on the time that would take the displacement.

In the table below are classified the pipes, its function, its diameter and the fluid that goes through them.

Taking into account these properties, it would have to be chosen the pipes to install them. It must be considered the fact of coating the pipes in order to isolate them from the external temperature. Even if in this process it is not always an essential fact, since most of the time the product transfers through the equipment at ambient temperature, it could be necessary in other processes performed in plant. Adding the coating could prevent and increase the flexibility of the equipment.

Pipe	Function	DN [mm]	Fluids
1	Water distribution	50	Purified water
2 , 17, 24, 29	Water charge	50	Purified water
6	Reagents charge	40	Benzonitrile and Hydroxylamine hydrochloride
7, 8, 14	DCE charge	50	DCE
10	Organic phase transfer	50	OXO1 and DCE
11	Aqueous phase discharge	50	Water and impurities
13	TEA charge	40	TEA
16	DCE and 3-CC charge	25	DCE and 3-Chloropropionyl chloride
18, 19, 25, 30	HCl charge	20	HCl
21	Organic phase transfer	50	OXO2 and DCE
22	Aqueous phase discharge	50	Water and impurities
23	DEA charge	40	DEA
27	Organic phase transfer	50	Oxolamine and DCE
28	Aqueous phase discharge	50	Water, HCl and impurities
32	Organic phase transfer	50	Citrate oxolamine and DCE
33	Aqueous phase discharge	50	Water, HCl and impurities
34, 35, 36	NaOH charge	25	NaOH
39	Reagents charge	50	Acetone and citric acid monohydrate
40	Organic phase transfer	50	Oxolamine Citrate, DCE and acetone

Table 15. Pipes properties

4.4. PLANT DISTRIBUTION

In this section are going to be mentioned many considerations that must be contemplated when it is built the project in the plant.

As can be seen above, in the point 3.4, the lines are only numerated in the order of the process (except when the same line is used twice). Anyway, it should be numbered also with the number of the plant or the section (or both). It would have to be changed one it had been installed. The plant would be all the same, but maybe not the floor or the area.

Since it is a pharmaceutical project, there are many special considerations when building the equipment in the plant.

- First of all, it is important the position of the 4 reactors. Even if the process is completely automatized, sometimes it is necessary to introduce solids inside the reactors through the manhole. This is why the lower side of the reactors are supposed to be in the first floor, and the upper side in the second floor. This way, there would be a platform or a slatted floor that would allow the operator arriving to the upper part of the reactors. It would not only serve to introduce the solids, but also to facilitate the maintenance of the equipment.
- The compliance with the regulations and also the assurance that the product is finished with the best quality prompt to do many of the operations in the named white rooms or clean rooms. They are used principally in the pharmaceutical area. The operations have to be carried out there when the product is in contact directly with the room. In COX process, are going to be performed there all the operations of the purification phase. These rooms have many properties that make them very different from the technical area. Inside them, can’t enter any kind of contamination. This is why the operators have to wear a special uniform, the pressure is higher than the pressure outside, often their temperatures is lower, and have laminar fluxes through the room to take out the contamination that could have entered. All these factors should be studied carefully.
- The control system, of which it is going to be talked next, has a huge relation with the plant distribution. For example, using the gravity to discharge the equipment or not using it, would change the necessity of a pump in that pipe.

5. P&ID

The automation is a very important part of every project. In this chapter is going to explain how is going to control the main variables that influence in the process.

- **Flow/weight:** It has to be controlled the flow that enters in the reactors, in order to introduce the necessary mass to carry out whatever operation. In this case, instead of having a flow control, the way to regulate it is through the load cells installed in the supply tanks where are found the reagents. Its control system will assure that the quantity introduced in the reactors is the one needed, thanks to the difference of weight in the supply tank or IBC. It will open or close the valves when it is needed. Furthermore, it is installed also a load cell in every reactor, just to see if the weight in the reactor is correct when it has been charged or discharged.
- **Temperature:** The temperature of each reactor is controlled and directly connected to the pipes of water-glycol and water steam, in order to open gradually the valves and having the optimal temperature in every moment.
- **Pressure:** On the top of the reactors, there are pressure safety valves (PSV) to ensure that the pressure inside the reactors is not too high due to the increase of temperature or to the agitation. If it was high, the valve would open and the vapors would leave to treat them.
- **Density:** Under every reactor, in the discharge line, there is a density transmitter that differentiates the organic phase from the aqueous phase. The signal is sent to the controller, which is connected to an on-off three-way valve that acts just after the signal of the transmitter, when the density has changed, and makes the solution go to one pipe or another.(9)
- **Level:** In the upper half of the reactor, there is a level controller in order to assure that the level of the reactor is not too high. (10)

In the next pages can be seen the P&ID diagram of the whole synthesis phase and also an amplified P&ID diagram of R1, so the details can be seen with more precision.

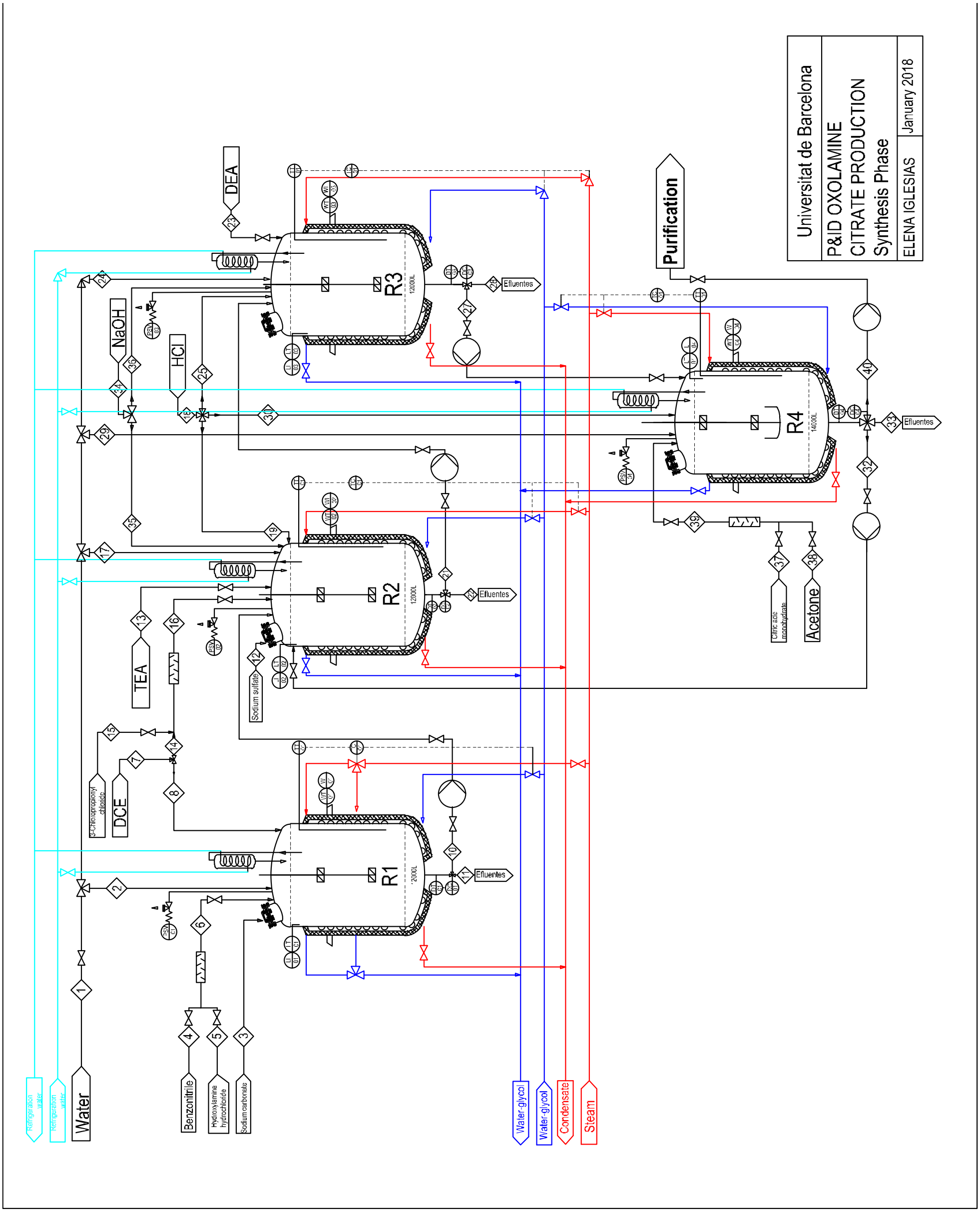
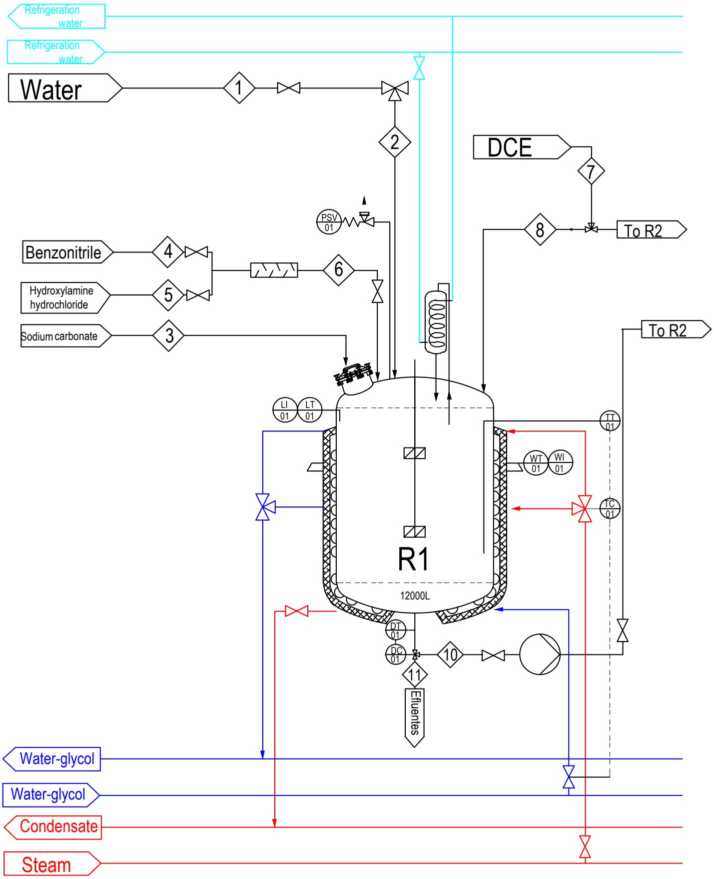


Figure 12. P&ID



Universitat de Barcelona

P&ID OXOLAMINE
CITRATE PRODUCTION
R1 Ampliation

ELENA IGLESIAS	January 2018

Figure 13. P&ID R1

6. SCHEDULING

6.1. GENERAL CONSIDERATIONS

In this chapter is going to be referred to the schedule of the project and the equipment organization. In order to know the batch time and also the time that would take the process of obtaining the quantity required of COX, have been assumed many considerations.

First of all, the main objective, that as it has been said before, is producing the annual amount of 100 tones. Another known quantity is that in every batch are produced 2180kg of product. Thanks to these known facts, which are both fixed, can be known the quantity of batches that have to be produced per year. The amount is 45.87 batches/year, that is to say, 46 batches/year.

Annual demand [kg COX]	100,000
kg COX / batch	2,180
Annual number of batches	46

Table 16. Main schedule considerations

Other considerations have to be contemplated. The equipment used in each moment has been chosen depending on the time that takes each operation and the requirements that they have. Even if there were operations that could be carried out in more than one of the reactors, then can be seen the criteria to be followed. In principle, this equipment assignment is fixed, even if it could change depending on the process requirements.

Another consideration taken into account is the fact that many improvements might be possible, because in this calculation has not been taking into consideration the limitations of raw materials, energy and costs. Anyway, it has been chosen the minimum number of equipment possible, and the minimum number of services of the plant. If the plant where was installed the process had other external services or auxiliary equipment available to be used, it should be considered the feasibility to change the process in the near future, in order to improve it.

Even if not all these improvements can be studied until the equipment is installed in the plant, because it is necessary to know the services in it, it is possible to study possible alternatives in respect of the sequence of the process, once it has been known the equipment used and the time that take all the operations. It will be commented below.

6.2. BATCH TIME

Right after knowing the number of batches that are necessary to acquire the COX annual demand, it has to be known the time that will last each batch.

Once known the batch time and the number of batches needed per year, it will be feaseble to study when and how is going to be produced: how many campaings will be needed and how many days per campaign.

It is important to take into account that in this chapter, as is needed to calculate the process time, is included also the time that would take the purification phase. Therefore, it is studied the time that take the operations of both synthesis and purification.

The calculation has been done asuming that the thing that limits the time is the equipment occupation, not the labor. It is assumed that there will always be enough workers to carry out the tasks assigned.

Down below, there is a table where can be seen all the operations conducted in the process and the time that they take, according to the equipment conditions. The operations in italics mean that they are being performed simultanelly to the successive operation. Consequently, the batch time, as it is going to be referenced later, is not the add of all the stages times.

Stage	Equipment	Step	Time [h]
Synthesis 1st	R1	Charge	1.25
		Heating	0.75
		OXO1 Reaction	5
		Cooling	1.75
		Extraction	2
		Discharge	1
		Cleaning	*2*
Synthesis 2nd	R2	Charge	1.5
		Heating	0.5
		OXO2 Reaction	1
		Ciclation	1.25
		Extraction	2.25
		Discharge	0.75
		Cleaning	*2*
Synthesis 3rd	R3	Charge	0.75
		Heating	1
		Oxolamine Reaction	1
		Cooling	1.5
		Extraction	1
		Discharge	0.75
		Cleaning	*2*
	R4	Charge + Extraction	1.5
		Discharge	0.75
		Cleaning	*2*
	R2	Charge + Extraction	3
		Discharge	0.75
		Cleaning	*2*
	R3	Charge + Extraction	3
		Discharge	0.75
		Cleaning	*2*
Synthesis 4th	R4	Charge	1
		Crystallization	3
		Total discharge + standby (x7)	*13.75*
		Cleaning	*2*
Purification	Centrifuge	Centrifuge	14.75
		Cleaning	*2*
	Dryer	Drying	13.75
		Cleaning	*2*
	Mills (alternating)	Milling	14.5
		Cleaning	*2*
	Packing	Packing	10.5

Table 17. Stages times

Down below can be seen the time required to produce one batch, that is, 2180 kg of COX. The batch time is 55.75 hours (55 hours and 45 minutes).

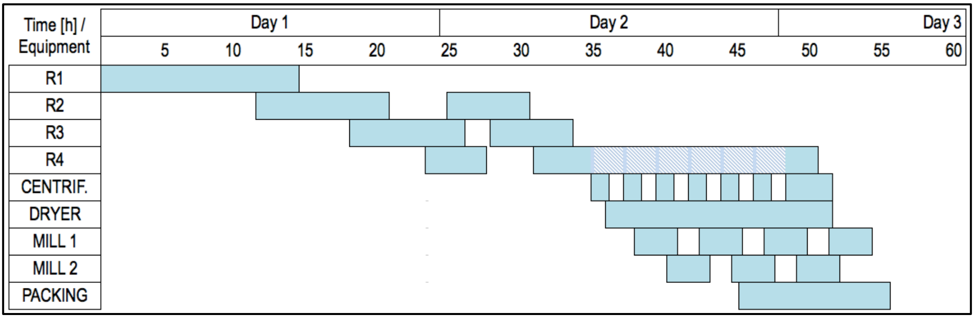


Figure 15. Batch time

Looking at the table above, there are many points that should be considered.

First of all, as it has been said before in the point 3.3. (Equipment Selection), in most of the reactors belonging to the synthesis phase are carried out more than one operation. In the Figure 15 is shown. Anyway, to see it more explicitness, it has been made a graphic where can be seen the difference of mass in every reactor with the time. It has been made taking into account the batch time and the mass balances calculated in the chapter 3.5.

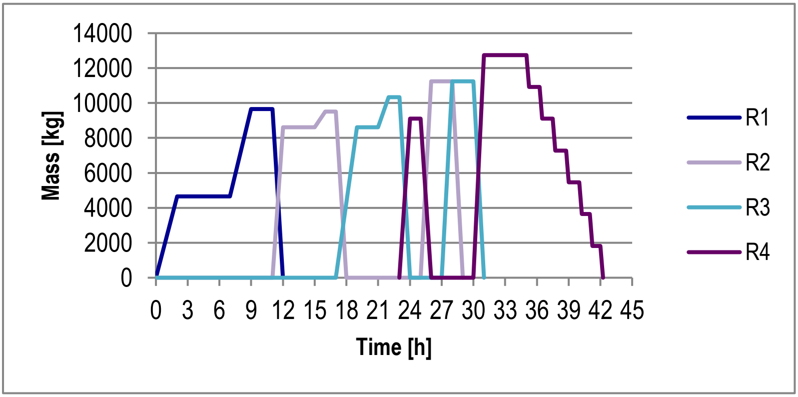


Figure 16. Mass in each reactor in time

After the crystallization the solution has to be traspased to the centrifuge. The volume of the centrifuge is smaller than the total solution volume in R4, this is why the transpase is done through 7 loads. The solution volume is 12744kg so in each load have to be traspassed approximatelly 1820kg of solution, since the centrifuge is not supposed to have a volume higher than 2000L. It can be seen at the end of Figure 16.

Anyway, the loads are not continued, as after the discharge of each load there is an hour in standby, with the rest of the solution inside R4. This is because the step after the centrifugation is the drying, which limitates the time since it is the step that takes more time. This is why the R4 does not discharge all the loads continually and the centrifuge does not work all the time, but it also has to stop after every load.

The next step is the milling. As there are two mills, each load will go to each one of them, alternaly. They work in continuous. Finally, all the moltured product has to be packed in order to sell it.

6.3. PRODUCTION CAPACITY

As it has been contemplated in the general specifications, the annual demand is of 100 tones of COX, and as in each batch are produced 2180kg of it, the annual number of batches to produce is of 46.

