

### Question 2

Refer to the procedure for the synthesis of **aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document**. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

**Use methanol in row 1 as an example.**

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials	Demand and supply	Job creation
Land pollution	Profits	Longevity of life
Air and water pollution	Prices of chemicals and drugs	Quality of life
Land degradation	Employment	Drug dependency and abuse
Global warming and climate change	Tax contribution	Human rights

Table of inputs, outputs and energy used during aspirin synthesis.			
	List	Impact	Explain the impact
Example	Methanol	<b>Environmental</b> <b>Social</b> <b>Economic</b>	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Economic Environmental	-As it reacts with acetic acid to create aspirin, which is used as a pain killer, it is in high demand and affordable. -it generates a wide response in plants -Affects the photosynthesis parameters and plant water relations
	Acetic anhydride	Social	Highly corrosive chemical -contact can severely irritate and burn the skin and cause eye damages.
	Sulfuric acid	Social Environmental	Exposure can cause headache and lung damages. Very corrosive and can burn any plants, birds or land animals.

Outputs	Aspirin	Social Economic	<ul style="list-style-type: none"> <li>→ People depend on it to relieve pain</li> <li>→ It is inexpensive and it is widely available in high demands.</li> </ul>
	Water	Environmental Economic Social	<p>Water is good and sometimes bad, Too much water can cause flooding, damage to houses, and severely death of people and animals.</p> <p>- Such disasters can cost the a lot of money to help those in need.</p> <p>Contaminated water can affect peoples health, causing cholera and diarrhoea. Even kill a threat to aquatic life.</p>
	Acetic acid	Environmental Social Economic	<p>high concentration over a prolonged period of time of acetic acid can be harmful to plants animals and aquatic life.</p> <p>high level of acetic acid can cause irritation of eyes, nose and throat</p> <p>→ Acetic acid is used in many industrial processes for the production of substrates</p>
Energy	Weighing Heating Boiling	Environmental Social Economic	<p>A correct amount of reagents must be used to avoid excess products, and throwing away, which can pollute to environment.</p> <p>And this will help us save and grow the economy.</p>

**Question 3**

Briefly define sustainability. <b>[1]</b>	It is the ability to maintain or support a process continuously over time. Meeting our own needs without compromising the ability of future generations to meet their own needs. ✓			
Briefly define system thinking. <b>[1]</b>	is a way of making sense of the complexity of the world by looking at it in terms of wholes and relationships rather than splitting it into parts. It offers a better way to predict future outcomes. ✓			
Tick (✓) the factors that are important in the choice of the drug synthesis route. <b>[1]</b> Do not tick if NOT important.	<input checked="" type="checkbox"/>	Source of raw materials	<input type="checkbox"/>	Solvents
	<input type="checkbox"/>	Energy used	<input checked="" type="checkbox"/>	Catalysts
	<input checked="" type="checkbox"/>	Amounts of reactants used	<input checked="" type="checkbox"/>	Amounts products formed
	<input type="checkbox"/>	Waste management	<input type="checkbox"/>	Byproducts

**Question 4**

What kind of engineer will you be? Mining engineer. As this engineer, what could you contribute to make a drug synthesis route more sustainable? **[2]**

Reduce the waste production as much as possible ✓  
 Also do not leave waste untreated. Minimize atomic economy by designing the synthesis in such a way that the final product contains the maximum percentage of initial material.

**Question 5**

Do you give consent for your submission to be used for research purposes? Yes or No.

<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No
---	-----------------------------

If your answer is **yes**, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is **No**.

The University of Pretoria Ethics Board has approved this research.

**Question 2**

Refer to the procedure for the synthesis of **aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document**. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

Use methanol in row 1 as an example.

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials Land pollution Air and water pollution Land degradation Global warming and climate change	Demand and supply Profits Prices of chemicals and drugs Employment Tax contribution	Job creation Longevity of life Quality of life Drug dependency and abuse Human rights

**Table of inputs, outputs and energy used during aspirin synthesis.**

	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Social Economic Environmental	Marine life and our water sources could be in jeopardy if not handled correctly. <del>Pollution from manufacturing</del> Widely used (medical/cosmetic industries) Valuable substance but expensive to make
	Acetic anhydride	Economic Social Environmental	Manufacturers exposed to dangerous/hazardous chemicals. Causes air pollution <del>health issues</del> . Large amounts of <del>waste</del> produced. Expensive to make but valuable product.
	Sulfuric acid	Social Economic Environmental	Acid rain can form due to this product. Highly corrosive - dangerous to work with <del>air pollution</del> and soil solidification. <del>Cost increase in case of the damage of infrastructure</del>

Outputs	Aspirin	Economical Social Environmental	Lots of energy required <del>to</del> and resources required to produce aspirin. Big environmental impact, e.g. greenhouse effect. It is non-biodegradable <del>so</del> will remain in the environment for a long period of time. Can be used as medication but can be highly addictive. <del>It is affordable.</del>
	Water	Social Environmental Economical	The treatment of water can add <sup>waste</sup> to the greenhouse gases. Using water will decrease the water levels in the area. The decrease of water locally can increase the pressure on the local community that need the water to survive. The cost of water and waste treatment can add costs.
	Acetic acid	Economical Environmental Social	If not handled correctly, it will have a negative impact on the environment as the acid has hazardous and corrosive properties. Also because of these properties it is dangerous and unhealthy for the people working with it when working in manufacturing. It must be disposed of correctly or destructive to the community.
Energy	Weighing Heating Boiling	Environmental Social Economical	Weighing correctly (precisely/accurately) might reduce waste and mistakes which assists in the reduction in pollution and cost. Pollution can occur because of the large amount of energy required for heating such like Boiling. The loss of water as it is being used a lot, amounts of waste water and the energy used impacts the local people badly.

### Question 3

Briefly define sustainability. [1]	Sustainability is the ability to maintain or support a process continuously over time or meet the demands of the present without being detrimental to the future.		
Briefly define system thinking. [1]	System thinking is a process of understanding the relationship of how different aspects and things influence each other as a whole and in a system.		
Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important.	<input checked="" type="checkbox"/> Source of raw materials	<input checked="" type="checkbox"/> Solvents	
	<input checked="" type="checkbox"/> Energy used	<input checked="" type="checkbox"/> Catalysts	
	<input checked="" type="checkbox"/> Amounts of reactants used	<input checked="" type="checkbox"/> Amounts products formed	
	<input checked="" type="checkbox"/> Waste management	<input checked="" type="checkbox"/> Byproducts	

### Question 4

What kind of engineer will you be? Civil Engineer. As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]

I can develop or plan a sustainable procedure for the building in which drug synthesis is taking place. For example including the value of environmentally friendly materials in the building.

