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CHM 172
Practical 5: Aspirin LCI worksheet

Fill in the name, student number and the signature of each group member.

Surname									**Initials**	
Student number									**Signature:**	

Surname									**Initials**	
Student number									**Signature:**	

Surname									**Initials**	
Student number									**Signature:**	

Name of your tutor:	**Date:**

EXPERIMENTAL DATA

FUNCTIONAL UNIT: This LCI is for the manufacture of **1500 kg** of Aspirin.

In order to produce **1500 kg of Aspirin**, we have to start with **1150 kg salicylic acid** and **616.67 kg** of methyl acetate.
Salicylic acid can be produced using 3 routes.
LCI will be used to find the greener route of producing **1150 kg of salicylic acid.**

Refer to the aspirin manufacture information document where necessary.

Question 1

Complete Table 1-3 below by calculating the mass of the components needed to synthesize the product per table. **Do not calculate the shaded blocks in the tables.**

a. Complete Table 1 below by calculating the exact mass (in kg to two decimal places) of the components needed to synthesize ***1150 kg of salicylic acid*** from phenol. **[5]**

Refer to the Table 1 *DATA SHEET* on page 7 in the aspirin manufacture document.

From Table 1 on page 7:

927 kg phenol was put in to produce 1000 kg of Salicylic acid

$$927\ kg\ C_6H_5OH\ =\ 1000\ kg\ SA$$
$$x\ kg\ \ C_6H_5OH\ =\ 1150\ kg\ SA$$

$$x\ kg\ C_6H_5OH = \frac{927\ kg\ C_6H_5OH\ x\ 1150\ kg\ SA}{1000\ kg\ SA} = \mathbf{1066.05\ kg}$$

Table 1: Material balance for the production of **1150 kg of salicylic acid from phenol**
(*Refer to Table 1 page 7)*

COMPONENT	INPUT (kg)	PRODUCT (kg)	WASTE (kg)
phenol	**1066.05**		**117.30**
Sodium hydroxide			
Carbon dioxide			
Sulfuric acid			
activated carbon			
water			
sodium sulfate			
salicylic acid		**1150**	

b. Complete Table 2 below by calculating the exact mass (in kg to two decimal places) of the components needed to synthesize 1150 kg of salicylic acid from oil of wintergreen. **[2.5]**

Refer to the Table 2 *DATA SHEET* on page 7 in the aspirin manufacture document.

<u>From Table 2 on page 7:</u>

1380.74 kg sodium hydroxide was put in to produce 1000 kg of Salicylic acid

$$1380.74\ kg\ NaOH = 1000\ kg\ SA$$
$$x\ kg\ \ NaOH\ \ = 1150\ kg\ SA$$

$$x\ kg\ NaOH\ = \frac{1380.74\ kg\ NaOH\ x\ 1150\ kg\ SA}{1000\ kg\ SA} = \mathbf{1587.85\ kg}$$

Table 2: Material balance for the production of **1150 kg of salicylic acid from oil of wintergreen** (***Refer to Table 2 page 7)***

COMPONENT	INPUT (kg)	PRODUCT (kg)	WASTE (kg)
Sodium hydroxide	**1587.85**		
Sulfuric acid			
Oil of wintergreen			
water			
salicylic acid		**1150**	
methanol			
Sodium sulfate			

c. Complete Table 3 below by calculating the exact mass (in kg to two decimal places) of the components needed to synthesize ***616.67 kg of methyl acetate.*** **[1.5]**

Refer to the Table 3 *DATA SHEET* on page 7 in the aspirin manufacture document.

<u>From Table 3 on page 7</u>:

866.48 kg methanol was put in to produce 1000 kg of methyl acetate

$$866.48\ kg\ CH_3OH = 1000\ kg\ MA$$
$$x\ kg\ \ CH_3OH\ \ = 616.67\ kg\ MA$$

$$x\ kg\ CH_3OH\ \ = \frac{866.48\ kg\ methanol\ x\ 616.67\ kg\ MA}{1000\ kg\ MA} = \mathbf{534.33\ kg}$$

Table 3: Material balance for the production of **616.67 kg of methyl acetate from natural gas** (***Refer to Table 3 page 7)***

COMPONENT	INPUT (kg)	PRODUCT (kg)	WASTE (kg)
methanol	**534.33**		**267.68**
water			
acetic acid			
methyl acetate		**616.67**	

Question 2

The % atom economy (calculated in the pre-practical) for route 1 and route 3 is shown in **Table 4 row 1**.
Refer to the **calculated mass in Table 1 and 2 and calculate:**

a. **in row 2** the % reaction mass efficiency of salicylic acid for the route 1 and route 3. **[2]**

b. **in row 3** the % yield of salicylic acid for the two routes**.** **[2]**
For route 1 theoretical yield of salicylic acid is **1359 kg**.
For route 3 theoretical yield of salicylic acid is **1191 kg**.

c. **in row 4** the E-factor (total waste) (in kg) **[2]**

d. Answer the four questions that follow. **[7]**

Table 4		
Green matrix and meaning	**Route 1**	**Route 3**
% Atom economy How efficient the process is in terms of atoms.	65.22 %	54.88 %
% Carbon efficiency *How efficient the process is in terms of C atoms.*	100 %	87.50 %
% Reaction mass efficiency How efficient the process is in terms of amounts of inputs to product.		
% Yield How efficient the chemical reactions are.		
E-factor (Total waste) (in kg) How efficient the chemical reactions in terms of waste produced.		