To know the time that would take to produce these 46 batches, it has to be studied the way to produce them. It will be in campaigns.

It has to be considered that there are two ways to produce. On the one hand, without overlapping, and on the other way with overlapping.

6.3.1. WORKING WITH AND WITHOUT OVERLAPPING CAMPAIGN

The two ways to produce are going to be compared in this point.

First of all, it is necessary to take into account that as each batch takes more than 2 days, the working schedule will be 24 hours/day and 7 days/weeks during the time that lasts each campaign.

Working with non-overlapping campaign

Working with non-overlapping campaign means that it is necessary that finishes one batch to start the next one. This way, only one batch is carrying out at every time.

The time that would take the process if it was worked by this mode is calculated next:

$$MS = BT + (N - 1)\ CT$$

The makespan (MS) of a project is the total time that elapses from the beggining to the end of it. It is calculated adding to the batch time (BT), that in this case would represent the time that would take the first batch of the campaign, the cycle time (CT) of the rest of the batches (it represents the time required to complete each of the following batches).

In the case of working with non-overlapping campaign, it means that the CT is equal to the BT, since the first batch duration is equal to the followings. Therefore, the results of this working mode are:

$$N = (kg\ COX/year)/(kg\ COX/batch) = 100000/2180 \approx 46\ batch/year$$

$$MS = 55.75h + (46 - 1) * 55.75 = 2564.5\ hours \approx 107\ days$$

Completing this process would take 107 days per year, in case of working in one campaign.

To appreciate this working mode, it can be seen on the Figure 17, located in the point 6.3.2.

Working with overlapping campaign

Working with overlapping campaign means that not necessarily a batch has to have finished before the next batch starts. This way, more than one batch might be carrying out at every time.

The time that would take the process is calculated with the same formula above. The difference, in this case, is that CT would take less time, as it counts the time that takes every batch but only after finishing the previous batch. In other words, the first batch of each campaign will take the BT, and the following batches will take the CT. The CT calculated is 27.25 hours.

Therefore, the MS differs from the calculated before.

$$MS = 55.75h + (46 - 1) * 27.25 = \ 1282\ hours \approx \ 54\ days$$

Completing this process would take 54 days per year, in case of working in one campaign. To appreciate this working mode, it can be seen on the Figure 18, located in the point 6.3.2.

6.3.2. WORKING MODE CHOSEN

Once it has been compared one working mode to the other, there is a main difference that can be compared.

The comparison has been made as it was worked in only one campaign. The result is that working without overlapping campaign takes almost the doble of time that working in overlapping campaign. Working this second way would allow leveraging the equipment, using it for other possible processes.

In addition, working in overlapping campaign makes that the equipment is used more time during the process, what is also an advantage to exploit it.

This is why it has been chosen working in overlapping campaign.

The next step would be deciding in how many campaigns it will be worked. It was seen that working in a only campaign would take approximately 54 days. Taking into account the manteinance, it would be around 2 months.

The calculation in case of working in 2 or 3 campaigns, respectively, are below:

2 campaigns: $MS = 55.75h + (23 - 1) * 27.25 = \ 655.25\ hours \approx \ 28\ days$

3 campaigns: $MS = 55.75h + (16 - 1) * 27.25 = \ 464.5\ hours \approx \ 20\ days$

Looking at the time that would take working in 2 campaings (twice a year) and working in 3 campaigns (three times every year), the conclusion is that working in 3 campaigns is not convenient as if it is added the time of manteinance to each campaign, it would take almost 3 months every year. Apart of it, if in each of the 3 campaings were produced 16 batches, in a year there had been done a total of 48 batches, that is two more than the necessaries. It would have to be done in one campaign 16 batches and in the other 2 campaigns 15. This working mode is not very practical as not all the campaigns would be equal and it could even lead to confusion.

In the case of working in two campaigns, the time of manteinance after each campaign would be smaller, even if the results are pretty similar to the results working in only one campaign. It could be a possible option.

	Total batches needed	Batches/ campaign	Total	Days needed/year
1 campaign	46	46	46	54
2 campaigns		23	46	56

Table 18. Number of campaigns comparison

As it can be seen, the difference between working in 1 or 2 campaigns is only of 2 days of difference. The difference is so small that none of them can be rejected.

In conclusion, it will work in overlapping campaign, so the time would be more profitable. In respect of the number of campaigns, it would have to be 1 or 2 campaigns. The times of production are so similar than none of them can be rejected. It could be chosen depending on the planned production of the plant, and if the equipment was or not used to carry out other operations.

In the next page can be seen the comparison of two graphics that show the beginning schedule of the process. The first one in the case of working without overlapping and the second one working with overlapping. There is a different colour for each batch. The option framed in red is the choosen option.

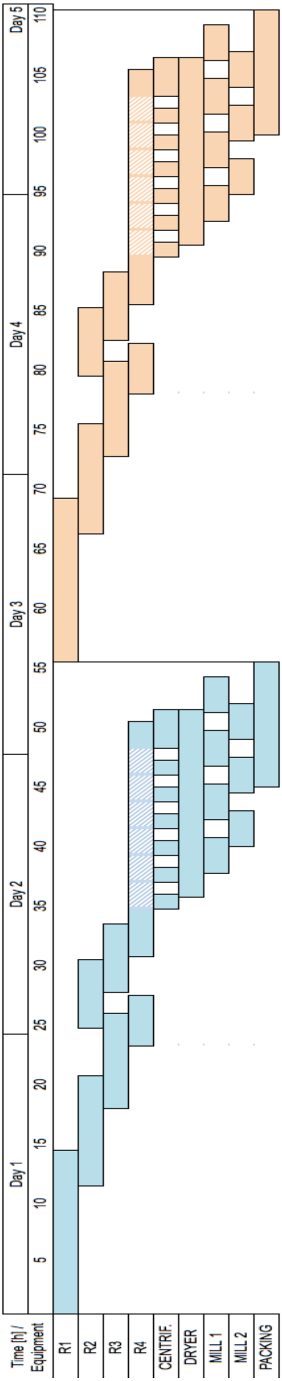


Figure 17. Production without overlapping campaign

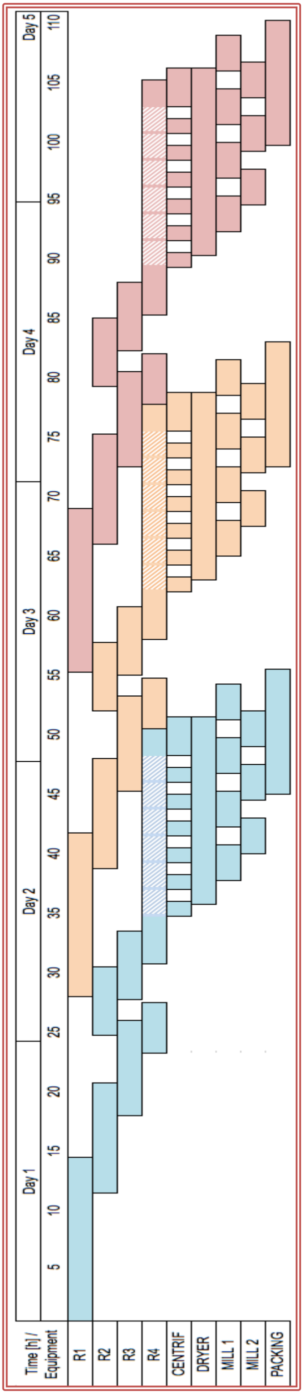


Figure 18. Production with overlapping campaign

6.4. POSSIBLE IMPROVEMENTS

As it can be seen, with the option chosen (the one framed in red) above, it is achieved to have the production of 100 tones in approximately 2 months/year. The remaining time of the year, this part of the plant can be used to carry out other operations.

Anyway, it might be that in the time was needed an improvement of the process due to a higher demand. It would be necessary to think all the possible options in order to obtain more product. Obviously, there is a myriad of possibilities to take into account.

Most of them go through changing chemical operations of the process. In any case, must be recalled that the process we are working on is an optimization of the original process. In this chapter is going to be talked about some improvements taken into consideration related with the batch time and the cycle time.

There are many possibilities for designing the schedule. It has been chosen one that uses the minimal number of equipment and that is easy enough, on the fact that all the batches use the same sequence. But it is not necessary to be always like this.

Alternative 1: Using 2 different sequences

The first option is changing the order of the use of the equipment, so that there would be two different sequences. All the odd batches would follow an order and the even batches would follow another order. This way, the CT is slightly decreased, but this working mode could lead to confusion sometime. As the difference is small, it is not going to be used unless there is an increase of the demand.

Alternative 2: Adding a second dryer

The second option is implementing another dryer to the process, since the drying step is the slower and makes stopping the preceding steps. If there were two dryers, the loads would go alternative to one or the other, after the centrifugation step. This option, unlike the previous, is expensive.

With this option would decrease both the BT and the CT.

In the table above, it can be seen the improvement of both alternatives. On the next page can be seen their graphics.

	Days/year needed to produce 100 tones	Production in the time used originally [kg]	Properties of improvements
MODE CHOSEN	54	-	-
Alternative 1	46	117,440	2 different sequences
Alternative 2	44	117,440	Addition of equipment

Table 19. Improvements

As can be seen, the time that they need to produce 100 tones is smaller, and the production that they would make using 54 days (as the original process) would be of 8 batches more.

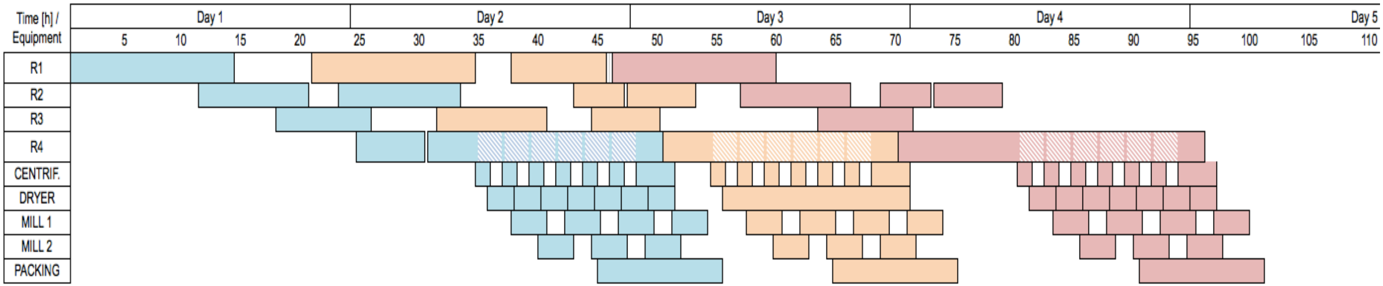


Figure 19. Alternative 1

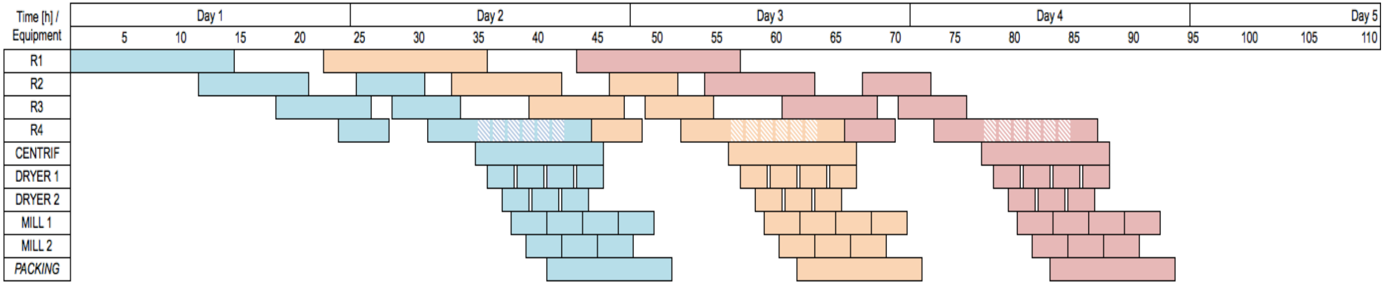


Figure 20. Alternative 2

7. CONCLUSIONS

Finally, it has been achieved to complete the process, studying the different alternatives that it could have. It has been proved that it is possible to obtain the sought claim working in batch mode. The quantity claimed is of 100 tones and in each batch are produced 2180kg of COX.

It has been done a predesign of the synthesis phase, until obtaining the product. After that, it should have to be purified.

The synthesis phase has been dimensioned. It consists of four different reactors where are performed several operations. Some auxiliary equipment is used in order to carry out the operations efficiently. Even though it has not been dimensioned the equipment in the purification, it has been selected to take it into account for the mass balances and the scheduling.

Furthermore, it has been studied the control system in order to manipulate the variables along the process and also to ensure better safety.

Lastly, it has been planned the time that would last producing the quantity ordered. The time that it would take is of 54 days working in only one campaign. If the plant where the project was implanted had the requirement, it could be possible to work in two campaigns, what would take 56 days in total. It should be added the cleaning and the maintenance time to the period said. The rest of the time, the installation might be used to other processes in the plant.

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ACRONYMS

A	Cross-sectional pipe Area [m^3]
BT	Batch time [h]
COX	Oxolamine Citrate
Cp	Specific heat [cal/g ºC]
CT	Cycle time [h]
DCE	1,2-Dicloroethane
DEA	Diethylamine
DN	Nominal Diameter [mm]
HCl	Hydrochloric Acid
IBC	Intermediate Bulk Container
m	Mass [kg]
MS	Makespan
NaOH	Sodium Hydroxide
OXO1	Oxolamine 1 (First subproduct)
OXO2	Oxolamine 2 (Second subproduct)
Q	Heat [kcal]
q	Volumetric flow [m^3/h]
R1	Reactor 1
R2	Reactor 2
R3	Reactor 3
R4	Reactor 4
t	Time [h]

TEA	Triethylamine
U	Coefficient heat transfer [W/m^2 ºC]
v	Velocity [m/s]
3-CC	3- Chloropropionyl Chloride

APPENDICES

APPENDIX 1: DESIGN CALCULATION

MASS BALANCE CALCULATION

As the claim ordered was known, and it was of 100 tones, it has been possible to calculate the different quantities involved in the process. It has been calculated through the yield of the different operations.

In the point 3.5. of the project there are two tables with the balances in all the equipment and in each line. What is more, in the Figure 16 can be seen the variation of mass along the reactors with the time. Anyway, in the table down below can be seen the yields and the mass of COX in each stage.

	Total [kg]	Each load [kg]	Yield [%]
Benzonitrile (limiting reagent)	800	-	-
OXO 1	952	-	94.0
OXO 2	1,488	-	94.5
Oxolamine	1,708	-	96.0
COX before crystallization	2,508	-	99.0
COX after crystallization	2,258	323	99.0
COX after centrifugation	2,247	321	99.5
COX after drying	2,205	315	99.0
COX obtained	**2,180**	311	99.0

Table 20. COX balance and operation yields

To calculate it has been made many assumptions. In the centrifugation are lost 2kg of product by load that will go to treat along with the acetone and the DCE. The rest is the wet solid with a 10% of humidity. The rest of liquid will leave the centrifuge. In the drying step the humidity is supposed to go from the 10% of the solid weight to the 0,1%. The quantities that are lost in the drying step and in the milling will leave the process as waste.

EQUIPMENT SIZING

On the next point is going to be mentioned the way that has been used to dimension the reactors where take place the different operations of the process.

To know the volume that was required to carry out the operations, and once known the mass, it was necessary to know the density of the mixture in every moment. Even if the volume of the mix cannot be considered the addition of all of their elements, it has been fixed an approximate volume taking into account the proportion of all of them in the final mixture. To that volume, has been added a 10-15% to ensure that it was enough and also for security.

As it has been said before, R1, R2 and R3 have the same volume and R4 is bigger. In the table below are summarized their sizing properties.

	R1	R2	R3	R4
Maximum volume inputs [m^3]	9.7	11.2	11.3	12.7
Diameter [m^2]	2.2	2.2	2.2	2.3
Height [m]	3.8	3.8	3.8	4.2
Volume [m^3]	12	12	12	14

Table 21. Equipment sizing

PIPING SIZING

In order to calculate how will be the piping (diameter, shared pipes, time of transfer…) it has been used the heuristic that the velocity of the fluids that are inside the pipes have a velocity of 2 m/s. Fixing this velocity, knowing the quantity that goes through the pipes and fixing the time that would take the transfer, it was possible to calculate the different diameters according to the formula: $q = v \cdot A$

Being *q* the volumetric flow, *v* the flow velocity and *A* the cross-sectional area of the pipe.

In a more specific design, it should be considered the head loss in the piping system. It would depend also on the length of the pipes.

Hereunder can be seen the size of the different pipes, as well as the flow that goes through them. As it can be seen, the diameter chosen is similar but not always exact to the one calculated. This is because, besides that the calculus is not exact as the velocity has been fixed, the nominal diameters chosen are easily to be found in order to facilitate their installation.

Pipe	Function	Time [h]	Volumetric flow [m3/h]	DN calculated [mm]	DN chosen [mm]
2	Water charge	0.25	11.2	44.6	50
6	Reagents charge	0.25	7.4	36.1	40
7	DCE charge	0.5	12.6	47.2	50
10	Organic phase transfer	0.5	14.9	50.3	50
11	Aqueous phase discharge	0.25	14.9	50.3	50
13	TEA charge	0.2	8.6	39.1	40
16	DCE and 3-CC charge	0.07	3.5	24.9	25
18	HCl charge	0.13	2.1	19.4	20
21	Organic phase transfer	0.5	11.5	45.1	50
22	Aqueous phase discharge	0.25	14.8	50.1	50
23	DEA charge	0.3	7.9	37.5	40
27	Organic phase transfer	0.5	12.4	46.9	50
28	Aqueous phase discharge	0.25	12.8	47.7	50
32	Organic phase transfer	0.5	12.4	46.9	50
33	Aqueous phase discharge	0.25	12.1	46.2	50
34	NaOH charge	0.25	12.0	46.0	25
39	Reagents charge	0.5	10.7	43.4	50
40	Organic phase transfer	0.17	12.0	46.0	50

Table 22. Piping sizing

In the case of the reagents that are solid, the operators introduce them through the manhole, instead of pipes. The sodium carbonate is introduced by bags of 25 kg. It has to be introduced almost 500 kg, so approximately are needed 20 bags per batch. The anhydrous sodium sulfate is also solid. It is introduced the same way. As it is needed to introduce approximately 75 kg per batch, it is going to be in three bags of 25 kg.