### Question 5

Do you give consent for your submission to be used for research purposes? Yes or No.

<input checked="" type="radio"/> Yes	<input type="radio"/> No
--------------------------------------	--------------------------

If your answer is **yes**, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is **No**.

The University of Pretoria Ethics Board has approved this research.

## Question 2

Refer to the procedure for the synthesis of **aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document**. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

**Use methanol in row 1 as an example.**

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials	Demand and supply	Job creation
Land pollution	Profits	Longevity of life
Air and water pollution	Prices of chemicals and drugs	Quality of life
Land degradation	Employment	Drug dependency and abuse
Global warming and climate change	Tax contribution	Human rights

**Table of inputs, outputs and energy used during aspirin synthesis.**

	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Environmental Social	* Salicylic acid is commonly used in skincare products due to its exfoliating and anti-inflammatory properties * Salicylic acid play role in plant growth and development.
	Acetic anhydride	* Environmental * Economic * Social	* Acetic anhydride is primarily used in the manufacturing of cellulose acetate. * Acetic anhydride is a key precursor chemical in the illegal production heroin
	Sulfuric acid	* Environmental * Economic * Social	* It is utilized in various industrial processes such as the production of fertilizers, dyes, detergents and more. * Sulfuric acid is a critical component in the production of lead-acid batteries commonly used in vehicles and uninterruptible

Outputs	Aspirin	<ul style="list-style-type: none"> <li>* Social</li> <li>* Economic</li> </ul>	<ul style="list-style-type: none"> <li>* Aspirin has a well-established role in cardiovascular health.</li> <li>* Aspirin has anti-inflammatory properties that can help reduce inflammation and swelling.</li> <li>* Aspirin is widely used as an analgesic to relieve pain.</li> </ul>
	Water	<ul style="list-style-type: none"> <li>* Environmental</li> <li>* Social</li> <li>* Economic</li> </ul>	<ul style="list-style-type: none"> <li>* Water is essential for drinking, hydration and maintaining bodily functions.</li> <li>* Water plays a critical role in supporting diverse ecosystems and biodiversity.</li> <li>* Used for generating electric through hydropower.</li> </ul>
	Acetic acid	<ul style="list-style-type: none"> <li>* Environmental</li> <li>* Economic</li> <li>* Social</li> </ul>	<ul style="list-style-type: none"> <li>* Serves as a building block for synthesis of various chemicals.</li> <li>* Is found in many cleaning and household products due to its antimicrobial and descaling properties.</li> <li>* Can be used for removing mineral deposits and limescale.</li> </ul>
Energy	Weighing Heating Boiling	<ul style="list-style-type: none"> <li>* Environmental</li> <li>* Social</li> <li>* Economic</li> </ul>	<ul style="list-style-type: none"> <li>* Fossil fuels is a major contributor to global climate change.</li> <li>* Renewable energy sources, such as solar, wind, hydro and geothermal have lower environmental impacts.</li> </ul>

**Question 3**

Briefly define sustainability. [1]	Sustainability refers to the practice of meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. It encompasses the responsible and balanced use of natural resources.		
Briefly define system thinking. [1]	System thinking emphasizes the interconnectedness and interdependence of elements within a system, and how they contribute to the system's overall behavior and outcomes. It involves examining the structure, patterns, and dynamics of the system to gain insights into its functioning and identify potential leverage points.		
Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important.	<input checked="" type="checkbox"/> Source of raw materials	<input type="checkbox"/> Solvents	
	<input type="checkbox"/> Energy used	<input type="checkbox"/> Catalysts	
	<input checked="" type="checkbox"/> Amounts of reactants used	<input type="checkbox"/> Amounts products formed	
	<input type="checkbox"/> Waste management	<input type="checkbox"/> Byproducts	

**Question 4**

What kind of engineer will you be? Electronic. As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]

\* As a future engineer I am going to make sure that I produce or make the electronic devices that are not harmful to the environment and the people.

**Question 5**

Do you give consent for your submission to be used for research purposes? Yes or No.

<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No
---	-----------------------------

If your answer is **yes**, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is **No**.

The University of Pretoria Ethics Board has approved this research.

**Question 2**

Refer to the procedure for the synthesis of **aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document**. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

**Use methanol in row 1 as an example.**

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials	Demand and supply	Job creation
Land pollution	Profits	Longevity of life
Air and water pollution	Prices of chemicals and drugs	Quality of life
Land degradation	Employment	Drug dependency and abuse
Global warming and climate change	Tax contribution	Human rights

Table of inputs, outputs and energy used during aspirin synthesis.			
	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	- Environmental - Social - economic	- Salicylic acid plays an important role in plants diseases resistance. - salicylic acid is use in medication to treat acne, improving quality of life.
	Acetic anhydride	- Environmental - Social - economic	- If in water it can form acetic acid, which is harmful to aquatic life. - Acetic anhydride is the 2971st most trade product.
	Sulfuric acid	- Environmental - Social - economic	- Sulfuric acid is corrosive, burning any plant or animal that it is in contact with. - There a projected shortage of sulfuric acid, which would

rise the price of sulfuric acid

6

Outputs	Aspirin	<ul style="list-style-type: none"> <li>- social</li> <li>- economic</li> </ul>	<ul style="list-style-type: none"> <li>- Aspirin improves people's quality of life ✓</li> <li>- Aspirin sales generate huge number of profits ✓</li> </ul>
	Water	<ul style="list-style-type: none"> <li>- social</li> <li>- environmental</li> </ul>	<ul style="list-style-type: none"> <li>- people need water to live, improves longevity of life ✗</li> <li>- plants and animals need water to live</li> </ul>
	Acetic acid	<ul style="list-style-type: none"> <li>- Environmental</li> <li>- economic</li> <li>- social</li> </ul>	<ul style="list-style-type: none"> <li>- Acetic acid in high concentrations are harmful to plants, animals and aquatic life ✓</li> <li>- Acetic acid creates job opportunities ✓</li> </ul>
Energy	Weighing Heating Boiling	<ul style="list-style-type: none"> <li>- Environmental</li> <li>- economic</li> <li>- social</li> </ul>	<ul style="list-style-type: none"> <li>- The process of generating energy causes air pollution ✓</li> <li>- The process of generating energy creates job opportunities ✓</li> </ul>

6

**Question 3**

Briefly define sustainability. [1]	The ability to maintain or support a process continuously over time ✗			
Briefly define system thinking. [1]	The ability to <del>recognis</del> recognize the components that make up a system ✓			
Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important.	✓	Source of raw materials	✓	Solvents
	✓	Energy used	✓	Catalysts
		Amounts of reactants used	✓	Amounts products formed
	✓	Waste management	✓	Byproducts

**Question 4**

What kind of engineer will you be? civil engineer. As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]

I can ~~desing~~ design a new way of transporting the raw materials in a way that is less harmful to the environment ✓✓

4

**Question 5**

Do you give consent for your submission to be used for research purposes? Yes or No.