Consider the calculated green metrics and decide which SA synthetic route you would select for your company. Justify your choice. **[2]**	
What type of system boundary (**Cradle to gate or Gate to grave or Cradle to grave or Gate to gate**) is implemented in this inventory? Refer to Figure 3, Page 4 of the Aspirin Manufacture document. **[1]**	
Would expansion of the boundaries to include the raw material extraction processes likely result in your change of choice of the more sustainable route? Explain in brief **[2]**	
Phenol is obtained from crude oil. Crude oil is a non-renewable resource. What effect would depletion of crude oil reserves have on the cost of buying aspirin? Briefly explain. **[2]**	

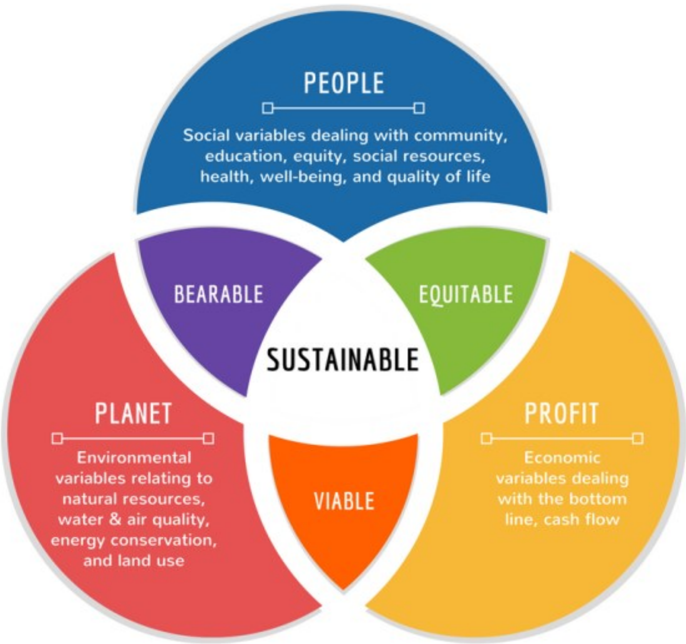
Question 3

Answer the following questions in the space provided:	
How can the impact (**environmental, social or economic)** of the inputs and output be minimized or managed to make the process sustainable**?** **[2]**	
How can the impact (**environmental, social or economic)** of energy be minimized or managed to make the process sustainable? **[2]**	
Besides the energy costs and the buying all the raw materials, what other cost implications do you anticipate the aspirin manufacturing process to incur? **[2]** Give 2 examples?	
How does the exercise you just carried out on synthesis of aspirin display the central role of chemistry in the mitigation of global sustainability issues**?** **[2]**	

SYSTEMS THINKING IN SUSTAINABILITY

Sustainability is all about systems and making sure we are thinking about the entire picture so we can address a problem from all angles. It is important that we start seeing the Earth as a system. Within this system, there are other systems such as People, Planet and Profit. All three systems are tightly interconnected and initiatives to address one often overlap with the other. Just like, there would not be people without a planet, there would not be a business without people, and there would not be prosperity without business.

Sustainable systems thinking is a mindset that helps us to untangle and work within the complexity of life on Earth. It helps us to better understand the impact of our work on the world around us and be responsible for what we create and how we innovate. An important step in developing a systemic approach is to find the source of the problems, as these increases the chances of identifying the leverage. Leverage is a small, focused action, that can produce significant changes with a minimum effort. Leverage can also be achieved by weakening the symptomatic response to the problem while strengthening the fundamental solution. Leverages results in viable, bearable and equitable options during problem solving. The aspirin manufacture forms a part of the aspirin system, which includes engineering, the planet, people, human health, and economics.



Sustainability strives for:

- **Viable** environmental-economic impact: Business is executed with the environment and resources in mind.
- **Bearable** socio-environmental impact: Develop healthy habits that benefit the society and the environment.
- **Equitable** socio-economic impact: The generation of economic opportunity for both businesses and individuals.

ROLE PLAY ACTIVITY

- An Engineer in partnership with a chemist decides that there is a need to upgrade the aspirin manufacturing plant for sustainability. They take up the idea to the board, which includes the **Finance manager, the Environmental officer and the Community representative.**

- Carry out a role play in which each group member assumes the stated role in the meeting. In the space provided, each member should write down his or her own expectations of the new plant.

Finance manager

1. Maximize profit
2.
3.
4.
5.
6.
7.
8.

Asprin Manufacturing

Commnunity represantative

1. Create jobs for local peoplemize profit
2.
3.
4.
5.
6.
7.
8.

Enviromental Officer

1. Minimize deforestation
2.
3.
4.
5.
6.
7.
8.

- Lastly, all group members should discussion amongst themselves and write down their ideal sustainable plant**.** There will be leverages, compromises, adjustments, and amendments as **viable, bearable and equitable spheres of sustainability** should be taken into consideration when designing the new sustainable plant.

  Hint: You are welcome to refer to the **17 sustainable development goals**.

Asprin Manufacturing Plant for sustainability

Financial manager, Enviromental officer and the community representative

1. The new plant will have solar panels
2. The community will assist with reforestation.
3.
4.
5.
6.
7.
8.
9.
10.

Are all group members happy with the new plant design?	***Yes***	***No***