HEATING AND COOLING CALCULATION

As it has been said before, the heating and the cooling of the reactors are done through a half-pipe jacket. On the one hand, it is used water-glycol at 50% at the temperature of -20ºC to cool. On the other hand, it is used water steam at the temperature of 120ºC in order to heat.

The calculation of the flows of water-glycol or water steam respectively, apart from the time that they take, has been calculated below.

Heating

Often the reactor has to be heated so the reaction can work out or also when it has to go back to the ambient temperature after being cooled. For that, it has been used water steam.

The main formula to calculate the exchanged heat is:

$$Q = m \cdot Cp \cdot \ \Delta T$$

Where Q is the exchanged heat, m the mass, Cp the specific heat, and ΔT the change in temperature.

Using this formula and fixing a time, it can be calculated the heating power: and the steam flow necessary, as all the values are known.

The heating power is calculated by:

$$\dot{Q} = \frac{Q}{t}$$

$\dot{Q}$ is the power heat, Q the exchanged heat and t the time.

To calculate the heat related to the phase change:

$$Q = m \cdot \lambda$$

Where Q is the heat, m the mass and λ the latent heat of vaporization. This formula is used because the water steam that enters to the jacket, when is in contact with the cold solution inside the reactor, gives its heat to the solution so it condenses. It is necessary to take into account the heat lost along this phase.

Then the steam mass flow necessary would be:

$$\dot{m} = \frac{\dot{Q}}{\lambda}$$

The water steam values used are:

Vapor pressure [kg/cm^2]	2
Vapor temperature [ºC]	119.6
Latent heat of vaporization [kcal/kg]	526.4

Table 23. Water steam properties

The pressure and the temperature have been searched in properties tables.

The values obtained of the three heating operations of the process (one in the first stage, another in the second stage and the last one in the third stage) are:

	1st stage heating	2nd stage heating	3rd stage heating
Solution mass [kg]	4,656	9,596	8,612
Time [h]	0.75	1	1
Cp [cal/g·ºC]	0.9	0.5	0.5
Initial temperature [ºC]	25	10	25
Final temperature [ºC]	75	80	80
Q [kcal]	209,520	300,856	284,215
Heating power [kcal/h]	279,360	300,856	284,215
Heating power [kW]	325	350	330
Heating flow [m^3/h]	0.6	0.6	0.6

Table 24. Heating values

Lastly, it has to be calculated the exchange area necessary to carry out the operation. The formula used is:

$$Q = U \cdot A \cdot \Delta T_m$$

Where U is the heat transfer coefficient (it has been chosen through a table values), A is the exchange area and ΔT_m is the logarithmic temperature difference. It is important to take into consideration that the water steam temperature is constant so the calculation of the logarithmic temperature difference can be simplified.

Calculating the exchange area can be also calculated the minimum height that should have the jacket in the reactor.

	1st stage heating	2nd stage heating	3rd stage heating
U coefficient [W/m^2 ºC]	800	600	500
Temperature difference [ºC]	44.6	39.6	39.6
Exchange area [m^2]	9.1	14.7	16.0
Minimum jacket height [m]	1.3	2.0	2.1

Table 25. Heating exchange area

Cooling

For the cooling operation is needed as a coolant a mixture of water and glycol at the proportion of 50% at the temperature of -20ºC. This is because the melting temperature of glycol is much lower than the one of water. With a mixture with enough quantity of glycol the temperature can be decreased from 0ºC.

The main formula to calculate the heat is the one used before:

$$Q = m \cdot Cp \cdot \ \Delta T$$

The heat that has to be taken from the substance inside the reactor is the same that takes the coolant.

It has been tried to calculate it taking water at 5ºC and water-glycol at 30% at the temperature of 0ºC, but the results obtained where not good enough for all the circumstances.

Anyway, if these two cases were already installed in the plant, it could be considered to use them when it is possible in order to decrease the energy wasted.

The cooling power is calculated as before:

$$\dot{Q} = \frac{Q}{t}$$

In that case, there is no phase change, so the latent heat has not to be taken into account.

The values obtained in the cooling operations of the process have been:

	1st stage cooling	2nd stage cooling 1	2nd stage cooling 2	3rd stage cooling
Solution mass [kg]	4,656	9,516	8,596	8,613
Time [h]	1.75	0.5	1.25	1.5
Cp [cal/g·ºC]	0.9	0.5	0.5	0.6
Initial temperature [ºC]	75	25	80	80
Final temperature [ºC]	25	10	25	25
Q [kcal]	209,520	71,370	236,386	284,215
Heating power [kcal/h]	119,725	142,740	1,891,209	189,476
Heating power [kW]	140	166	220	220
Heating flow [m3/h]	4.1	8.6	6.5	6.5

Table 26. Cooling values

Lastly, it has to be calculated the exchange area necessary to carry out the operation. The formula used is:

$$Q = U \cdot A \cdot \Delta T_m$$

In this case the logarithmic temperature difference cannot be simplified as before, since the temperature of the coolant is not constant. Anyway, there is a formula that is possible to apply that can be considered also a simplification, even if in a discontinuous process would not be the most exact calculous.

$$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\frac{\Delta T_1}{\Delta T_2}}$$

The exchange areas and the necessary heights of the jacket are calculated below:

	1st stage cooling	2nd stage cooling 1	2nd stage cooling 2	3rd stage cooling
U coefficient [W/m² ºC]	600	600	600	600
Temperature difference [ºC]	23.3	18.2	23.2	23.2
Exchange area [m²]	9	16	16	16
Minimum jacket height [m]	1.4	2.2	2.2	2.2

Table 27. Cooling exchange area

AGITATION SYSTEM

The agitation system is not the same for all the reactors, are used pitch-blade paddle agitators and anchor agitators. Their properties and sizing have been explained above.

As the approximate rotational velocity of the agitators has been fixed because of the operations carried out and the properties of the fluid, it has been chosen the dimensions of the agitators. Known the rotational velocity and the sizes needed, the provider would fix the power of the agitator.

The paddle agitator and the anchor agitator have this form, respectively (11):

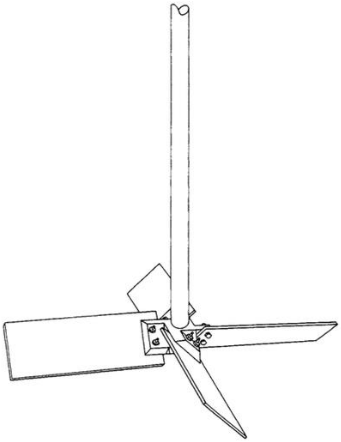


Figure 21. 4 Pitch-Blade Paddle Agitator

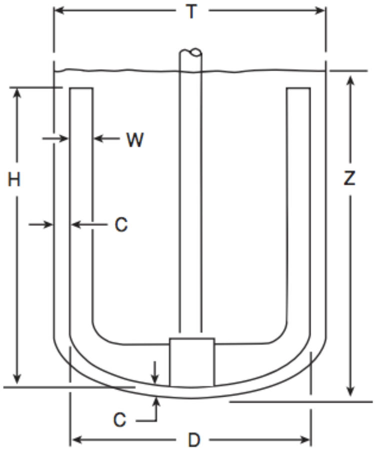


Figure 22. Anchor Agitator

APPENDIX 2: SPECIFICATION SHEETS

In this point there are the provisional specification sheets. They are provisional because they have the properties calculated that could change lightly depending on the offers of the providers that could be adapted to the process.

This is why the drawings are just approximate representations, which should be substituted by the original draws, with the real sizing if possible.

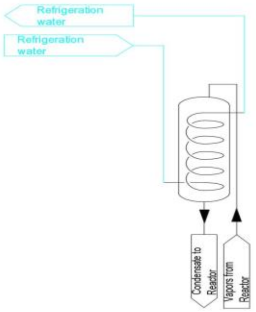
SPECIFICATION SHEET		Equipment	Condensers
		N equipment	-
PROJECT	Oxolamine Citrate production		
DESIGN DATA			
Type	Coil condenser		
Work temperature [ºC]	+25/+80		
Work pressure [atm]	1		
Position	Vertical		
Operation	Cooling / condensing		
Fluid	Refrigeration Water		
Flow [kg/h]	30		
Exchange area [m2]	1.5		

Table 28. Condensers specifications sheet

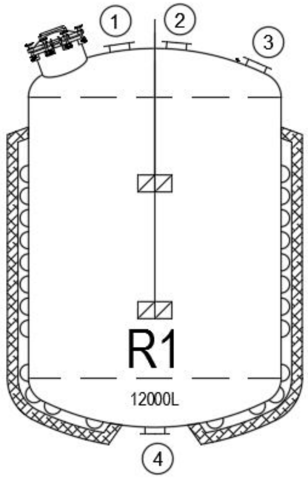
<table>
<tr><td colspan="2" rowspan="2">SPECIFICATION SHEET</td><td>Equipment</td><td>Reactor</td></tr>
<tr><td>N equipment</td><td>R1</td></tr>
<tr><td>PROJECT</td><td colspan="3">Oxolamine Citrate production</td></tr>
<tr><td colspan="4">DESIGN DATA</td></tr>
<tr><td>Volume [m3]</td><td>12</td><td>Position</td><td>Vertical</td></tr>
<tr><td>Work temperature [ºC]</td><td>+25/+80</td><td colspan="2">Material</td></tr>
<tr><td>Work pressure [atm]</td><td>1</td><td>Contact</td><td>AISI 316L</td></tr>
<tr><td>H/D</td><td>1.7</td><td>No-Contact</td><td>AISI 304</td></tr>
<tr><td colspan="4">HEAT TRANSFER DATA</td></tr>
<tr><td>Exchanger</td><td colspan="3">Split half-pipe</td></tr>
<tr><td rowspan="2">Operation</td><td>Heating</td><td rowspan="2">Fluid</td><td>Water Steam</td></tr>
<tr><td>Cooling</td><td>Water-glycol</td></tr>
<tr><td>Exchange area [m3]</td><td>9</td><td colspan="2" rowspan="7">
</td></tr>
<tr><td colspan="2">AGITATION DATA</td></tr>
<tr><td>Type</td><td>Paddle</td></tr>
<tr><td>Number of axes</td><td>1</td></tr>
<tr><td>Number of impellers</td><td>2</td></tr>
<tr><td>Impeller shape</td><td>4 pitched blades</td></tr>
<tr><td>Rotational speed [rpm]</td><td>80</td></tr>
</table>

Table 29. R1 specifications sheet

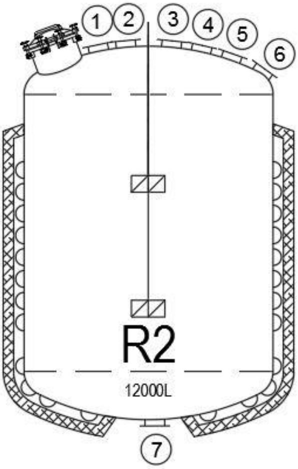
SPECIFICATION SHEET		Equipment	Reactor
		N equipment	R2
PROJECT	Oxolamine Citrate production		
DESIGN DATA			
Volume [m3]	12	Position	Vertical
Work temperature [ºC]	+10/+80	Material	
Work pressure [atm]	1	Contact	AISI 316L
H/D	1.7	No-Contact	AISI 304
HEAT TRANSFER DATA			
Exchanger	Half-pipe		
Operation	Heating	Fluid	Water Steam
	Cooling		Water-glycol
Exchange area [m3]	16		
AGITATION DATA			
Type	Paddle		
Number of axes	1		
Number of impellers	2		
Impeller shape	4 pitched blades		
Rotational speed [rpm]	80		

Table 30. R2 specifications sheet

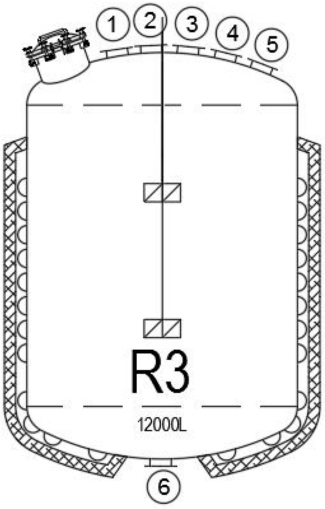
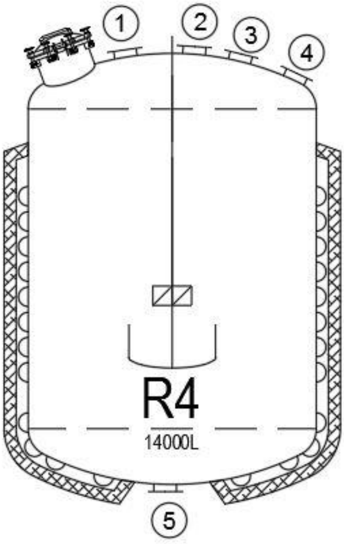
SPECIFICATION SHEET		Equipment	Reactor
		N equipment	R3
PROJECT	Oxolamine Citrate production		
DESIGN DATA			
Volume [m3]	12	Position	Vertical
Work temperature [ºC]	+25/+80	Material	
Work pressure [atm]	1	Contact	AISI 316L
H/D	1.7	No-Contact	AISI 304
HEAT TRANSFER DATA			
Exchanger	Half-pipe		
Operation	Heating	Fluid	Water Steam
	Cooling		Water-glycol
Exchange area [m3]	16		
AGITATION DATA			
Type	Paddle		
Number of axes	1		
Number of impellers	2		
Impeller shape	4 pitched blades		
Rotational speed [rpm]	80		

Table 31. R3 specifications sheet

<table>
<tr><td colspan="2" rowspan="2">SPECIFICATION SHEET</td><td>Equipment</td><td>Reactor</td></tr>
<tr><td>N equipment</td><td>R4</td></tr>
<tr><td>PROJECT</td><td colspan="3">Oxolamine Citrate production</td></tr>
<tr><td colspan="4">DESIGN DATA</td></tr>
<tr><td>Volume [m3]</td><td>14</td><td>Position</td><td>Vertical</td></tr>
<tr><td>Work temperature [ºC]</td><td>+10/+25</td><td colspan="2">Material</td></tr>
<tr><td>Work pressure [atm]</td><td>1</td><td>Contact</td><td>AISI 316L</td></tr>
<tr><td>H/D</td><td>1.7</td><td>No-Contact</td><td>AISI 304</td></tr>
<tr><td colspan="4">HEAT TRANSFER DATA</td></tr>
<tr><td>Exchanger</td><td colspan="3">Half-pipe</td></tr>
<tr><td rowspan="2">Operation</td><td>Heating</td><td rowspan="2">Fluid</td><td>Water Steam</td></tr>
<tr><td>Cooling</td><td>Water-glycol</td></tr>
<tr><td>Exchange area [m3]</td><td>16</td><td colspan="2" rowspan="13">
</td></tr>
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<tr><td>Type</td><td>Paddle</td></tr>
<tr><td>Number of axes</td><td>1</td></tr>
<tr><td>Number of impellers</td><td>2</td></tr>
<tr><td>Impeller shape</td><td>4 pitched blades</td></tr>
<tr><td>Rotational speed [rpm]</td><td>80</td></tr>
<tr><td>Type</td><td>Anchor</td></tr>
<tr><td>Number of axes</td><td>1</td></tr>
<tr><td>Number of impellers</td><td>1</td></tr>
<tr><td>Impeller shape</td><td>U-shaped</td></tr>
<tr><td>Rotational speed [rpm]</td><td>20</td></tr>
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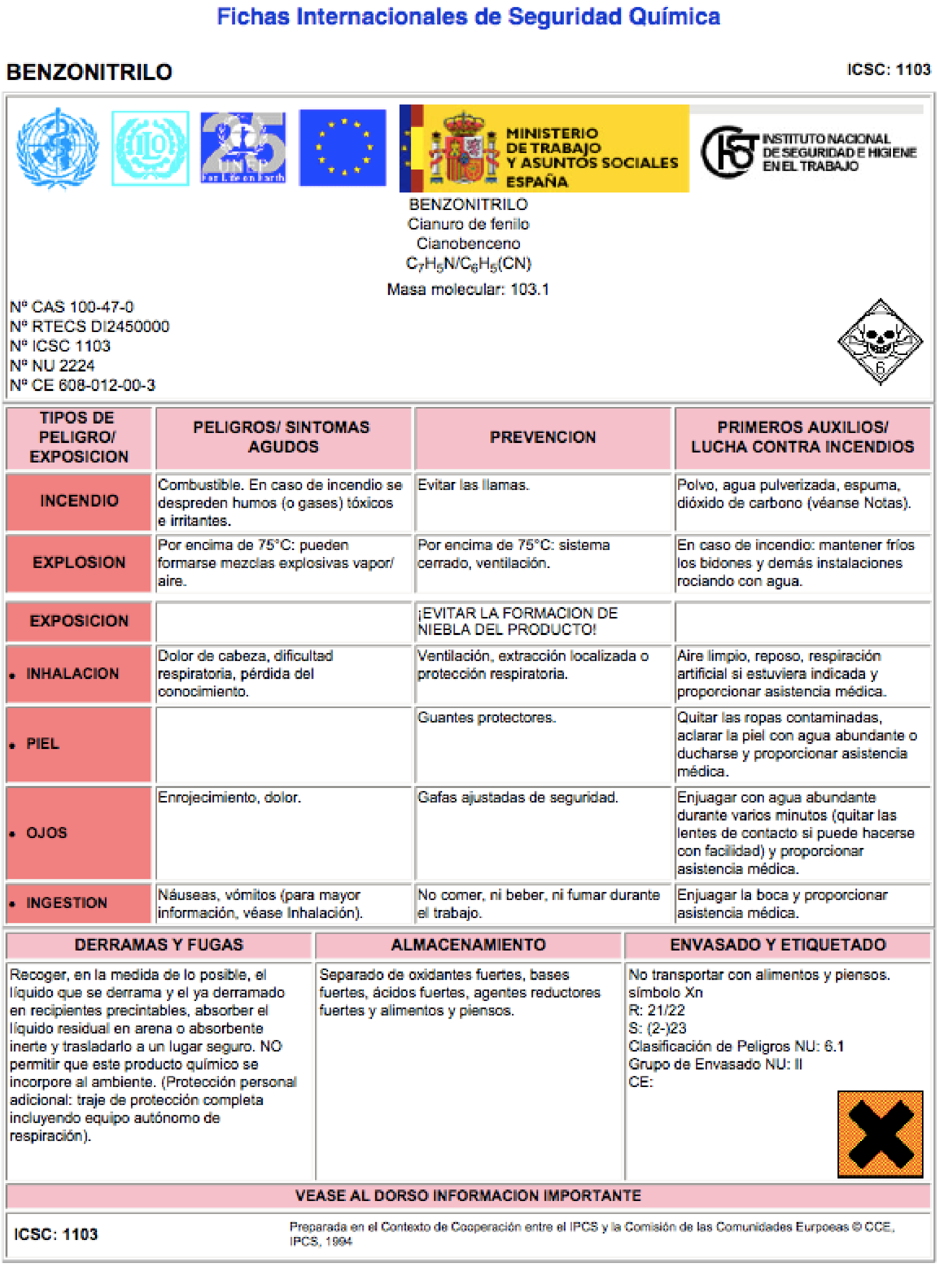
Table 32. R4 specifications sheet