Yes  No

If your answer is **yes**, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is **No**.

The University of Pretoria Ethics Board has approved this research.

25

30

## CHM 171

## Practical 5: Pre-practical Exercise

Surname	JONES	Initials	ST
Student number	2 3 8 6 9 8 4 5	Signature:	Shane
Name of your tutor:	Brian Mhaleni	Date:	19/05/2023

**Question 1**

Calculate the % atom economy and the % carbon efficiency green chemistry metrics in the table below for the three salicylic acid synthetic routes.

The three routes are found on page 1 of the Aspirin Manufacture document:

Refer to the Green Chemistry metrics on page 5-6. The molar masses of the compounds are presented in Table 4 page 7 of the Aspirin Manufacture document.

	Route 1: Salicylic acid from phenol	Route 2 Salicylic acid from salicin	Route 3 Salicylic acid from oil of wintergreen
% Atom economy	$\frac{138}{94 + 40 + 16 + 44 + 98} \times 100 = 50\%$	$\frac{138}{286 + 18 + 32} \times 100 = 41.1\%$	$\frac{138}{150 + 40 + 98} \times 100 = 47.9\%$
% Carbon efficiency	$\frac{7}{6 + 17} \times 100 = 100\%$	$\frac{7}{13} \times 100 = 53.8\%$	$\frac{7}{8} = 87.5\%$
Why are we unable to calculate reaction mass efficiency for the above reactions from the given reaction equations?		We do not have the masses	
Of the three metrics (% atom economy, % carbon efficiency or % mass efficiency) which metric do you consider the most important in deciding the route to take?		% mass efficiency is, in my opinion, the most important as it relates back to cost and usage.	
Refer to the calculated % atom economy for all three routes, which route of making salicylic acid do you consider the least green? Briefly explain your choice.		Route 2 is least green since it has the lowest % Atom economy of the 3 routes.	

## Question 2

Refer to the procedure for the synthesis of **aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document**. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

**Use methanol in row 1 as an example.**

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials Land pollution Air and water pollution Land degradation Global warming and climate change	Demand and supply Profits Prices of chemicals and drugs Employment Tax contribution	Job creation Longevity of life Quality of life Drug dependency and abuse Human rights

Table of inputs, outputs and energy used during aspirin synthesis.			
	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Environmental impact	Salicylic acid can be produced from crude oil leading to an unsustainable use of crude oil.
	Acetic anhydride	Environmental impact	Acetic anhydride is produced from natural gas leading to the burning of fuels contributing to global warming.
	Sulfuric acid	Environmental impact	But when sulfuric acid is made, gases that can be released leading to acid rain.

Outputs	Aspirin	Social impact	<p><del>Aspirin</del> Aspirin can cause long lasting side effects, such as: loss of hearing, Bloody vomit, fast heart beat (which could cause an unwanted shock from a pacemaker). These all effect quality of life.</p> <p>✓</p>
	Water	<del>fact</del> Economic impact	<p>Any water produced could be cleaned and bottled to be given away or sold leading to another profit avenue or potentially a greater media presence.</p> <p>✓</p>
	Acetic acid	Environmental impact	<p>Acetic acid is harmful to Aquatic life, if not disposed of correctly it could cause water or land pollution.</p> <p>✓</p>
Energy	Weighing Heating Boiling	Environmental impact	<p>The energy used could cause <del>the global</del> warming or climate change if it is not taken from a renewable and/or sustainable source.</p>

### Question 3

Briefly define sustainability. [1]	Sustainability is the act of reducing negative environmental, <del>impacts</del> social and economic impacts. While maximising positive impacts.			
Briefly define system thinking. [1]	System thinking is a way of handling a problem by looking at <del>how</del> its relationships with other aspects of <del>the</del> scenario.			
Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important.	<input checked="" type="checkbox"/>	Source of raw materials	<input checked="" type="checkbox"/>	Solvents
	<input checked="" type="checkbox"/>	Energy used	<input checked="" type="checkbox"/>	Catalysts
	<input checked="" type="checkbox"/>	Amounts of reactants used	<input checked="" type="checkbox"/>	Amounts products formed
	<input checked="" type="checkbox"/>	Waste management	<input checked="" type="checkbox"/>	Byproducts

### Question 4

What kind of engineer will you be? Civil engineer. As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]

With regards to the drug synthesis, I ~~not~~ would only be able to stop leaks and <sup>large</sup> scale spills of the reactants by making the transport as safe and efficient as possible.

### Question 5

Do you give consent for your submission to be used for research purposes? Yes or No.

<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No
---	-----------------------------

If your answer is **yes**, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is **No**.

The University of Pretoria Ethics Board has approved this research.

**Question 2**

Refer to the procedure for the synthesis of **aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document**. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

Use **methanol in row 1 as an example**.

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials	Demand and supply	Job creation
Land pollution	Profits	Longevity of life
Air and water pollution	Prices of chemicals and drugs	Quality of life
Land degradation	Employment	Drug dependency and abuse
Global warming and climate change	Tax contribution	Human rights

**Table of inputs, outputs and energy used during aspirin synthesis.**

	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Environmental Social Economic	<ul style="list-style-type: none"> <li>Extraction of salicylic acid from natural sources can result in habitats being destroyed.</li> <li>Disposal of salicylic acid can cause damage to the soil and ground water.</li> </ul>
	Acetic anhydride	Environmental Social Economic	<ul style="list-style-type: none"> <li>Production may cause pollution and greenhouse gases to be produced, which will add to climate change.</li> <li>Acetic anhydride is a reactant used in the production of heroin.</li> </ul>
	Sulfuric acid	Environmental Social Economic	<ul style="list-style-type: none"> <li>Sulfuric acid is highly corrosive and may cause severe damage to environment, water bodies and living organisms.</li> <li>Exposure to sulfuric acid can cause respiratory issues to the exposed person.</li> </ul>

Outputs	Aspirin	Environmental Social Economic	<ul style="list-style-type: none"> <li>The byproducts produced in the production of aspirin <del>and</del> can be harmful to the environment, and can cause pollution of soil and groundwater when disposed of.</li> <li>Aspirin generate high revenue for the medical industry.</li> </ul>
	Water	Environmental	<ul style="list-style-type: none"> <li>The water from this process may contain impurities such as salicylic acid, acetic acid and other chemicals. These impurities can be harmful to the environment.</li> <li>Manufacturers may lose profits as they may have to purify it.</li> </ul>
	Acetic acid	Environmental Social Economic	<ul style="list-style-type: none"> <li>The production of this product releases harmful greenhouse gases, which can impose the air.</li> </ul>
Energy	Weighing Heating Boiling	Environmental Social Economic	<ul style="list-style-type: none"> <li>The large amount of energy required for weighing, heating, and boiling causes greenhouse gases to be produced in order to produce the energy.</li> </ul>

**Question 3**

Briefly define sustainability. [1]	It is the ability to balance the needs of the current generation, while planning for the future in order to <del>not</del> compromise the future generations.	
Briefly define system thinking. [1]	It is a thought process used when understanding complex systems by focusing on the relationships between all the components of a system, rather than focusing on each individual part as its own component.	
Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important.	<input checked="" type="checkbox"/> Source of raw materials	<input checked="" type="checkbox"/> Solvents
	<input checked="" type="checkbox"/> Energy used	<input checked="" type="checkbox"/> Catalysts
	<input type="checkbox"/> Amounts of reactants used	<input type="checkbox"/> Amounts products formed
	<input checked="" type="checkbox"/> Waste management	<input checked="" type="checkbox"/> Byproducts

**Question 4**

What kind of engineer will you be? Chemical ~~X~~. As this engineer, what could you contribute to make a drug synthesis route more sustainable? ① [2]

I could develop processes which utilize less toxic substances to reduce the waste produced.

**Question 5**

Do you give consent for your submission to be used for research purposes? Yes or No.

<input checked="" type="radio"/> Yes	<input type="radio"/> No
--------------------------------------	--------------------------

If your answer is **yes**, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is **No**.

The University of Pretoria Ethics Board has approved this research.

## Question 2

Refer to the procedure for the synthesis of aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

Use methanol in row 1 as an example.

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials Land pollution Air and water pollution Land degradation Global warming and climate change	Demand and supply Profits Prices of chemicals and drugs Employment Tax contribution	Job creation Longevity of life Quality of life Drug dependency and abuse Human rights

Table of inputs, outputs and energy used during aspirin synthesis.			
	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Environmental Social Economic	Land degradation, air and water pollution. Longevity of life and quality affected, drug dependency can be a social issue. Prices of chemicals and drugs and can tribute to employment.
	Acetic anhydride	Environmental Social Economic	Lead to pollution and the release of greenhouse gases. Employment opportunities for individuals involved in the production and distribution of the chemical. Drive up prices, impact the profitability of aspirin manufacturers.
	Sulfuric acid	Environmental Social Economic	Can cause acid rain and soil acidification, lead to pollution. Job creation, Exposure can cause health problems. Prices can go up for sulfuric acid and cost of final product for consumers.

Outputs	Aspirin	Environmental Social Economic	<p>Improper disposal of aspirin causes water pollution and harm to aquatic life. ✓</p> <p>Misuse can cause health problems such as gastrointestinal bleeding. ✓</p> <p>Cost of producing can affect the profitability of pharmaceutical companies.</p>
	Water	Environmental Social Economic	<p>Wastewater can cause pollution if not properly treated. ✓</p> <p>Access to clean water can be affected if it contaminates local water sources. ✓</p> <p>Cost treating and disposing of wastewater can affect prices of chemicals.</p>
	Acetic acid	Environmental Social Economic	<p>Improper disposal of acetic acid can cause water and land pollution. ✓</p> <p>Exposure to the acid in the workplace can cause health problems and affect longevity of life. ✓</p> <p>Cost of producing can affect profitability of chemical companies with demand and supply.</p>
Energy	Weighing Heating Boiling	Environmental Social Economic	<p>Waste generation. Produces greenhouse gas emissions ✓ contributes to climate change.</p> <p>Not properly ventilated can cause health risks such as longevity of life. ✓</p> <p>Cost of energy and equipment used rises for <del>exp</del> profits.</p>

8

### Question 3

Briefly define sustainability. [1]	Involves designing chemical processes and products that minimize negative impacts on the environment and promote social, environmental and economic well being. ✓																
Briefly define system thinking. [1]	Involves considering chemical processes and products as part of larger systems, rather than isolated entities. Analyzing relationships between various components. ✓																
Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important. ✓	<table border="1"><tr><td>✓</td><td>Source of raw materials</td><td>✓</td><td>Solvents</td></tr><tr><td>✓</td><td>Energy used</td><td>✓</td><td>Catalysts</td></tr><tr><td>✓</td><td>Amounts of reactants used</td><td>✓</td><td>Amounts products formed</td></tr><tr><td>✓</td><td>Waste management</td><td>✓</td><td>Byproducts</td></tr></table>	✓	Source of raw materials	✓	Solvents	✓	Energy used	✓	Catalysts	✓	Amounts of reactants used	✓	Amounts products formed	✓	Waste management	✓	Byproducts
✓	Source of raw materials	✓	Solvents														
✓	Energy used	✓	Catalysts														
✓	Amounts of reactants used	✓	Amounts products formed														
✓	Waste management	✓	Byproducts														

### Question 4

What kind of engineer will you be? Bio-medical engineer. As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]

I would use alternative energy sources such as solar, wind or biomass to reduce carbon emissions with the drug synthesis. ✓✓

### Question 5

Do you give consent for your submission to be used for research purposes? Yes or No.

<input checked="" type="radio"/> Yes	<input type="radio"/> No
--------------------------------------	--------------------------

If your answer is yes, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is No.

The University of Pretoria Ethics Board has approved this research.

## Question 2

Refer to the procedure for the synthesis of **aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document**. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

**Use methanol in row 1 as an example.**

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials Land pollution Air and water pollution Land degradation Global warming and climate change	Demand and supply Profits Prices of chemicals and drugs Employment Tax contribution	Job creation Longevity of life Quality of life Drug dependency and abuse Human rights

Table of inputs, outputs and energy used during aspirin synthesis.			
	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Environmental Social Economic	Salicylic acid is dangerous to life and can cause severe eye damage. it <del>is a product</del> has many steps to synthesis and results in waste.
	Acetic anhydride	Environmental Social Economic	the vapour can be fatal if inhaled it is quite dangerous. <del>it is a product</del> it is a product not an efficient process.
	Sulfuric acid	Environmental	if not disposed of properly environment can be harmed.