APPENDIX 3: SAFETY DATA SHEETS(12)



Fichas Internacionales de Seguridad Química

BENZONITRILO **ICSC: 1103**

MINISTERIO DE TRABAJO Y ASUNTOS SOCIALES ESPAÑA

INSTITUTO NACIONAL DE SEGURIDAD E HIGIENE EN EL TRABAJO

BENZONITRILO
Cianuro de fenilo
Cianobenceno
$C_7H_5N/C_6H_5(CN)$
Masa molecular: 103.1

Nº CAS 100-47-0
Nº RTECS DI2450000
Nº ICSC 1103
Nº NU 2224
Nº CE 608-012-00-3

TIPOS DE PELIGRO/ EXPOSICION	PELIGROS/ SINTOMAS AGUDOS	PREVENCION	PRIMEROS AUXILIOS/ LUCHA CONTRA INCENDIOS
INCENDIO	Combustible. En caso de incendio se desprenden humos (o gases) tóxicos e irritantes.	Evitar las llamas.	Polvo, agua pulverizada, espuma, dióxido de carbono (véanse Notas).
EXPLOSION	Por encima de 75°C: pueden formarse mezclas explosivas vapor/ aire.	Por encima de 75°C: sistema cerrado, ventilación.	En caso de incendio: mantener fríos los bidones y demás instalaciones rociando con agua.
EXPOSICION		¡EVITAR LA FORMACION DE NIEBLA DEL PRODUCTO!	
• **INHALACION**	Dolor de cabeza, dificultad respiratoria, pérdida del conocimiento.	Ventilación, extracción localizada o protección respiratoria.	Aire limpio, reposo, respiración artificial si estuviera indicada y proporcionar asistencia médica.
• **PIEL**		Guantes protectores.	Quitar las ropas contaminadas, aclarar la piel con agua abundante o ducharse y proporcionar asistencia médica.
• **OJOS**	Enrojecimiento, dolor.	Gafas ajustadas de seguridad.	Enjuagar con agua abundante durante varios minutos (quitar las lentes de contacto si puede hacerse con facilidad) y proporcionar asistencia médica.
• **INGESTION**	Náuseas, vómitos (para mayor información, véase Inhalación).	No comer, ni beber, ni fumar durante el trabajo.	Enjuagar la boca y proporcionar asistencia médica.

DERRAMAS Y FUGAS	ALMACENAMIENTO	ENVASADO Y ETIQUETADO
Recoger, en la medida de lo posible, el líquido que se derrama y el ya derramado en recipientes precintables, absorber el líquido residual en arena o absorbente inerte y trasladarlo a un lugar seguro. NO permitir que este producto químico se incorpore al ambiente. (Protección personal adicional: traje de protección completa incluyendo equipo autónomo de respiración).	Separado de oxidantes fuertes, bases fuertes, ácidos fuertes, agentes reductores fuertes y alimentos y piensos.	No transportar con alimentos y piensos. símbolo Xn R: 21/22 S: (2-)23 Clasificación de Peligros NU: 6.1 Grupo de Envasado NU: II CE:

VEASE AL DORSO INFORMACION IMPORTANTE

ICSC: 1103

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Fichas Internacionales de Seguridad Química

BENZONITRILO **ICSC: 1103**

DATOS IMPORTANTES	**ESTADO FISICO; ASPECTO** Líquido incoloro, de olor característico. **PELIGROS FISICOS** **PELIGROS QUIMICOS** La sustancia se descompone al calentarla intensamente o al arder, produciendo humos muy tóxicos de ácido cianhídrico y óxidos nitrosos. Reacciona violentamente con ácidos fuertes, produciendo humos muy tóxicos de cianuro de hidrógeno. Ataca a algunos plásticos. **LIMITES DE EXPOSICION** TLV no establecido. MAK no establecido.	**VIAS DE EXPOSICION** La sustancia se puede absorber por inhalación, a través de la piel y por ingestión. **RIESGO DE INHALACION** No puede indicarse la velocidad a la que se alcanza una concentración nociva en el aire por evaporación de esta sustancia a 20°C. **EFECTOS DE EXPOSICION DE CORTA DURACION** La sustancia y su vapor irritan los ojos. La exposición a altas concentraciones puede producir insuficiencia respiratoria, convulsiones y pérdida del conocimiento. **EFECTOS DE EXPOSICION PROLONGADA O REPETIDA** (Véanse Notas).
PROPIEDADES FISICAS	Punto de ebullición: 190.7°C Punto de fusión: -12.8°C Densidad relativa (agua = 1): 1.0 Solubilidad en agua: Escasa (0.1-0.5 g/100 ml a 22°C) Presión de vapor, Pa a 20°C: 100	Densidad relativa de vapor (aire = 1): 3.6 Densidad relativa de la mezcla vapor/aire a 20°C (aire = 1): 1.00 Punto de inflamación: 75°C (c.c.) Temperatura de autoignición: 550°C Coeficiente de reparto octanol/agua como log Pow: 1.56
DATOS AMBIENTALES		

NOTAS

En caso de envenenamiento con esta sustancia es necesario realizar un tratamiento específico; así como disponer de los medios adecuados junto las instrucciones respectivas. Los datos disponibles sobre efectos de esta sustancia en la salud humana son insuficientes, por consiguiente, debe procederse con gran cuidado. INCENDIO/LUCHA CONTRA INCENDIOS: Los bomberos deberían emplear indumentaria de protección completa, incluyendo equipo autónomo de respiración.

Ficha de emergencia de transporte (Transport Emergency Card): TEC (R)-61G17

INFORMACION ADICIONAL

FISQ: 4-031 BENZONITRILO	

ICSC: 1103 **BENZONITRILO**

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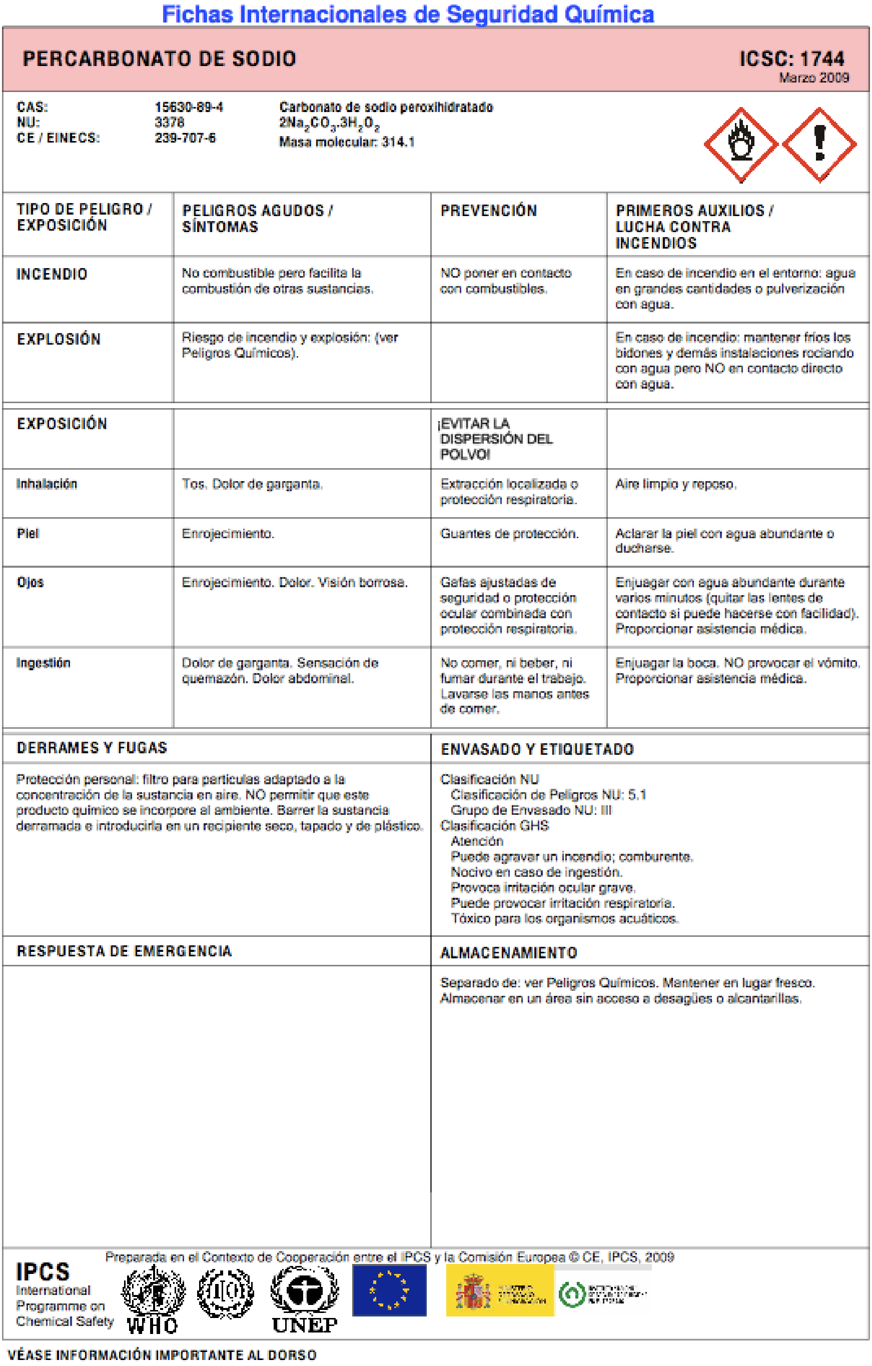

Fichas Internacionales de Seguridad Química

PERCARBONATO DE SODIO

ICSC: 1744
Marzo 2009

CAS:	15630-89-4	**Carbonato de sodio peroxihidratado**
NU:	3378	$2Na_2CO_3.3H_2O_2$
CE / EINECS:	239-707-6	Masa molecular: 314.1

TIPO DE PELIGRO / EXPOSICIÓN	PELIGROS AGUDOS / SÍNTOMAS	PREVENCIÓN	PRIMEROS AUXILIOS / LUCHA CONTRA INCENDIOS
INCENDIO	No combustible pero facilita la combustión de otras sustancias.	NO poner en contacto con combustibles.	En caso de incendio en el entorno: agua en grandes cantidades o pulverización con agua.
EXPLOSIÓN	Riesgo de incendio y explosión: (ver Peligros Químicos).		En caso de incendio: mantener fríos los bidones y demás instalaciones rociando con agua pero NO en contacto directo con agua.
EXPOSICIÓN		¡EVITAR LA DISPERSIÓN DEL POLVO!	
Inhalación	Tos. Dolor de garganta.	Extracción localizada o protección respiratoria.	Aire limpio y reposo.
Piel	Enrojecimiento.	Guantes de protección.	Aclarar la piel con agua abundante o ducharse.
Ojos	Enrojecimiento. Dolor. Visión borrosa.	Gafas ajustadas de seguridad o protección ocular combinada con protección respiratoria.	Enjuagar con agua abundante durante varios minutos (quitar las lentes de contacto si puede hacerse con facilidad). Proporcionar asistencia médica.
Ingestión	Dolor de garganta. Sensación de quemazón. Dolor abdominal.	No comer, ni beber, ni fumar durante el trabajo. Lavarse las manos antes de comer.	Enjuagar la boca. NO provocar el vómito. Proporcionar asistencia médica.

DERRAMES Y FUGAS	ENVASADO Y ETIQUETADO
Protección personal: filtro para partículas adaptado a la concentración de la sustancia en aire. NO permitir que este producto químico se incorpore al ambiente. Barrer la sustancia derramada e introducirla en un recipiente seco, tapado y de plástico.	Clasificación NU Clasificación de Peligros NU: 5.1 Grupo de Envasado NU: III Clasificación GHS Atención Puede agravar un incendio; comburente. Nocivo en caso de ingestión. Provoca irritación ocular grave. Puede provocar irritación respiratoria. Tóxico para los organismos acuáticos.
RESPUESTA DE EMERGENCIA	**ALMACENAMIENTO**
	Separado de: ver Peligros Químicos. Mantener en lugar fresco. Almacenar en un área sin acceso a desagües o alcantarillas.

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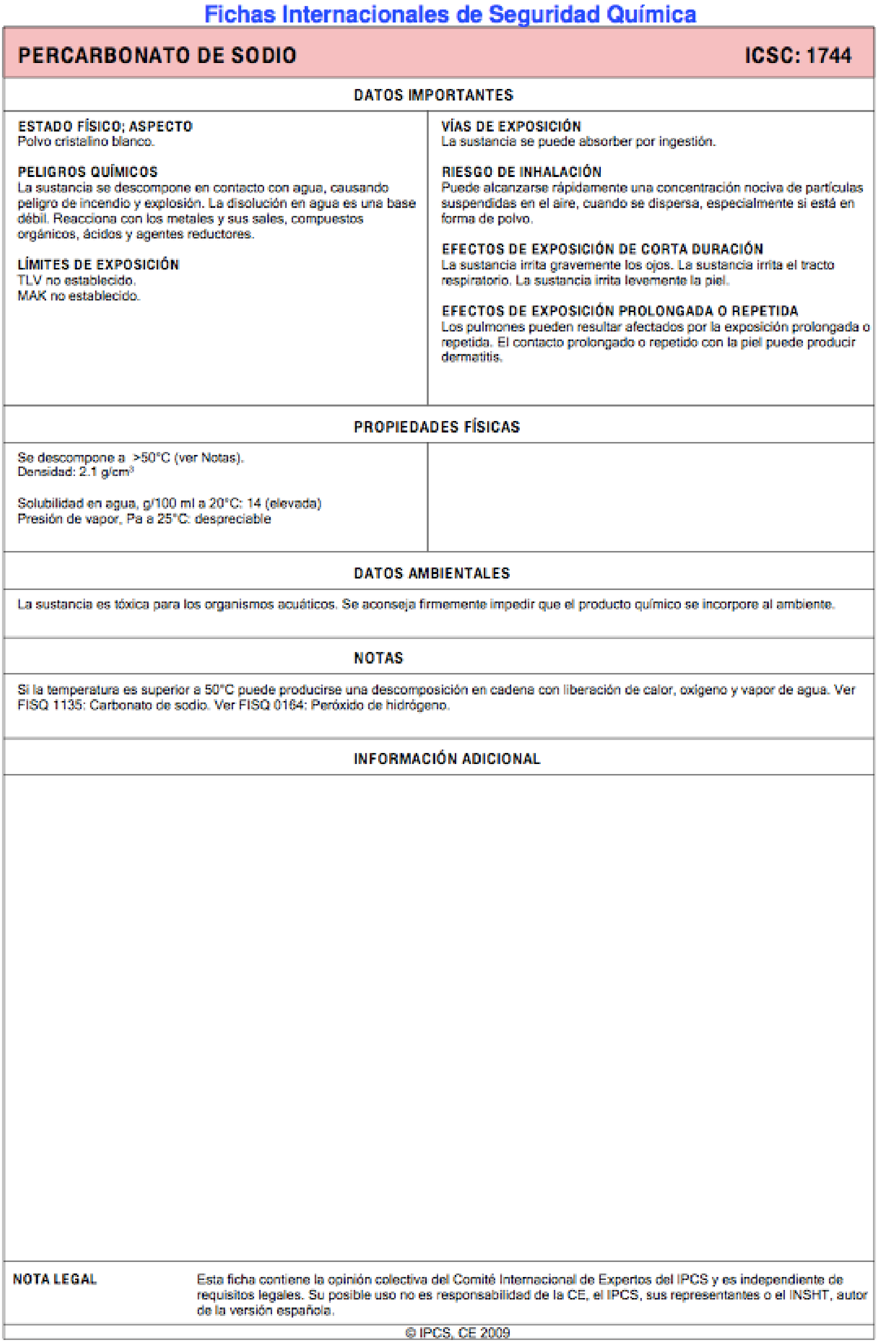
IPCS
International
Programme on
Chemical Safety

VÉASE INFORMACIÓN IMPORTANTE AL DORSO



Fichas Internacionales de Seguridad Química

PERCARBONATO DE SODIO — ICSC: 1744

DATOS IMPORTANTES

ESTADO FÍSICO; ASPECTO
Polvo cristalino blanco.