Outputs	Aspirin	Environmental Social Economic	<p>People have <del>now</del> got a generic medication to treat a wide range of mild <del>other</del> symptoms ✓          There will be more pharma waste in the form of the medicine and packaging ✓          There will be people that abuse the medication.</p>
	Water	Environmental Social Economic	<p>This water can be used in other processes. This <del>saves</del> <del>provides</del> <del>and</del> <del>thus</del> <del>provides</del> <del>and</del> <del>thus</del> <del>provides</del> <del>and</del> <del>thus</del> ✓          a small amount of money in the drug synthesis process ✓ and allows for more money to be given to wages and equipment</p>
	Acetic acid	Environmental Social Economic	<p>Acetic acid is harmful to aquatic life potentially leading to their death ✓</p>
Energy	Weighing Heating Boiling	Environmental Economic	<p>Heating and boiling use quite a bit of energy - it can <del>lead</del> <del>to</del> <del>air</del> <del>pollution</del> <del>due</del> <del>to</del> non-green energy production lead to air pollution ✓          Energy costs money and it will be lost to heat and boil.</p>

(7)

**Question 3**

Briefly define sustainability. [1]	The use of raw/natural resources in a way that reduces depletion of those resources to maintain healthy environments and so that we don't run out of that resource ✓		
Briefly define system thinking. [1]	System thinking helps us make sense of the world and <del>reduces</del> helps us make sense of its complexity. This is done by looking at it in wholes and relationships instead of parts ✓		
Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important.	✓ ✓ ✓ ✓	Source of raw materials Energy used Amounts of reactants used Waste management	Solvents Catalysts Amounts products formed Byproducts

**Question 4**

What kind of engineer will you be? Electronics. As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]

As ~~an~~ electronics engineer I will be able to design systems of sensors to determine where the most losses are taking place in the synthesis route, so that more efficient <sup>methods</sup> can be found ✓✓

5

**Question 5**

Do you give consent for your submission to be used for research purposes? Yes or No.

Yes  No

If your answer is **yes**, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is **No**.

The University of Pretoria Ethics Board has approved this research.

## Question 2

Refer to the procedure for the synthesis of aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

Use methanol in row 1 as an example.

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials Land pollution Air and water pollution Land degradation Global warming and climate change	Demand and supply Profits Prices of chemicals and drugs Employment Tax contribution	Job creation Longevity of life Quality of life Drug dependency and abuse Human rights

Table of inputs, outputs and energy used during aspirin synthesis.			
	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Environmental Social Economic	<ul style="list-style-type: none"> <li>Over extraction can lead to deforestation and depletion in plant populations.</li> <li>Improper disposal can harm aquatic ecosystems and marine life.</li> <li>Used in skin-care products and improves quality of life.</li> <li>High demand in skin-care products.</li> </ul>
	Acetic anhydride	Environmental Social Economic	<ul style="list-style-type: none"> <li>Improper disposal can lead to pollution and harm the environment.</li> <li>Contributes to production of medications that improve health and well-being.</li> <li>Contributes to the medication industry with medication in high demand.</li> </ul>
	Sulfuric acid	Environmental Economic	<ul style="list-style-type: none"> <li>Improper disposal can pollute water and be toxic to aquatic life.</li> <li>Can also pollute land disrupt ecosystems of other organisms.</li> <li>Sulfuric acid is also used alot in the agricultural industry for crops and supports agricultural production.</li> </ul>

Outputs	Aspirin	Environmental Social	<ul style="list-style-type: none"> <li>Manufacturing process can be harmful to environment and cause pollution.</li> <li>Used as medication to <del>relieve</del> relieve pain and improve quality of life.</li> </ul>
	Water	Environmental Social	<ul style="list-style-type: none"> <li>If not treated correctly it can get contaminated with toxic chemicals.</li> <li>It is good for your <del>health</del> health and hydration, thus improves quality of life.</li> </ul>
	Acetic acid	Environmental Social Economic	<ul style="list-style-type: none"> <li>Improper disposal can cause water pollution and disrupt <del>aquatic</del> aquatic eco-systems.</li> <li>Can also be toxic to marine-life.</li> <li>Production of acetic acid can <del>create</del> create job opportunities in the <del>industry</del> medical and chemical industries.</li> <li>Acetic acid <del>severs</del> serves as a raw material in various products, thus is in high demand.</li> </ul>
Energy	Weighing Heating Boiling	Environmental Social Economic	<ul style="list-style-type: none"> <li>Greenhouse gas <del>emissions</del> emissions occur and can lead to <del>climate</del> climate change.</li> <li>Inadequate <del>ventilation</del> ventilation can lead to health risks such as longevity of life.</li> </ul>

**Question 3**

Briefly define sustainability. [1]	Sustainability is a practice to fulfil the need of the current generations in such way that it does not compromise the needs of future generations.			
Briefly define system thinking. [1]	Is a way of thinking where you think about all factors and relationships within a system to gain better understanding of it.			
Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important.	✓	Source of raw materials	✓	Solvents
	✓	Energy used	✓	Catalysts
	✓	Amounts of reactants used	✓	Amounts products formed
	✓	Waste management	✓	Byproducts

**Question 4**

What kind of engineer will you be? Electronics X . As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]

Make the process more energy efficient and implement energy-saving measures. Automate the process to minimize error and monitor the process to reduce resource wastage.

**Question 5**

Do you give consent for your submission to be used for research purposes? Yes or No.

Yes ✓	No
-------	----

If your answer is **yes**, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received. You will not be penalized or be disadvantaged in anyway if your answer is **No**. The University of Pretoria Ethics Board has approved this research.

17,5  
30

**CHM 171**

**Practical 5: Pre-practical Exercise**

<b>Surname</b>	Buthelezi	<b>Initials</b>	T.
<b>Student number</b>	2 3 5 9 1 5 5 3	<b>Signature:</b>	T. Buthelezi
<b>Name of your tutor:</b>	Eric	<b>Date:</b>	09 May 2023

**Question 1**

Calculate the % atom economy and the % carbon efficiency green chemistry metrics in the table below for the three salicylic acid synthetic routes.

**The three routes are found on page 1 of the Aspirin Manufacture document:**

**Refer to the Green Chemistry metrics on page 5-6. The molar masses of the compounds are presented in Table 4 page 7 of the Aspirin Manufacture document.**

	Route 1: Salicylic acid from phenol	Route 2 Salicylic acid from salicin	Route 3 Salicylic acid from oil of wintergreen
% Atom economy	$\frac{138g}{258.1839g} \times 100$ $= 53.45\%$ X	$\frac{138g}{156.1378g} \times 100$ $= 88.4\%$ X	$\frac{138g}{280.1658g} \times 100$ $= 49.3\%$ X
% Carbon efficiency	$= \frac{7}{7} \times 100$ $= 100\%$	$\frac{7}{7} \times 100$ $= 100\%$ X	$\frac{7}{7} \times 100$ $= 100\%$ X
Why are we unable to calculate reaction mass efficiency for the above reactions from the given reaction equations?	Because we don't have the actual mass of the desired product and total mass of the reactants for all the three reactions.		
Of the three metrics (% atom economy, % carbon efficiency or % mass efficiency) which metric do you consider the most important in deciding the route to take?	Percentage atom economy. X		
Refer to the calculated % atom economy for all three routes, which route of making salicylic acid do you consider the least green? Briefly explain your choice.	Route 3. X there was waste there is, the lower the atomic economy there is, more materials are wasted, more energy is used so making the process less economic greener		

**Question 2**

Refer to the procedure for the synthesis of aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

Use methanol in row 1 as an example.