PELIGROS QUÍMICOS
La sustancia se descompone en contacto con agua, causando peligro de incendio y explosión. La disolución en agua es una base débil. Reacciona con los metales y sus sales, compuestos orgánicos, ácidos y agentes reductores.

LÍMITES DE EXPOSICIÓN
TLV no establecido.
MAK no establecido.

VÍAS DE EXPOSICIÓN
La sustancia se puede absorber por ingestión.

RIESGO DE INHALACIÓN
Puede alcanzarse rápidamente una concentración nociva de partículas suspendidas en el aire, cuando se dispersa, especialmente si está en forma de polvo.

EFECTOS DE EXPOSICIÓN DE CORTA DURACIÓN
La sustancia irrita gravemente los ojos. La sustancia irrita el tracto respiratorio. La sustancia irrita levemente la piel.

EFECTOS DE EXPOSICIÓN PROLONGADA O REPETIDA
Los pulmones pueden resultar afectados por la exposición prolongada o repetida. El contacto prolongado o repetido con la piel puede producir dermatitis.

PROPIEDADES FÍSICAS

Se descompone a >50°C (ver Notas).
Densidad: 2.1 g/cm^3

Solubilidad en agua, g/100 ml a 20°C: 14 (elevada)
Presión de vapor, Pa a 25°C: despreciable

DATOS AMBIENTALES

La sustancia es tóxica para los organismos acuáticos. Se aconseja firmemente impedir que el producto químico se incorpore al ambiente.

NOTAS

Si la temperatura es superior a 50°C puede producirse una descomposición en cadena con liberación de calor, oxígeno y vapor de agua. Ver FISQ 1135: Carbonato de sodio. Ver FISQ 0164: Peróxido de hidrógeno.

INFORMACIÓN ADICIONAL

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Fichas Internacionales de Seguridad Química

HIDROXILAMINA

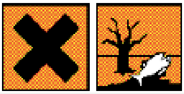
ICSC: 0661

HIDROXILAMINA
Oxiamoníaco
H_3NO/NH_2OH

Masa molecular: 33.0

Nº CAS 7803-49-8
Nº RTECS NC2975000
Nº ICSC 0661
Nº CE 612-122-00-7

TIPOS DE PELIGRO/ EXPOSICION	PELIGROS/ SINTOMAS AGUDOS	PREVENCION	PRIMEROS AUXILIOS/ LUCHA CONTRA INCENDIOS
INCENDIO	Puede explotar en contacto con el calor intenso. En caso de incendio se desprenden humos (o gases) tóxicos e irritantes.	Evitar las llamas, NO producir chispas y NO fumar. NO poner en contacto con superficies calientes.	Agua en grandes cantidades, espuma resistente al alcohol, polvo.
EXPLOSION	Riesgo de incendio y explosión en contacto con muchas sustancias (véanse Peligros Químicos).		En caso de incendio: mantener fríos los bidones y demás instalaciones rociando con agua. Combatir el incendio desde un lugar protegido.
EXPOSICION		¡EVITAR TODO CONTACTO!	
• **INHALACION**	Labios o uñas azulados, piel azulada, tos, vértigo, dolor de cabeza y garganta, debilidad.	Ventilación, extracción localizada o protección respiratoria.	Aire limpio, reposo y proporcionar asistencia médica (véanse Notas).
• **PIEL**	¡PUEDE ABSORBERSE! Enrojecimiento, dolor (para mayor información, véase Inhalación).	Guantes protectores y traje de protección.	Quitar las ropas contaminadas. Aclarar y lavar la piel con agua y jabón y proporcionar asistencia médica.
• **OJOS**	Enrojecimiento, dolor, quemaduras profundas graves.	Pantalla facial o protección ocular combinada con la protección respiratoria.	Enjuagar con agua abundante durante varios minutos (quitar las lentes de contacto si puede hacerse con facilidad) y proporcionar asistencia médica.
• **INGESTION**	Dificultad respiratoria, náuseas, jadeo, vómitos (para mayor información, véase Inhalación).	No comer, ni beber, ni fumar durante el trabajo.	Enjuagar la boca y proporcionar asistencia médica (véanse Notas).

DERRAMAS Y FUGAS	ALMACENAMIENTO	ENVASADO Y ETIQUETADO
Barrer la sustancia derramada e introducirla en un recipiente precintable; si fuera necesario, humedecer el polvo para evitar su dispersión. Recoger cuidadosamente el residuo y trasladarlo a continuación a un lugar seguro. (Protección personal adicional: respirador de filtro P2 contra partículas nocivas).	A prueba de incendio. Separado de sustancias incompatibles (véanse Peligros Químicos). Mantener en lugar fresco, seco y bien cerrado.	símbolo Xn símbolo N R: 5-22-37/38-41-43-48/22-50 S: (2)-22-26-36/37/39-61 CE: 

VEASE AL DORSO INFORMACION IMPORTANTE

ICSC: 0661

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Fichas Internacionales de Seguridad Química

HIDROXILAMINA **ICSC: 0661**

DATOS IMPORTANTES

ESTADO FISICO; ASPECTO
Copos o agujas blancos muy higroscópicos.

PELIGROS FISICOS

PELIGROS QUIMICOS
Puede explotar por calentamiento intenso por encima de 70°C o en contacto con llama abierta. La sustancia se descompone rápidamente a temperatura ambiente, especialmente en presencia de humedad y dióxido de carbono y violentamente al calentarla intensamente, produciendo humos tóxicos, incluyendo óxidos de nitrógeno. La disolución en agua es una base débil. Reacciona violentamente con oxidantes, metales tales como el cinc finamente dividido, óxidos metálicos, sulfato de cobre (II) y cloruros de fósforo, originando peligro de incendio y explosión .

LIMITES DE EXPOSICION
TLV no establecido. MAK: Sh (DFG 2005).

VIAS DE EXPOSICION
La sustancia se puede absorber por inhalación, a través de la piel y por ingestión.

RIESGO DE INHALACION
No puede indicarse la velocidad a la que se alcanza una concentración nociva en el aire por evaporación de esta sustancia a 20°C.

EFECTOS DE EXPOSICION DE CORTA DURACION
La sustancia irrita la piel y el tracto respiratorio, y es corrosivo para los ojos. La sustancia puede causar efectos en la sangre, dando lugar a la formación de metahemoglobina. Los efectos pueden aparecer de forma no inmediata. Se recomienda vigilancia médica.

EFECTOS DE EXPOSICION PROLONGADA O REPETIDA
El contacto prolongado o repetido puede producir sensibilización de la piel. La sustancia puede afectar sangre, dando lugar a la formación de metahemoglobina dando lugar a anemia.

PROPIEDADES FISICAS

Punto de ebullición a 2.9-8.0 kPa: 56.5-70.0°C
Se descompone por debajo del punto de ebullición a <70°c
Punto de fusión: 33°C
Densidad relativa (agua = 1): 1.2
Solubilidad en agua, g/100 ml a 20°C: Elevada.
Presión de vapor, kPa a 47°C: 1.3
Densidad relativa de vapor (aire = 1): 1.1
Densidad relativa de la mezcla vapor/aire a 20°C (aire = 1): 1.00
Punto de inflamación: Explota a 129°C.
Temperatura de autoignición: 265°C
Coeficiente de reparto octanol/agua como log Pow: -1.5

DATOS AMBIENTALES

La sustancia es muy tóxica para los organismos acuáticos.

NOTAS

Está indicado examen médico periódico dependiendo del grado de exposición. Los síntomas de náusea, vómito y cianosis no se ponen de manifiesto hasta pasadas algunas horas. En caso de envenenamiento con esta sustancia es necesario realizar un tratamiento específico; así como disponer de los medios adecuados junto las instrucciones respectivas. No puede indicarse la relación entre el olor y el límite de exposición laboral. La descomposición de la sustancia durante su almacenamiento puede causar un aumento de la presión en el container. Consultar también la FISQ: 0709

Ficha de emergencia de transporte (Transport Emergency Card): TEC (R)-80G15.
Código NFPA: H 2; F 0; R 3;

INFORMACION ADICIONAL

FISQ: 5-106 HIDROXILAMINA

ICSC: 0661 **HIDROXILAMINA**

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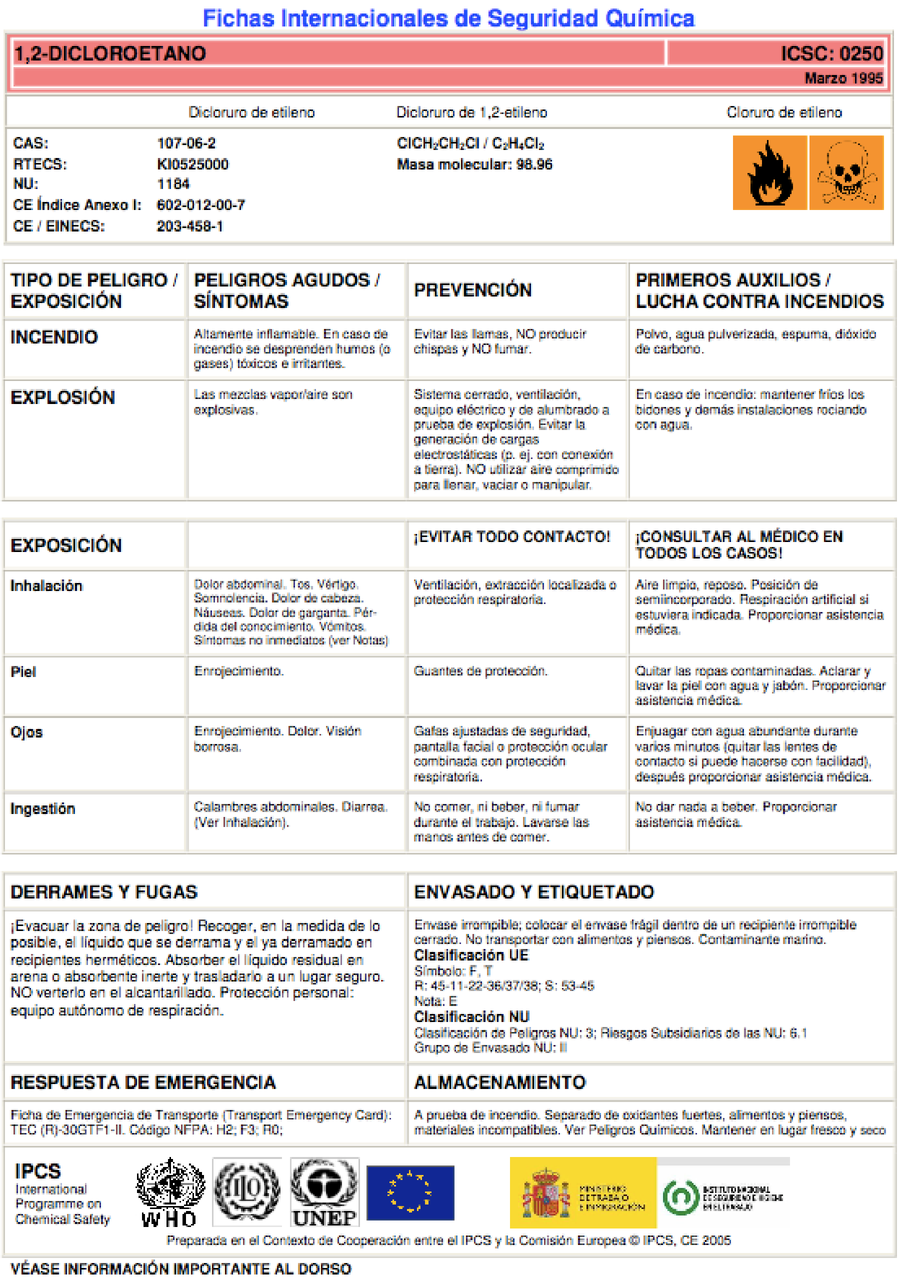

Fichas Internacionales de Seguridad Química

1,2-DICLOROETANO **ICSC: 0250**

Marzo 1995

Dicloruro de etileno Dicloruro de 1,2-etileno Cloruro de etileno

CAS:	**107-06-2**	**$ClCH_2CH_2Cl$ / $C_2H_4Cl_2$**
RTECS:	**KI0525000**	**Masa molecular: 98.96**
NU:	**1184**	
CE Índice Anexo I:	**602-012-00-7**	
CE / EINECS:	**203-458-1**	

TIPO DE PELIGRO / EXPOSICIÓN	PELIGROS AGUDOS / SÍNTOMAS	PREVENCIÓN	PRIMEROS AUXILIOS / LUCHA CONTRA INCENDIOS
INCENDIO	Altamente inflamable. En caso de incendio se desprenden humos (o gases) tóxicos e irritantes.	Evitar las llamas, NO producir chispas y NO fumar.	Polvo, agua pulverizada, espuma, dióxido de carbono.
EXPLOSIÓN	Las mezclas vapor/aire son explosivas.	Sistema cerrado, ventilación, equipo eléctrico y de alumbrado a prueba de explosión. Evitar la generación de cargas electrostáticas (p. ej. con conexión a tierra). NO utilizar aire comprimido para llenar, vaciar o manipular.	En caso de incendio: mantener fríos los bidones y demás instalaciones rociando con agua.

EXPOSICIÓN		**¡EVITAR TODO CONTACTO!**	**¡CONSULTAR AL MÉDICO EN TODOS LOS CASOS!**
Inhalación	Dolor abdominal. Tos. Vértigo. Somnolencia. Dolor de cabeza. Náuseas. Dolor de garganta. Pérdida del conocimiento. Vómitos. Síntomas no inmediatos (ver Notas)	Ventilación, extracción localizada o protección respiratoria.	Aire limpio, reposo. Posición de semiincorporado. Respiración artificial si estuviera indicada. Proporcionar asistencia médica.
Piel	Enrojecimiento.	Guantes de protección.	Quitar las ropas contaminadas. Aclarar y lavar la piel con agua y jabón. Proporcionar asistencia médica.
Ojos	Enrojecimiento. Dolor. Visión borrosa.	Gafas ajustadas de seguridad, pantalla facial o protección ocular combinada con protección respiratoria.	Enjuagar con agua abundante durante varios minutos (quitar las lentes de contacto si puede hacerse con facilidad), después proporcionar asistencia médica.
Ingestión	Calambres abdominales. Diarrea. (Ver Inhalación).	No comer, ni beber, ni fumar durante el trabajo. Lavarse las manos antes de comer.	No dar nada a beber. Proporcionar asistencia médica.

DERRAMES Y FUGAS

¡Evacuar la zona de peligro! Recoger, en la medida de lo posible, el líquido que se derrama y el ya derramado en recipientes herméticos. Absorber el líquido residual en arena o absorbente inerte y trasladarlo a un lugar seguro. NO verterlo en el alcantarillado. Protección personal: equipo autónomo de respiración.

ENVASADO Y ETIQUETADO

Envase irrompible; colocar el envase frágil dentro de un recipiente irrompible cerrado. No transportar con alimentos y piensos. Contaminante marino.

Clasificación UE

Símbolo: F, T

R: 45-11-22-36/37/38; S: 53-45

Nota: E

Clasificación NU

Clasificación de Peligros NU: 3; Riesgos Subsidiarios de las NU: 6.1

Grupo de Envasado NU: II

RESPUESTA DE EMERGENCIA

Ficha de Emergencia de Transporte (Transport Emergency Card): TEC (R)-30GTF1-II. Código NFPA: H2; F3; R0;

ALMACENAMIENTO

A prueba de incendio. Separado de oxidantes fuertes, alimentos y piensos, materiales incompatibles. Ver Peligros Químicos. Mantener en lugar fresco y seco

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Chemical Safety

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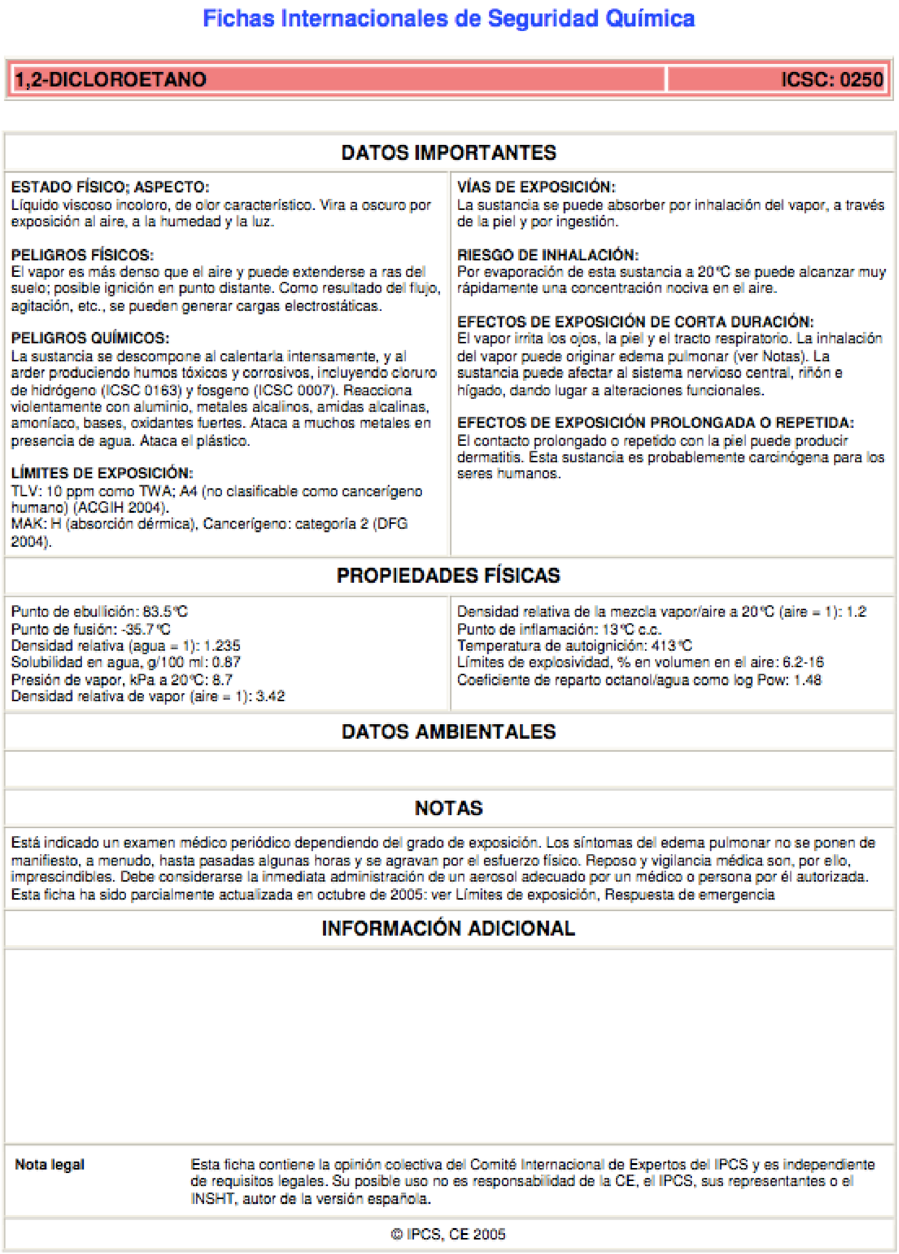
VÉASE INFORMACIÓN IMPORTANTE AL DORSO



Fichas Internacionales de Seguridad Química

1,2-DICLOROETANO **ICSC: 0250**

DATOS IMPORTANTES

ESTADO FÍSICO; ASPECTO:
Líquido viscoso incoloro, de olor característico. Vira a oscuro por exposición al aire, a la humedad y la luz.