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials	Demand and supply	Job creation
Land pollution	Profits	Longevity of life
Air and water pollution	Prices of chemicals and drugs	Quality of life
Land degradation	Employment	Drug dependency and abuse
Global warming and climate change	Tax contribution	Human rights

Table of inputs, outputs and energy used during aspirin synthesis.			
	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Environmental	It may affect plant growth negatively.
		Social	Reduces acne by exfoliating the skin and keeping pores clear.
		Economic	Is used as food preservative, a bactericide and an antiseptic.
	Acetic anhydride	Environmental	Contact can severely irritate and burn the skin and eyes.
		Social	used to make fibers, plastic, pharmaceuticals, dyes and explosives.
		Economic	Creates employment
	Sulfuric acid	Environmental	Sulfuric acid is very corrosive and would burn any plants, birds or land animals exposed to it.
		Social	It is used to produce phosphate fertilizers.
		Economic	lowers pH which reduces the availability of soil nutrients to plants.

Outputs	Aspirin	Environmental	• It can prevent air pollution harms.	
		Social	• Can be part of a treatment plan for people who recently had stroke.	(2)
		Economic	• Reduces cancer incidence and mortality.	
	Water	Environmental	• Lower water levels can contribute to higher concentrations of human pollutants	
		Social	• Shortage of water can lead to poverty.	(2)
		Economic	• Diminishing water supplies translates into slower growth.	
	Acetic acid	Environmental	• High concentration of acid can be harmful to plants, animals and aquatic life.	
		Social	• It can cause health issues.	(2)
		Economic	• Used for manufacture of inks and dyes and it is also used in making perfumes.	
Energy	Weighing Heating Boiling	Environmental	May emit gases which may pollute atmosphere.	(2)
		Social	Heat waves may have discernible impacts on society including rise in mortality.	
		Economic	Increase in temperature will lead to increase in agriculture productivity.	

### Question 3

Briefly define sustainability. [1] 0/5	Ability to be maintained at a certain rate.								
Briefly define system thinking. [1]	A way of making sense of the complexity of the world by looking at it in terms of wholes and relationships rather than by splitting it down into its parts.								
Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important.	<table border="1"><tr><td>Source of raw materials</td><td>Solvents</td></tr><tr><td>Energy used</td><td>✓ Catalysts</td></tr><tr><td>Amounts of reactants used</td><td>Amounts products formed</td></tr><tr><td>Waste management</td><td>Byproducts</td></tr></table>	Source of raw materials	Solvents	Energy used	✓ Catalysts	Amounts of reactants used	Amounts products formed	Waste management	Byproducts
Source of raw materials	Solvents								
Energy used	✓ Catalysts								
Amounts of reactants used	Amounts products formed								
Waste management	Byproducts								

### Question 4

What kind of engineer will you be? \_\_\_\_\_ . As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]


### Question 5

Do you give consent for your submission to be used for research purposes? Yes or No.

Yes ✓	No
-------	----

If your answer is **yes**, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is **No**.

The University of Pretoria Ethics Board has approved this research.

## Question 2

Refer to the procedure for the synthesis of **aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document**. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

Use **methanol in row 1 as an example**.

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials Land pollution Air and water pollution Land degradation Global warming and climate change	Demand and supply Profits Prices of chemicals and drugs Employment Tax contribution	Job creation Longevity of life Quality of life Drug dependency and abuse Human rights

Table of inputs, outputs and energy used during aspirin synthesis.			
	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Environmental	Release into the environment can promote growth of algae as well as affect photosynthesis of plants. <i>is-rely or +rely?</i> (1)
	Acetic anhydride	Environmental Social	• Can be harmful to plants, animals, and aquatic life in large amounts. (e) • Can cause skin irritations and burns as well as eye damage.
	Sulfuric acid	Social Environmental Economy	• May cause severe burns and eye damage (2) • Short-term harm to aquatic life and can burn plants and animals exposed to it. • Can reduce fertility of farm land.

Outputs	Aspirin	<ul style="list-style-type: none"> <li>Social</li> <li>Economic</li> <li>Environmental</li> </ul>	<ul style="list-style-type: none"> <li>Increasing immunity to drugs, as well as health risks and potential addiction/dependency</li> <li>Can increase employment.</li> <li>Can help protect lungs from spikes in air pollution.</li> </ul>	①
	Water	<ul style="list-style-type: none"> <li>Environmental</li> <li>Social</li> <li>Economical</li> </ul>	<ul style="list-style-type: none"> <li>Wastage can cause harm to environment in water-scarce areas</li> <li><del>Can be</del> wastage can be detrimental in water-scarce areas as there will be less water for the people to <del>drink</del> drink.</li> <li>Wastage can increase price as it is limited.</li> </ul>	②
	Acetic acid	<ul style="list-style-type: none"> <li>Economy</li> <li>Environment</li> <li>Social</li> </ul>	<ul style="list-style-type: none"> <li>Production of acetic acid creates many jobs.</li> <li>Can be harmful to animals, plants, and aquatic life in large amounts/concentrations</li> <li>Can be harmful to breathe in. Can cause Irritation/damage to eyes.</li> </ul>	②
Energy	Weighing Heating Boiling	<ul style="list-style-type: none"> <li>Economy</li> <li>Environment</li> <li>Social</li> </ul>	<ul style="list-style-type: none"> <li>These steps can take a lot of power in large scale operations which will cost a lot.</li> <li>If <del>no</del> renewable energy sources are being used, it can cause pollution.</li> <li>Potential pollution caused may harm the people in the area.</li> </ul>	②

### Question 3

Briefly define sustainability. [1] ○	Sustainability is a goal of using materials and energy from renewable sources as not to impede future generations and keep the environment healthy. α	
Briefly define system thinking. [1] ○	System thinking is the analysis of a process concerning its effects on the environment, society and economy, in order to weigh the pros and cons and see if the system is in need of improvement.	
Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] ○ Do not tick if NOT important.	<input checked="" type="checkbox"/> Source of raw materials	<input checked="" type="checkbox"/> Solvents
	<input checked="" type="checkbox"/> Energy used	<input checked="" type="checkbox"/> Catalysts
	<input checked="" type="checkbox"/> Amounts of reactants used	<input checked="" type="checkbox"/> Amounts products formed
	<input checked="" type="checkbox"/> Waste management	<input checked="" type="checkbox"/> Byproducts

### Question 4

What kind of engineer will you be? Civil Engineer. . As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]

I could promote sustainable energy sources and use more sustainable materials with less impact on the environment.