PELIGROS FÍSICOS:
El vapor es más denso que el aire y puede extenderse a ras del suelo; posible ignición en punto distante. Como resultado del flujo, agitación, etc., se pueden generar cargas electrostáticas.

PELIGROS QUÍMICOS:
La sustancia se descompone al calentarla intensamente, y al arder produciendo humos tóxicos y corrosivos, incluyendo cloruro de hidrógeno (ICSC 0163) y fosgeno (ICSC 0007). Reacciona violentamente con aluminio, metales alcalinos, amidas alcalinas, amoníaco, bases, oxidantes fuertes. Ataca a muchos metales en presencia de agua. Ataca el plástico.

LÍMITES DE EXPOSICIÓN:
TLV: 10 ppm como TWA; A4 (no clasificable como cancerígeno humano) (ACGIH 2004).
MAK: H (absorción dérmica), Cancerígeno: categoría 2 (DFG 2004).

VÍAS DE EXPOSICIÓN:
La sustancia se puede absorber por inhalación del vapor, a través de la piel y por ingestión.

RIESGO DE INHALACIÓN:
Por evaporación de esta sustancia a 20°C se puede alcanzar muy rápidamente una concentración nociva en el aire.

EFECTOS DE EXPOSICIÓN DE CORTA DURACIÓN:
El vapor irrita los ojos, la piel y el tracto respiratorio. La inhalación del vapor puede originar edema pulmonar (ver Notas). La sustancia puede afectar al sistema nervioso central, riñón e hígado, dando lugar a alteraciones funcionales.

EFECTOS DE EXPOSICIÓN PROLONGADA O REPETIDA:
El contacto prolongado o repetido con la piel puede producir dermatitis. Esta sustancia es probablemente carcinógena para los seres humanos.

PROPIEDADES FÍSICAS

Punto de ebullición: 83.5°C
Punto de fusión: -35.7°C
Densidad relativa (agua = 1): 1.235
Solubilidad en agua, g/100 ml: 0.87
Presión de vapor, kPa a 20°C: 8.7
Densidad relativa de vapor (aire = 1): 3.42
Densidad relativa de la mezcla vapor/aire a 20°C (aire = 1): 1.2
Punto de inflamación: 13°C c.c.
Temperatura de autoignición: 413°C
Límites de explosividad, % en volumen en el aire: 6.2-16
Coeficiente de reparto octanol/agua como log Pow: 1.48

DATOS AMBIENTALES

NOTAS

Está indicado un examen médico periódico dependiendo del grado de exposición. Los síntomas del edema pulmonar no se ponen de manifiesto, a menudo, hasta pasadas algunas horas y se agravan por el esfuerzo físico. Reposo y vigilancia médica son, por ello, imprescindibles. Debe considerarse la inmediata administración de un aerosol adecuado por un médico o persona por él autorizada.
Esta ficha ha sido parcialmente actualizada en octubre de 2005: ver Límites de exposición, Respuesta de emergencia

INFORMACIÓN ADICIONAL

Nota legal Esta ficha contiene la opinión colectiva del Comité Internacional de Expertos del IPCS y es independiente de requisitos legales. Su posible uso no es responsabilidad de la CE, el IPCS, sus representantes o el INSHT, autor de la versión española.

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Fichas Internacionales de Seguridad Química

SULFATO DE SODIO **ICSC: 0952**

MINISTERIO DE TRABAJO Y ASUNTOS SOCIALES ESPAÑA

INSTITUTO NACIONAL DE SEGURIDAD E HIGIENE EN EL TRABAJO

SULFATO DE SODIO
Sulfato sódico (anhídro)
Na_2SO_4
Masa molecular: 142.1

Nº CAS 7757-82-6
Nº RTECS WE1650000
Nº ICSC 0952

TIPOS DE PELIGRO/ EXPOSICION	PELIGROS/ SINTOMAS AGUDOS	PREVENCION	PRIMEROS AUXILIOS/ LUCHA CONTRA INCENDIOS
INCENDIO	No combustible. En caso de incendio se despreden humos (o gases) tóxicos e irritantes.		En caso de incendio en el entorno: están permitidos todos los agentes extintores.
EXPLOSION			
EXPOSICION			
• **INHALACION**		Ventilación.	Aire limpio, reposo.
• **PIEL**		Guantes protectores.	Aclarar y lavar la piel con agua y jabón.
• **OJOS**		Gafas de protección de seguridad.	Enjuagar con agua abundante durante varios minutos (quitar las lentes de contacto si puede hacerse con facilidad) y proporcionar asistencia médica.
• **INGESTION**	Dolor abdominal, diarrea, náuseas, vómitos.	No comer, ni beber, ni fumar durante el trabajo.	Provocar el vómito (¡UNICAMENTE EN PERSONAS CONSCIENTES!) y proporcionar asistencia médica.

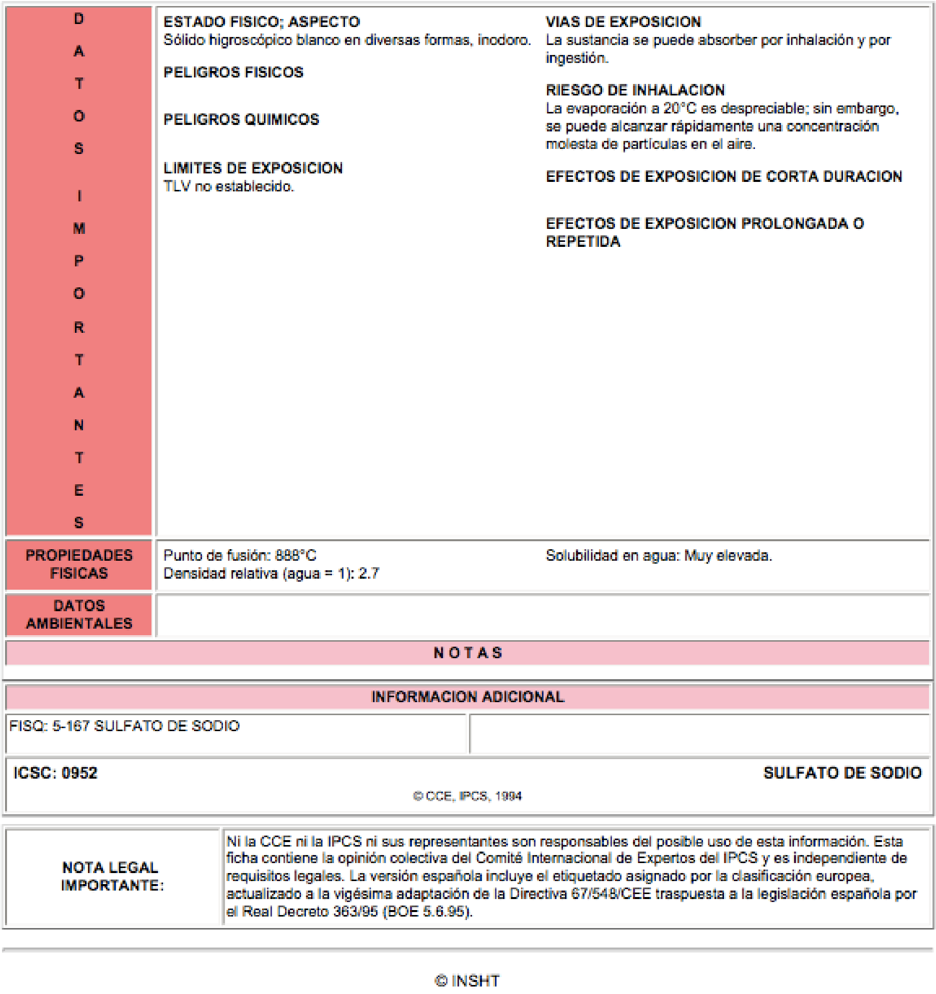
DERRAMAS Y FUGAS	ALMACENAMIENTO	ENVASADO Y ETIQUETADO
Barrer la sustancia derramada e introducirla en un recipiente tapado; si fuera necesario, humedecer el polvo para evitar su dispersión. (Protección personal adicional: respirador de filtro P1 contra partículas inertes).		

VEASE AL DORSO INFORMACION IMPORTANTE

ICSC: 0952 Preparada en el Contexto de Cooperación entre el IPCS y la Comisión de las Comunidades Europeas © CCE, IPCS, 1994

Fichas Internacionales de Seguridad Química

SULFATO DE SODIO **ICSC: 0952**



DATOS IMPORTANTES	**ESTADO FISICO; ASPECTO** Sólido higroscópico blanco en diversas formas, inodoro. **PELIGROS FISICOS** **PELIGROS QUIMICOS** **LIMITES DE EXPOSICION** TLV no establecido.	**VIAS DE EXPOSICION** La sustancia se puede absorber por inhalación y por ingestión. **RIESGO DE INHALACION** La evaporación a 20°C es despreciable; sin embargo, se puede alcanzar rápidamente una concentración molesta de partículas en el aire. **EFECTOS DE EXPOSICION DE CORTA DURACION** **EFECTOS DE EXPOSICION PROLONGADA O REPETIDA**
PROPIEDADES FISICAS	Punto de fusión: 888°C Densidad relativa (agua = 1): 2.7	Solubilidad en agua: Muy elevada.
DATOS AMBIENTALES		

NOTAS

INFORMACION ADICIONAL

FISQ: 5-167 SULFATO DE SODIO	

ICSC: 0952 **SULFATO DE SODIO**

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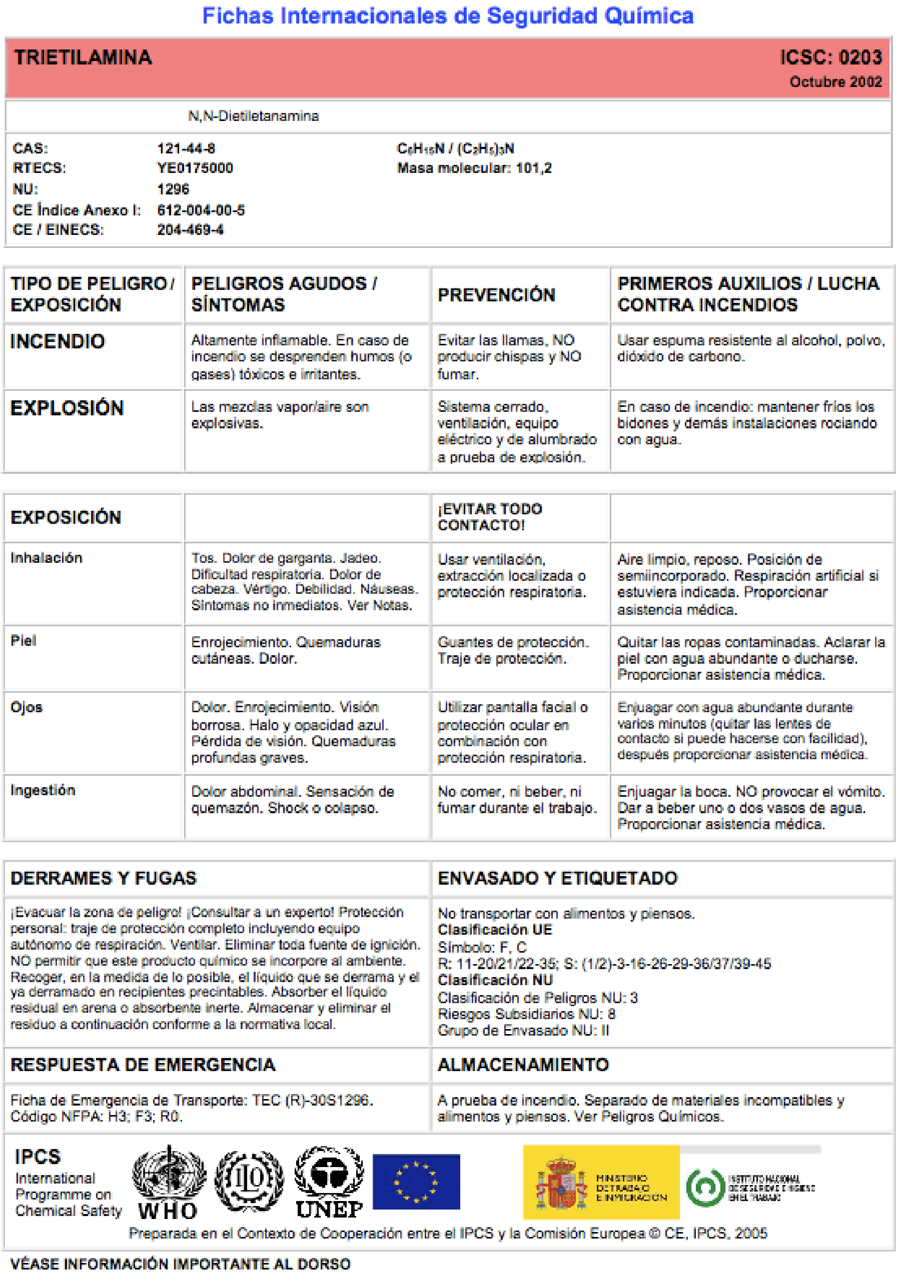

Fichas Internacionales de Seguridad Química

TRIETILAMINA	**ICSC: 0203** **Octubre 2002**

N,N-Dietiletanamina

CAS:	**121-44-8**	**$C_6H_{15}N$ / $(C_2H_5)_3N$**
RTECS:	**YE0175000**	**Masa molecular: 101,2**
NU:	**1296**	
CE Índice Anexo I:	**612-004-00-5**	
CE / EINECS:	**204-469-4**	

TIPO DE PELIGRO / EXPOSICIÓN	**PELIGROS AGUDOS / SÍNTOMAS**	**PREVENCIÓN**	**PRIMEROS AUXILIOS / LUCHA CONTRA INCENDIOS**
INCENDIO	Altamente inflamable. En caso de incendio se desprenden humos (o gases) tóxicos e irritantes.	Evitar las llamas, NO producir chispas y NO fumar.	Usar espuma resistente al alcohol, polvo, dióxido de carbono.
EXPLOSIÓN	Las mezclas vapor/aire son explosivas.	Sistema cerrado, ventilación, equipo eléctrico y de alumbrado a prueba de explosión.	En caso de incendio: mantener fríos los bidones y demás instalaciones rociando con agua.

EXPOSICIÓN		**¡EVITAR TODO CONTACTO!**	
Inhalación	Tos. Dolor de garganta. Jadeo. Dificultad respiratoria. Dolor de cabeza. Vértigo. Debilidad. Náuseas. Síntomas no inmediatos. Ver Notas.	Usar ventilación, extracción localizada o protección respiratoria.	Aire limpio, reposo. Posición de semiincorporado. Respiración artificial si estuviera indicada. Proporcionar asistencia médica.
Piel	Enrojecimiento. Quemaduras cutáneas. Dolor.	Guantes de protección. Traje de protección.	Quitar las ropas contaminadas. Aclarar la piel con agua abundante o ducharse. Proporcionar asistencia médica.
Ojos	Dolor. Enrojecimiento. Visión borrosa. Halo y opacidad azul. Pérdida de visión. Quemaduras profundas graves.	Utilizar pantalla facial o protección ocular en combinación con protección respiratoria.	Enjuagar con agua abundante durante varios minutos (quitar las lentes de contacto si puede hacerse con facilidad), después proporcionar asistencia médica.
Ingestión	Dolor abdominal. Sensación de quemazón. Shock o colapso.	No comer, ni beber, ni fumar durante el trabajo.	Enjuagar la boca. NO provocar el vómito. Dar a beber uno o dos vasos de agua. Proporcionar asistencia médica.

DERRAMES Y FUGAS	**ENVASADO Y ETIQUETADO**
¡Evacuar la zona de peligro! ¡Consultar a un experto! Protección personal: traje de protección completo incluyendo equipo autónomo de respiración. Ventilar. Eliminar toda fuente de ignición. NO permitir que este producto químico se incorpore al ambiente. Recoger, en la medida de lo posible, el líquido que se derrama y el ya derramado en recipientes precintables. Absorber el líquido residual en arena o absorbente inerte. Almacenar y eliminar el residuo a continuación conforme a la normativa local.	No transportar con alimentos y piensos. **Clasificación UE** Símbolo: F, C R: 11-20/21/22-35; S: (1/2)-3-16-26-29-36/37/39-45 **Clasificación NU** Clasificación de Peligros NU: 3 Riesgos Subsidiarios NU: 8 Grupo de Envasado NU: II
RESPUESTA DE EMERGENCIA	**ALMACENAMIENTO**
Ficha de Emergencia de Transporte: TEC (R)-30S1296. Código NFPA: H3; F3; R0.	A prueba de incendio. Separado de materiales incompatibles y alimentos y piensos. Ver Peligros Químicos.

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VÉASE INFORMACIÓN IMPORTANTE AL DORSO

Fichas Internacionales de Seguridad Química

TRIETILAMINA **ICSC: 0203**

DATOS IMPORTANTES

ESTADO FÍSICO; ASPECTO:
LÍQUIDO INCOLORO DE OLOR CARACTERÍSTICO.

PELIGROS FÍSICOS:
El vapor es más denso que el aire y puede extenderse a ras del suelo; posible ignición en punto distante.

PELIGROS QUÍMICOS:
Se descompone al arder. Esto produce gases tóxicos e irritantes incluyendo óxidos de nitrógeno. La sustancia es una base fuerte. Reacciona violentamente con ácido y es corrosivo para el aluminio, cinc, cobre y sus aleaciones en presencia de humedad. Reacciona violentamente con oxidantes fuertes. Esto genera peligro de incendio y explosión. Ataca algunas formas de plásticos, el caucho y revestimientos.

LÍMITES DE EXPOSICIÓN:
TLV: 0,5 ppm como TWA; 1 ppm como STEL; (piel); A4 no clasificado como cancerígeno humano); (ACGIH 2014).
LEP UE: 2 ppm, 8.4 mg/m³ como TWA; 3 ppm, 12.6 mg/m³ como STEL

VÍAS DE EXPOSICIÓN:
La sustancia se puede absorber por inhalación, a través de la piel y por ingestión.

RIESGO DE INHALACIÓN:
Por evaporación de esta sustancia a 20°C se puede alcanzar muy rápidamente una concentración nociva en el aire.

EFECTOS DE EXPOSICIÓN DE CORTA DURACIÓN:
La sustancia es corrosiva para los ojos, la piel y el tracto respiratorio. Corrosivo por ingestión. La inhalación puede causar edema pulmonar. Ver Notas. Los efectos pueden aparecer de forma no inmediata. Se recomienda vigilancia médica. La sustancia puede afectar al sistema nervioso central.

EFECTOS DE EXPOSICIÓN PROLONGADA O REPETIDA:

PROPIEDADES FÍSICAS

Punto de ebullición: 89°C
Punto de fusión: -115°C
Densidad relativa (agua = 1): 0.7
Solubilidad en agua, g/100ml a 20°C: 17 (elevada)
Presión de vapor, kPa a 20°C: 7.2

Densidad relativa de vapor (aire = 1): 3.5
Densidad relativa de la mezcla vapor/aire a 20°C (aire = 1): 1.2
Punto de inflamación: -17°C c.c.
Temperatura de autoignición: 230°C
Límites de explosividad, % en volumen en el aire: 1.2-8
Coeficiente de reparto octanol/agua como log Pow: 1.45

DATOS AMBIENTALES

La sustancia es nociva para los organismos acuáticos.

NOTAS

Los síntomas del edema pulmonar no se ponen de manifiesto, a menudo, hasta pasadas algunas horas y se agravan por el esfuerzo físico. Reposo y vigilancia médica son, por ello, imprescindibles. Debe considerarse la inmediata administración de un aerosol adecuado por un médico o persona por él autorizada. La alerta por el olor cuando se supera el límite de exposición es insuficiente.

INFORMACIÓN ADICIONAL

Límites de exposición profesional (INSHT 2011):

VLA-ED: 2 ppm; 8,4 mg/m³

VLA-EC: 3 ppm; 12,6 mg/m³

Notas: vía dérmica. Reacciona con agentes nitrosantes que pueden dar lugar a la formación de N-Nitrosaminas carcinógenas. Agente químico que tiene un valor límite indicativo por la UE.

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Fichas Internacionales de Seguridad Química

DIETILAMINA

ICSC: 0444
Noviembre 2008

CAS:	**109-89-7**	**N,N-Dietilamina**
RTECS:	**HZ8750000**	**N-Etiletanamina**
NU:	**1154**	**Dietamina**
CE Índice Anexo I:	**612-003-00-X**	**$C_4H_{11}N$ / $(C_2H_5)_2NH$**
CE / EINECS:	**203-716-3**	**Masa molecular: 73.1**

TIPO DE PELIGRO / EXPOSICIÓN	PELIGROS AGUDOS / SÍNTOMAS	PREVENCIÓN	PRIMEROS AUXILIOS / LUCHA CONTRA INCENDIOS
INCENDIO	Inflamable. En caso de incendio se desprenden humos (o gases) tóxicos e irritantes.	Evitar las llamas, NO producir chispas y NO fumar.	Polvo, espuma resistente al alcohol, agua en grandes cantidades o dióxido de carbono.
EXPLOSIÓN	Las mezclas vapor/aire son explosivas.	Sistema cerrado, ventilación, equipo eléctrico y de alumbrado a prueba de explosión. NO utilizar aire comprimido para llenar, vaciar o manipular.	En caso de incendio: mantener fríos los bidones y demás instalaciones rociando con agua. Combatir el incendio desde un lugar protegido.
EXPOSICIÓN		¡EVITAR TODO CONTACTO!	¡CONSULTAR AL MÉDICO EN TODOS LOS CASOS!
Inhalación	Dolor de garganta. Tos. Jadeo. Sensación de quemazón detrás del esternón. Dificultad respiratoria. Síntomas no inmediatos (ver Notas).	Sistema cerrado y ventilación.	Aire limpio, reposo. Posición de semiincorporado. Proporcionar asistencia médica.
Piel	Enrojecimiento. Dolor. Ampollas. Quemaduras cutáneas graves.	Guantes de protección. Traje de protección.	Aclarar con agua abundante durante 15 minutos como mínimo, después quitar la ropa contaminada y aclarar de nuevo. Proporcionar asistencia médica.
Ojos	Enrojecimiento. Dolor. Quemaduras.	Gafas ajustadas de seguridad, pantalla facial y protección ocular combinada con protección respiratoria.	Enjuagar con agua abundante durante varios minutos (quitar las lentes de contacto si puede hacerse con facilidad). Proporcionar asistencia médica inmediatamente.
Ingestión	Sensación de quemazón en la garganta y el pecho. Dolor abdominal. Diarrea. Vómitos. Shock o colapso.	No comer, ni beber, ni fumar durante el trabajo.	Enjuagar la boca. NO provocar el vómito. Proporcionar asistencia médica inmediatamente.

DERRAMES Y FUGAS

¡Evacuar la zona de peligro! Protección personal: traje de protección química, incluyendo equipo autónomo de respiración. Eliminar toda fuente de ignición. NO permitir que este producto químico se incorpore al ambiente. NO verterlo en el alcantarillado. Ventilar. Recoger el líquido procedente de la fuga en recipientes de plástico precintables. Recoger cuidadosamente el residuo y trasladarlo a continuación a un lugar seguro.

ENVASADO Y ETIQUETADO

Envase irrompible; colocar el envase frágil dentro de un recipiente irrompible cerrado. No transportar con alimentos y piensos.

Clasificación UE
  Símbolo: F, C
  R: 11-20/21/22-35
  S: (1/2-)3-16-26-29-36/37/39-45
Clasificación NU
  Clasificación de Peligros NU: 3
  Riesgos Subsidiarios de las NU: 8
  Grupo de Envasado NU: II
Clasificación GHS
  Peligro
  Líquido y vapores muy inflamables.
  Nocivo en caso de ingestión.
  Tóxico en contacto con la piel.
  Nocivo si se inhala.
  Provoca graves quemaduras en la piel y lesiones oculares.
  Puede provocar irritación respiratoria.
  Nocivo para los organismos acuáticos.

RESPUESTA DE EMERGENCIA

Ficha de Emergencia de Transporte (Transport Emergency Card): TEC (R)-30S1154 o 30GFC-II. Código NFPA: H3; F3; R0

ALMACENAMIENTO

A prueba de incendio. Separado de oxidantes fuertes, ácidos fuertes, compuestos orgánicos, alimentos y piensos. Mantener en lugar fresco. Bien cerrado. Almacenar en el recipiente original. Almacenar en un área sin acceso a desagües o alcantarillas.

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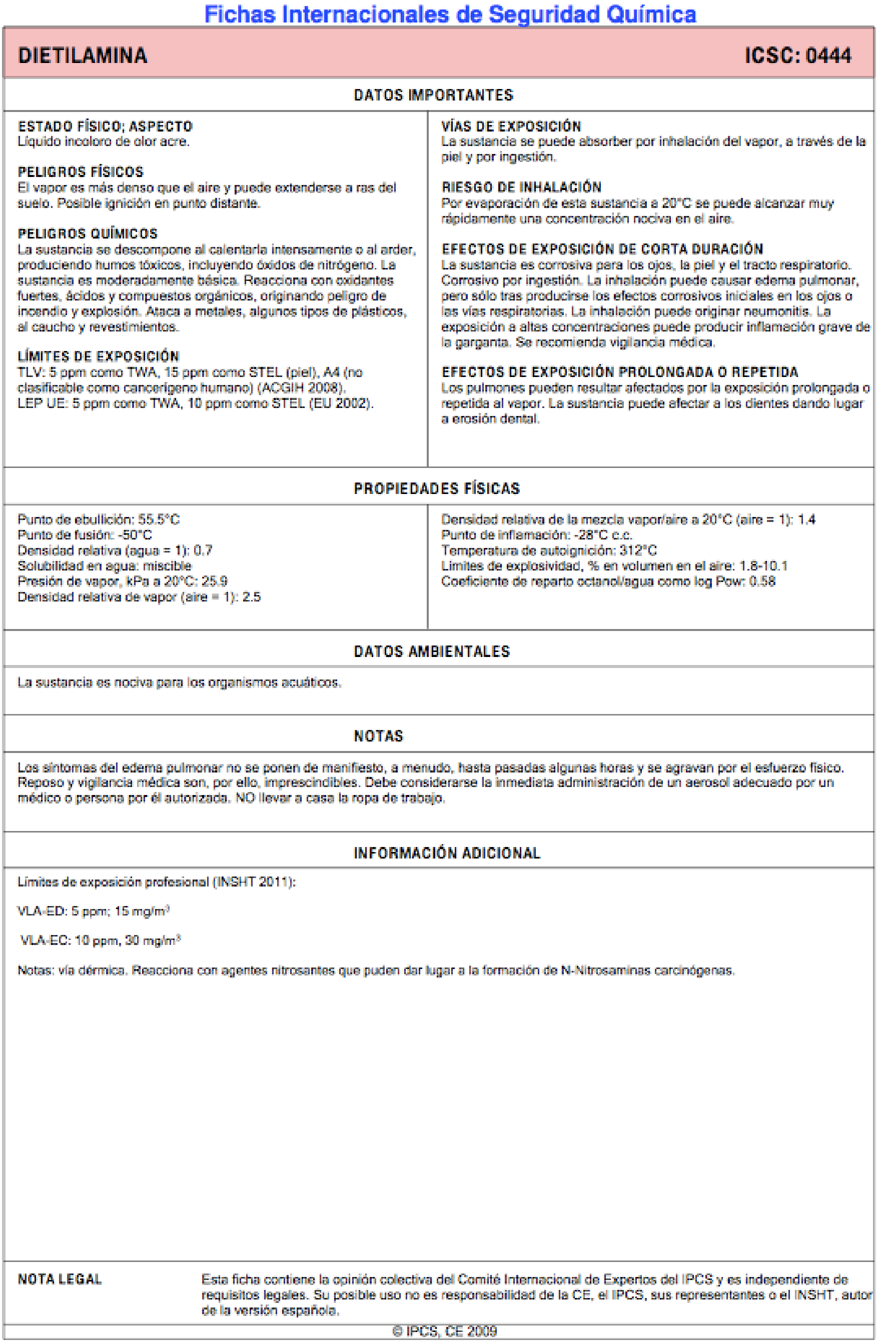
VÉASE INFORMACIÓN IMPORTANTE AL DORSO



Fichas Internacionales de Seguridad Química

DIETILAMINA **ICSC: 0444**

DATOS IMPORTANTES

ESTADO FÍSICO; ASPECTO
Líquido incoloro de olor acre.

PELIGROS FÍSICOS
El vapor es más denso que el aire y puede extenderse a ras del suelo. Posible ignición en punto distante.

PELIGROS QUÍMICOS
La sustancia se descompone al calentarla intensamente o al arder, produciendo humos tóxicos, incluyendo óxidos de nitrógeno. La sustancia es moderadamente básica. Reacciona con oxidantes fuertes, ácidos y compuestos orgánicos, originando peligro de incendio y explosión. Ataca a metales, algunos tipos de plásticos, al caucho y revestimientos.

LÍMITES DE EXPOSICIÓN
TLV: 5 ppm como TWA, 15 ppm como STEL (piel), A4 (no clasificable como cancerígeno humano) (ACGIH 2008).
LEP UE: 5 ppm como TWA, 10 ppm como STEL (EU 2002).

VÍAS DE EXPOSICIÓN
La sustancia se puede absorber por inhalación del vapor, a través de la piel y por ingestión.

RIESGO DE INHALACIÓN
Por evaporación de esta sustancia a 20°C se puede alcanzar muy rápidamente una concentración nociva en el aire.

EFECTOS DE EXPOSICIÓN DE CORTA DURACIÓN
La sustancia es corrosiva para los ojos, la piel y el tracto respiratorio. Corrosivo por ingestión. La inhalación puede causar edema pulmonar, pero sólo tras producirse los efectos corrosivos iniciales en los ojos o las vías respiratorias. La inhalación puede originar neumonitis. La exposición a altas concentraciones puede producir inflamación grave de la garganta. Se recomienda vigilancia médica.

EFECTOS DE EXPOSICIÓN PROLONGADA O REPETIDA
Los pulmones pueden resultar afectados por la exposición prolongada o repetida al vapor. La sustancia puede afectar a los dientes dando lugar a erosión dental.

PROPIEDADES FÍSICAS

Punto de ebullición: 55.5°C
Punto de fusión: -50°C
Densidad relativa (agua = 1): 0.7
Solubilidad en agua: miscible
Presión de vapor, kPa a 20°C: 25.9
Densidad relativa de vapor (aire = 1): 2.5
Densidad relativa de la mezcla vapor/aire a 20°C (aire = 1): 1.4
Punto de inflamación: -28°C c.c.
Temperatura de autoignición: 312°C
Límites de explosividad, % en volumen en el aire: 1.8-10.1
Coeficiente de reparto octanol/agua como log Pow: 0.58

DATOS AMBIENTALES

La sustancia es nociva para los organismos acuáticos.

NOTAS

Los síntomas del edema pulmonar no se ponen de manifiesto, a menudo, hasta pasadas algunas horas y se agravan por el esfuerzo físico. Reposo y vigilancia médica son, por ello, imprescindibles. Debe considerarse la inmediata administración de un aerosol adecuado por un médico o persona por él autorizada. NO llevar a casa la ropa de trabajo.

INFORMACIÓN ADICIONAL

Límites de exposición profesional (INSHT 2011):

VLA-ED: 5 ppm; 15 mg/m^3

VLA-EC: 10 ppm, 30 mg/m^3

Notas: vía dérmica. Reacciona con agentes nitrosantes que puden dar lugar a la formación de N-Nitrosaminas carcinógenas.

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Fichas Internacionales de Seguridad Química

ACIDO CITRICO MONOHIDRATO **ICSC: 0704**

MINISTERIO
DE TRABAJO
Y ASUNTOS SOCIALES
ESPAÑA

INSTITUTO NACIONAL
DE SEGURIDAD E HIGIENE
EN EL TRABAJO

ACIDO CITRICO MONOHIDRATO
Acido 2-hidroxi-1,2,3-propanotricarboxílico monohidratado
Acido ß-hidroxitricarboxílico monohidratado
$C_6H_8O_7.H_2O$
Masa molecular: 210.1

Nº CAS 5949-29-1
Nº RTECS GE7810000
Nº ICSC 0704

TIPOS DE PELIGRO/ EXPOSICION	PELIGROS/ SINTOMAS AGUDOS	PREVENCION	PRIMEROS AUXILIOS/ LUCHA CONTRA INCENDIOS
INCENDIO	Combustible.	Evitar llama abierta.	Pulverización con agua, polvos.
EXPLOSION	Las partículas finamente dispersas forman mezclas explosivas en el aire.		
EXPOSICION			
• **INHALACION**	Tos, dolor de garganta.	Extracción localizada o protección respiratoria.	Aire limpio, reposo y someter a atención médica.
• **PIEL**	Enrojecimiento.	Guantes protectores.	Quitar las ropas contaminadas, aclarar la piel con agua abundante o ducharse.
• **OJOS**	Enrojecimiento, dolor.	Gafas ajustadas de seguridad.	Enjuagar con agua abundante durante varios minutos (quitar las lentes de contacto si puede hacerse con facilidad), después consultar a un médico.
• **INGESTION**	Dolor de garganta, leve sensación de quemazón.	No comer, beber ni fumar durante el trabajo.	Enjuagar la boca y someter a atención médica.