### Question 5

Do you give consent for your submission to be used for research purposes? Yes or No.

Yes  No

If your answer is **yes**, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is **No**.

The University of Pretoria Ethics Board has approved this research.

**CHM 171**  
**Practical 5: Pre-practical Exercise**

<b>Surname</b>	Schmidt	<b>Initials</b>	MM
<b>Student number</b>	2 3 5 7 6 4 5 7	<b>Signature:</b>	
<b>Name of your tutor:</b> Chrizelda Visser		<b>Date:</b> 18/05/2023	

**Question 1**

Calculate the % atom economy and the % carbon efficiency green chemistry metrics in the table below for the three salicylic acid synthetic routes.

The three routes are found on page 1 of the Aspirin Manufacture document:

Refer to the Green Chemistry metrics on page 5-6. The molar masses of the compounds are presented in Table 4 page 7 of the Aspirin Manufacture document.

	Route 1: Salicylic acid from phenol	Route 2 Salicylic acid from salicin	Route 3 Salicylic acid from oil of wintergreen
% Atom economy	$\frac{138}{94+40+44+98} \times 100\%$ = 50% <span style="color: red; font-size: 2em;">X</span>	$\frac{138}{246+18+32} \times 100\%$ = 41.07% <span style="color: red; font-size: 2em;">X</span>	$\frac{138}{150+80+98} \times 100\%$ = 42.07% <span style="color: red; font-size: 2em;">X</span>
% Carbon efficiency	$\frac{7}{7} \times 100\%$ = 100% <span style="color: red; font-size: 2em;">✓</span>	$\frac{7}{13} \times 100\%$ = 53.85% <span style="color: red; font-size: 2em;">✓</span>	$\frac{7}{8} \times 100\%$ = 87.50% <span style="color: red; font-size: 2em;">✓</span>
Why are we unable to calculate reaction mass efficiency for the above reactions from the given reaction equations?	The mass of the desired product and all reactants aren't provided and it is needed to calculate reaction mass efficiency. <span style="color: red; font-size: 2em;">✓</span>		
Of the three metrics (% atom economy, % carbon efficiency or % mass efficiency) which metric do you consider the most important in deciding the route to take?	% Mass efficiency <span style="color: red; font-size: 2em;">✓</span>		
Refer to the calculated % atom economy for all three routes, which route of making salicylic acid do you consider the least green? Briefly explain your choice.	Route 2. Route 2 produces the least amount of the desired product meaning it produces the most waste out of all the routes, making it the least green. <span style="color: red; font-size: 2em;">✓✓</span>		

**Question 2**

Refer to the procedure for the synthesis of aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

Use methanol in row 1 as an example.

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials	Demand and supply	Job creation
Land pollution	Profits	Longevity of life
Air and water pollution	Prices of chemicals and drugs	Quality of life
Land degradation	Employment	Drug dependency and abuse
Global warming and climate change	Tax contribution	Human rights

**Table of inputs, outputs and energy used during aspirin synthesis.**

	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Environmental Social	Salicylic acid is found to encourage algae development, but during the drug synthesis it can produce waste and contribute to greenhouse gas emissions. Can improve people's quality of life through the products it can produce, like skincare products for certain skin conditions.
	Acetic anhydride	Environmental Economic Social	Acetic anhydride has the potential for air and water pollution and contributes to the formation of smog and acid rain. It is used in various industries and can contribute to job creation. It can be used to produce illegal drugs and contribute to drug addiction and crime.
	Sulfuric acid	Environmental Economic	• Sulfuric acid can burn plants and animals exposed to it and has moderate long-term toxic effects on aquatic life. • It's used in the production of phosphate fertilizers and is the largest volume industrial chemical.

<b>Outputs</b>	<b>Aspirin</b>	Social Economic Environmental	Quality of life improves because an easy and inexpensive method to alleviate pain is provided ✓ Aspirin sale generate substantial economic activity and contributes to the growth of the pharmaceutical industry. ✓ When disposed of incorrectly, it can lead to the contamination of water and can have adverse effects on aquatic organisms.
	<b>Water</b>	Social Environmental	Clean water can increase a persons quality of life All living organisms need water to live. ✓
	<b>Acetic acid</b>	Environmental	If disposed of incorrectly is can seep into the soil and contaminate the groundwater. When released into the air it can react with other compounds and contribute to smog and air pollution. ✓
<b>Energy</b>	<b>Weighing Heating Boiling</b>	Environmental Social	When heating or boiling particlaks are released into the air and contributes to air pollution ✓ Energy from gas or electricity is consumed and the production of the energy source can contribute to greenhouse gas emissions The increased air pollution lowers people's quality of life.

6

### Question 3

<p>Briefly define sustainability. [1]</p>	<p>sustainability is to maintain a process over time, <sup>so</sup> that the current generations' needs are fulfilled in such a way that the needs of future generations aren't in danger of not being fulfilled. ✓</p>		
<p>Briefly define system thinking. [1]</p>	<p>System thinking is a way of understanding problems by looking at the "bigger picture", and focusing on how different parts of the system interact and affect each other. ✓</p>		
<p>Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important.</p>		<p>Source of raw materials</p>	<p>Solvents</p>
	✓	<p>Energy used ✓</p>	<p>Catalysts</p>
		<p>Amounts of reactants used</p>	<p>Amounts products formed ✓</p>
	✓	<p>Waste management</p>	<p>Byproducts ✓</p>

### Question 4

What kind of engineer will you be? Civil ✓ . As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]

I can help optimize the infrastructure used when the waste produced during the drug synthesis route is disposed of. ✓

### Question 5

Do you give consent for your submission to be used for research purposes? Yes or No.

Yes  No

If your answer is yes, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is No.

The University of Pretoria Ethics Board has approved this research.

4

**Question 2**

Refer to the procedure for the synthesis of **aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document**. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

Use **methanol in row 1 as an example**.