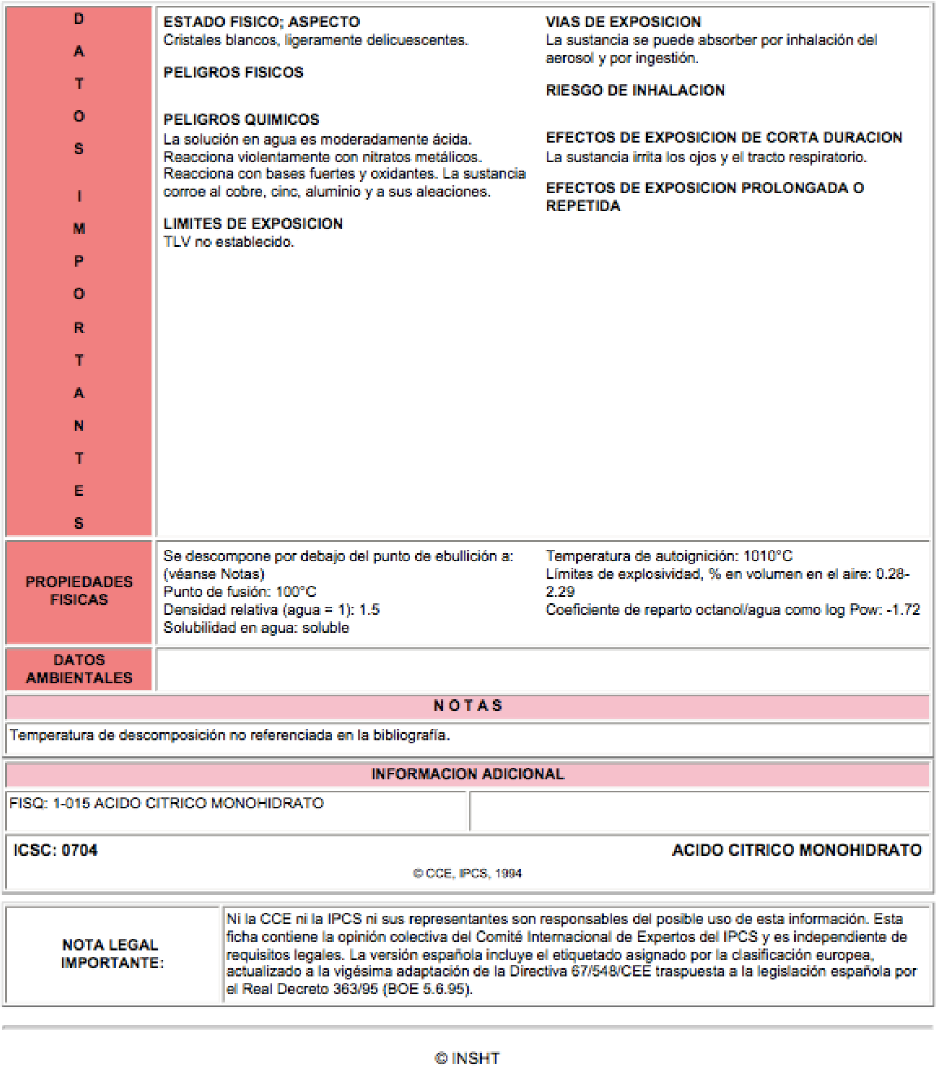
DERRAMAS Y FUGAS	ALMACENAMIENTO	ENVASADO Y ETIQUETADO
Barrer lo mejor posible; eliminar el residuo con agua abundante.	Separado de oxidantes, bases fuertes.	

VEASE AL DORSO INFORMACION IMPORTANTE

ICSC: 0704 Preparada en el Contexto de Cooperación entre el IPCS y la Comisión de las Comunidades Europeas © CCE, IPCS, 1994

Fichas Internacionales de Seguridad Química

ACIDO CITRICO MONOHIDRATO **ICSC: 0704**



DATOS IMPORTANTES	**ESTADO FISICO; ASPECTO** Cristales blancos, ligeramente delicuescentes. **PELIGROS FISICOS** **PELIGROS QUIMICOS** La solución en agua es moderadamente ácida. Reacciona violentamente con nitratos metálicos. Reacciona con bases fuertes y oxidantes. La sustancia corroe al cobre, cinc, aluminio y a sus aleaciones. **LIMITES DE EXPOSICION** TLV no establecido.	**VIAS DE EXPOSICION** La sustancia se puede absorber por inhalación del aerosol y por ingestión. **RIESGO DE INHALACION** **EFECTOS DE EXPOSICION DE CORTA DURACION** La sustancia irrita los ojos y el tracto respiratorio. **EFECTOS DE EXPOSICION PROLONGADA O REPETIDA**
PROPIEDADES FISICAS	Se descompone por debajo del punto de ebullición a: (véanse Notas) Punto de fusión: 100°C Densidad relativa (agua = 1): 1.5 Solubilidad en agua: soluble	Temperatura de autoignición: 1010°C Límites de explosividad, % en volumen en el aire: 0.28-2.29 Coeficiente de reparto octanol/agua como log Pow: -1.72
DATOS AMBIENTALES		

NOTAS
Temperatura de descomposición no referenciada en la bibliografía.

INFORMACION ADICIONAL	
FISQ: 1-015 ACIDO CITRICO MONOHIDRATO	
ICSC: 0704	**ACIDO CITRICO MONOHIDRATO**

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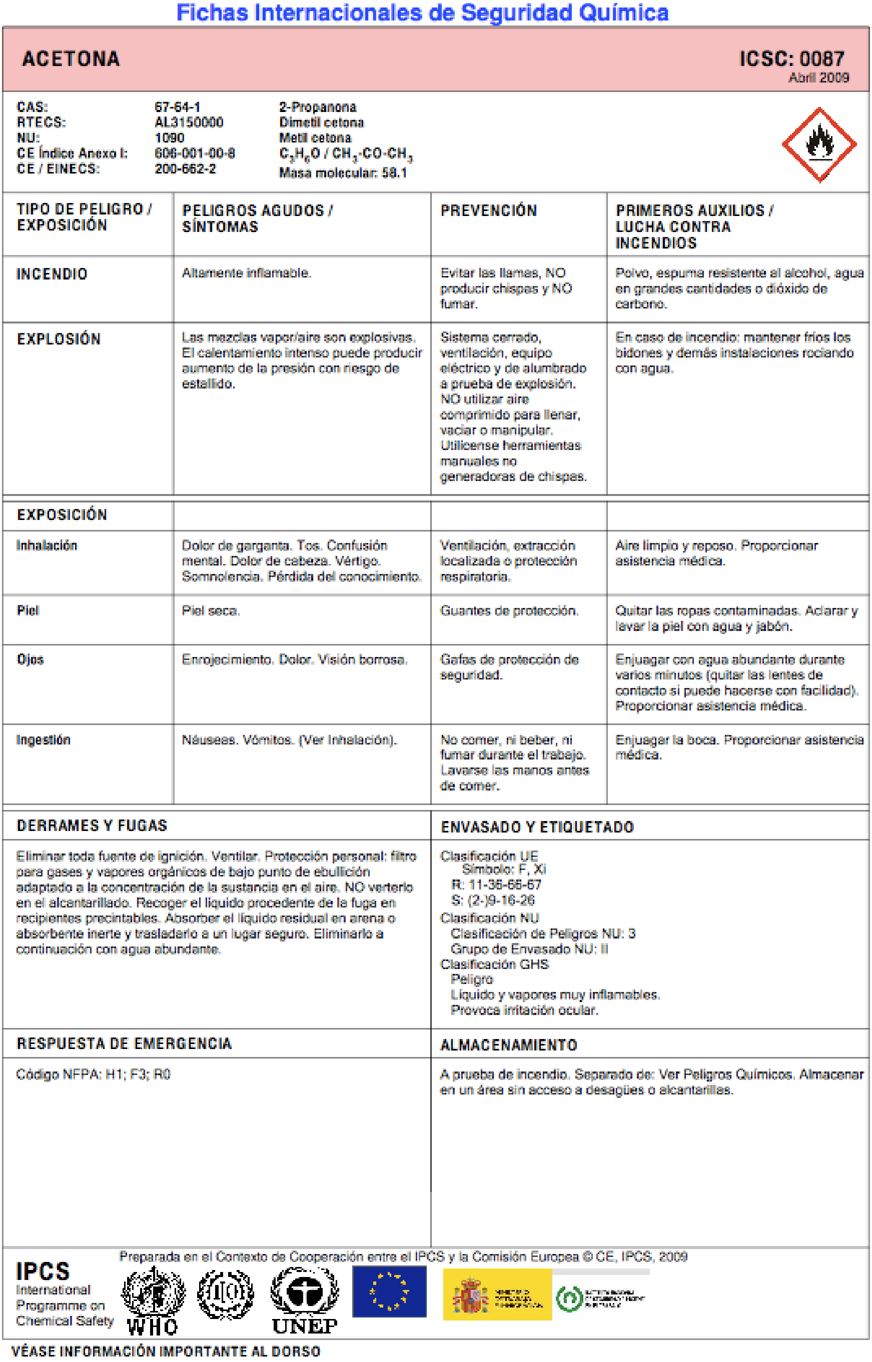

Fichas Internacionales de Seguridad Química

ACETONA

ICSC: 0087
Abril 2009

CAS:	**67-64-1**	**2-Propanona**
RTECS:	**AL3150000**	**Dimetil cetona**
NU:	**1090**	**Metil cetona**
CE Índice Anexo I:	**606-001-00-8**	**C_3H_6O / CH_3-CO-CH_3**
CE / EINECS:	**200-662-2**	**Masa molecular: 58.1**

TIPO DE PELIGRO / EXPOSICIÓN	PELIGROS AGUDOS / SÍNTOMAS	PREVENCIÓN	PRIMEROS AUXILIOS / LUCHA CONTRA INCENDIOS
INCENDIO	Altamente inflamable.	Evitar las llamas, NO producir chispas y NO fumar.	Polvo, espuma resistente al alcohol, agua en grandes cantidades o dióxido de carbono.
EXPLOSIÓN	Las mezclas vapor/aire son explosivas. El calentamiento intenso puede producir aumento de la presión con riesgo de estallido.	Sistema cerrado, ventilación, equipo eléctrico y de alumbrado a prueba de explosión. NO utilizar aire comprimido para llenar, vaciar o manipular. Utilícense herramientas manuales no generadoras de chispas.	En caso de incendio: mantener fríos los bidones y demás instalaciones rociando con agua.
EXPOSICIÓN			
Inhalación	Dolor de garganta. Tos. Confusión mental. Dolor de cabeza. Vértigo. Somnolencia. Pérdida del conocimiento.	Ventilación, extracción localizada o protección respiratoria.	Aire limpio y reposo. Proporcionar asistencia médica.
Piel	Piel seca.	Guantes de protección.	Quitar las ropas contaminadas. Aclarar y lavar la piel con agua y jabón.
Ojos	Enrojecimiento. Dolor. Visión borrosa.	Gafas de protección de seguridad.	Enjuagar con agua abundante durante varios minutos (quitar las lentes de contacto si puede hacerse con facilidad). Proporcionar asistencia médica.
Ingestión	Náuseas. Vómitos. (Ver Inhalación).	No comer, ni beber, ni fumar durante el trabajo. Lavarse las manos antes de comer.	Enjuagar la boca. Proporcionar asistencia médica.

DERRAMES Y FUGAS

Eliminar toda fuente de ignición. Ventilar. Protección personal: filtro para gases y vapores orgánicos de bajo punto de ebullición adaptado a la concentración de la sustancia en el aire. NO verterlo en el alcantarillado. Recoger el líquido procedente de la fuga en recipientes precintables. Absorber el líquido residual en arena o absorbente inerte y trasladarlo a un lugar seguro. Eliminarlo a continuación con agua abundante.

ENVASADO Y ETIQUETADO

Clasificación UE
  Símbolo: F, Xi
  R: 11-36-66-67
  S: (2-)9-16-26
Clasificación NU
  Clasificación de Peligros NU: 3
  Grupo de Envasado NU: II
Clasificación GHS
  Peligro
  Líquido y vapores muy inflamables.
  Provoca irritación ocular.

RESPUESTA DE EMERGENCIA

Código NFPA: H1; F3; R0

ALMACENAMIENTO

A prueba de incendio. Separado de: Ver Peligros Químicos. Almacenar en un área sin acceso a desagües o alcantarillas.

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IPCS
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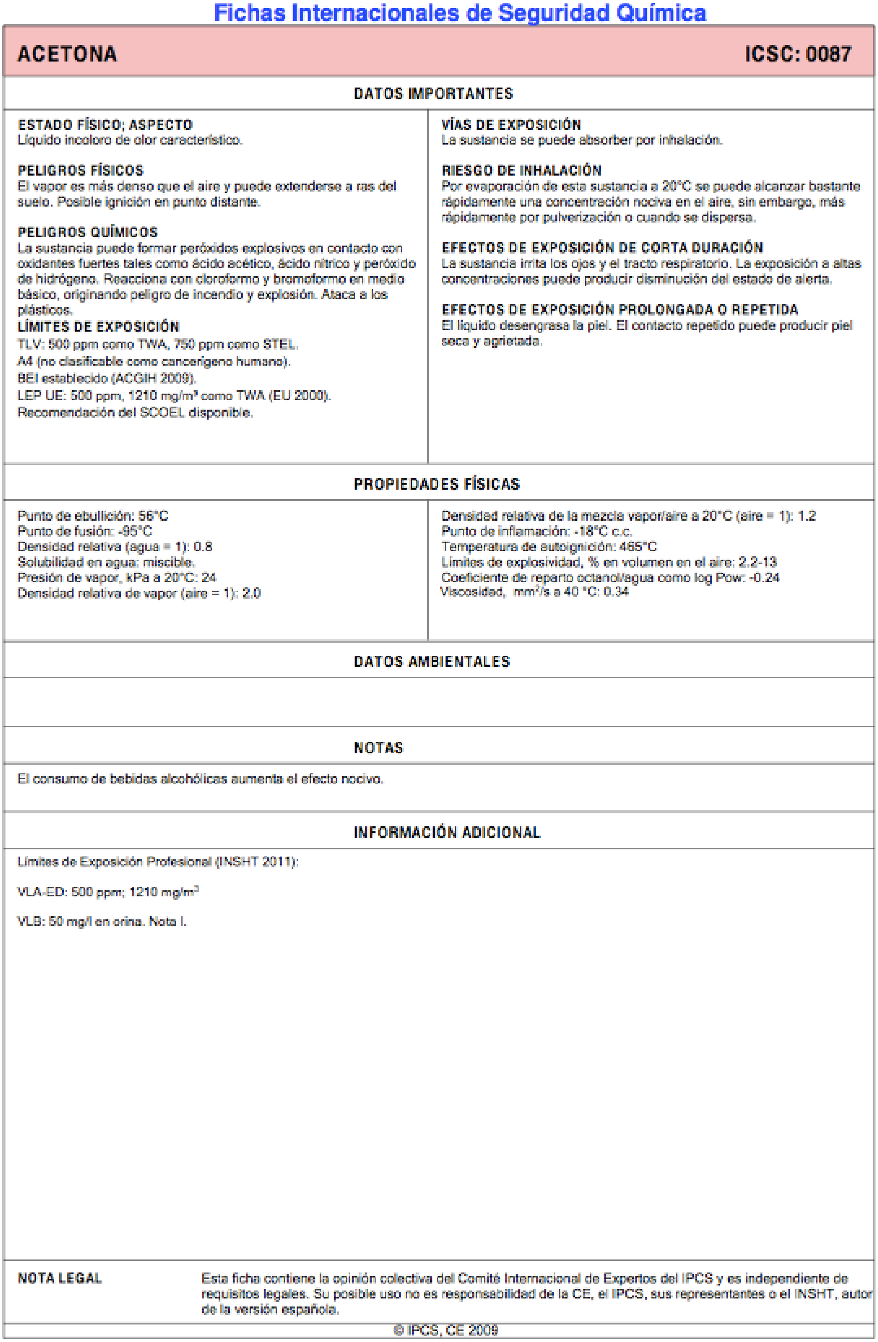
Chemical Safety

VÉASE INFORMACIÓN IMPORTANTE AL DORSO



Fichas Internacionales de Seguridad Química

ACETONA **ICSC: 0087**

DATOS IMPORTANTES

ESTADO FÍSICO; ASPECTO
Líquido incoloro de olor característico.

PELIGROS FÍSICOS
El vapor es más denso que el aire y puede extenderse a ras del suelo. Posible ignición en punto distante.

PELIGROS QUÍMICOS
La sustancia puede formar peróxidos explosivos en contacto con oxidantes fuertes tales como ácido acético, ácido nítrico y peróxido de hidrógeno. Reacciona con cloroformo y bromoformo en medio básico, originando peligro de incendio y explosión. Ataca a los plásticos.

LÍMITES DE EXPOSICIÓN
TLV: 500 ppm como TWA, 750 ppm como STEL.
A4 (no clasificable como cancerígeno humano).
BEI establecido (ACGIH 2009).
LEP UE: 500 ppm, 1210 mg/m³ como TWA (EU 2000).
Recomendación del SCOEL disponible.

VÍAS DE EXPOSICIÓN
La sustancia se puede absorber por inhalación.

RIESGO DE INHALACIÓN
Por evaporación de esta sustancia a 20°C se puede alcanzar bastante rápidamente una concentración nociva en el aire, sin embargo, más rápidamente por pulverización o cuando se dispersa.

EFECTOS DE EXPOSICIÓN DE CORTA DURACIÓN
La sustancia irrita los ojos y el tracto respiratorio. La exposición a altas concentraciones puede producir disminución del estado de alerta.

EFECTOS DE EXPOSICIÓN PROLONGADA O REPETIDA
El líquido desengrasa la piel. El contacto repetido puede producir piel seca y agrietada.

PROPIEDADES FÍSICAS

Punto de ebullición: 56°C
Punto de fusión: -95°C
Densidad relativa (agua = 1): 0.8
Solubilidad en agua: miscible.
Presión de vapor, kPa a 20°C: 24
Densidad relativa de vapor (aire = 1): 2.0
Densidad relativa de la mezcla vapor/aire a 20°C (aire = 1): 1.2
Punto de inflamación: -18°C c.c.
Temperatura de autoignición: 465°C
Límites de explosividad, % en volumen en el aire: 2.2-13
Coeficiente de reparto octanol/agua como log Pow: -0.24
Viscosidad, mm²/s a 40 °C: 0.34

DATOS AMBIENTALES

NOTAS

El consumo de bebidas alcohólicas aumenta el efecto nocivo.

INFORMACIÓN ADICIONAL

Límites de Exposición Profesional (INSHT 2011):

VLA-ED: 500 ppm; 1210 mg/m³

VLB: 50 mg/l en orina. Nota I.

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