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials Land pollution Air and water pollution Land degradation Global warming and climate change	Demand and supply Profits Prices of chemicals and drugs Employment Tax contribution	Job creation Longevity of life Quality of life Drug dependency and abuse Human rights

**Table of inputs, outputs and energy used during aspirin synthesis.**

	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid (SA)	Environmental Social Economic	<ul style="list-style-type: none"> <li>• Low concentrations of Salicylic acid may be used to enhance photosynthesis growth in plants, however higher concentrations may cause plants stress.</li> <li>• SA found in <del>coners</del> <del>makeup</del> &amp; <del>masks</del>.</li> <li>• High demand for facial creams containing SA</li> </ul>
	Acetic anhydride	Social Economic	<ul style="list-style-type: none"> <li>• contact with skin, eyes or nose may cause irritation.</li> <li>• High demand for acetic anhydride as it is used in the food industry for food additives &amp; preservatives</li> <li>• (no environmental harm)</li> </ul>
	Sulfuric acid	Environmental Social Economic	<ul style="list-style-type: none"> <li>• Highly corrosive substance that will burn any plant, bird or animal it makes contact with</li> <li>• contact with humans may cause eye, nose, lung irritation and fluid build-up.</li> <li>• Economic impact on agriculture as it reduces the availability of nutrients in soil.</li> </ul>

Outputs	Aspirin	Social Economic	<ul style="list-style-type: none"> <li>• used as medication by humans to reduce and relieve pain, fevers, headaches, aches, arthritis.</li> <li>• Aspirin may help lower the risk of heart attacks and strokes in its patients.</li> <li>• High demand for aspirin for the prevention of cardiovascular diseases (CVD).</li> </ul>
	Water	Environmental Social Economy	<ul style="list-style-type: none"> <li>• water is a vital resource for all living creatures and sustains full ecosystems.</li> <li>• Over exploitation of water and/or pollution of water would lead to environmental degradation &amp; drought.</li> <li>• used for cleaning and leisurely activities.</li> <li>• bottled water companies contribute towards economy.</li> </ul>
	Acetic acid	Environmental Social	<ul style="list-style-type: none"> <li>• Acetic acid is generally not considered harmful towards the environment, however in high concentrations it may prove harmful towards plants, animals and aquatic life.</li> <li>• Inhaling high concentrations of Acetic acid may cause throat and chest irritation resulting in headaches, chest tightness and fevers.</li> <li>• Acetic acid is widely used in the food industry (preserved foods) as well as agriculture (herbicides).</li> </ul>
Energy	Weighing Heating Boiling	Environmental Economic	<ul style="list-style-type: none"> <li>• weighing is necessary to ensure the correct amount of a substance is reacted or produced. This prevents wastage and over exploitation of resources.</li> <li>• Heating &amp; boiling elevate air temp. potentially contributing toward global warming.</li> <li>• Electricity/ fuel input for heating is a cost.</li> </ul>

**Question 3**

<p>Briefly define sustainability. [1]</p>	<p>Sustainability in the simplest sense may be described as a process that may be continuously supported and maintained over a period of time. The sustainability of a process may be measured by its impact on the economy, society and environment, and their long-term prosperity.</p>			
<p>Briefly define system thinking. [1]</p>	<p>Systems thinking may be defined as a holistic approach to the interpretation, analysis and interrelations of systems and its data.</p>			
<p>Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important.</p>	✓	Source of raw materials		Solvents
	✓	Energy used		Catalysts
		Amounts of reactants used		Amounts products formed
	✓	Waste management	✓	Byproducts

**Question 4**

What kind of engineer will you be? Civil Engineer. As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]

As a civil engineer, I may survey the extraction sites of raw materials needed for the manufacturing of a drug and ensure that the environment is not negatively affected by the extraction process based off predictions & calculations.

**Question 5**

Do you give consent for your submission to be used for research purposes? Yes or No.

Yes	No
-----	----

If your answer is yes, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is No.

The University of Pretoria Ethics Board has approved this research.

## Question 2

Refer to the procedure for the synthesis of **aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document**. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

Use **methanol in row 1 as an example**.

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials	Demand and supply	Job creation
Land pollution	Profits	Longevity of life
Air and water pollution	Prices of chemicals and drugs	Quality of life
Land degradation	Employment	Drug dependency and abuse
Global warming and climate change	Tax contribution	Human rights

Table of inputs, outputs and energy used during aspirin synthesis.			
	List	Impact	Explain the impact
Example	Methanol	<b>Environmental</b> <b>Social</b> <b>Economic</b>	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Environmental	Enhances algae growth; yet high concentrations are toxic
		Social	Used in pharmaceutical products and make up/cosmetic industry
		Economic	Production & distribution create job opportunities & contribute to economy
	Acetic anhydride	Environmental	High concentrations are harmful to aquatic life. Skin & eye irritation
		Social	Employment opportunities in manufacturing, distribution & retail
		Economic	Used in pharmaceutical, textile & chemical industries; creates jobs & contributes to GDP
	Sulfuric acid	Environmental	Very corrosive; can cause acid rain, soil, water & air pollution
		Social	Employment opportunities in production & distribution; health risks
		Economic	Industrial production, storage & distribution generates wealth

Outputs	Aspirin	Environmental	<ul style="list-style-type: none"> <li>• water pollution, manufacturing waste, soil contamination, packaging waste, threatens aquatic life</li> </ul>	②
		Social	<ul style="list-style-type: none"> <li>• improves health if used correctly; accessible &amp; affordable; generates jobs</li> </ul>	
		Economic	<ul style="list-style-type: none"> <li>• Generates jobs → supply &amp; demand; production &amp; distribution increases economic growth</li> </ul>	
Outputs	Water	Environmental	<ul style="list-style-type: none"> <li>• Pure water is a necessity for life on earth; however contaminated water is dangerous and threatens life &amp; vegetation</li> </ul>	②
		Social	<ul style="list-style-type: none"> <li>• Necessary for human survival, hygiene, health, agriculture, sanitation</li> </ul>	
		Economic	<ul style="list-style-type: none"> <li>• Used in industry &amp; production</li> </ul>	
Outputs	Acetic acid	Environmental	<ul style="list-style-type: none"> <li>• Biodegradable if disposed correctly; if not can cause air &amp; water pollution, harm aquatic life &amp; release greenhouse emissions</li> </ul>	②
		Social	<ul style="list-style-type: none"> <li>• Creates job opportunities; health risk for workers as they can be exposed to harmful chemicals</li> </ul>	
		Economic	<ul style="list-style-type: none"> <li>• Generates wealth through international trade exports; production &amp; distribution processes create jobs</li> </ul>	
Energy	Weighing Heating Boiling	Environmental	<ul style="list-style-type: none"> <li>• Uses a lot of energy and water resources; generates air pollution and waste</li> </ul>	①
	Social	<ul style="list-style-type: none"> <li>• Poses health &amp; safety risks if not done correctly</li> </ul>		
	Economic	<ul style="list-style-type: none"> <li>• Production costs, market demand and job opportunities contribute to wealth generation for economy</li> </ul>		

**Question 3**

Briefly define sustainability. [1]	Sustainability is the balance between meeting the needs of the current generation in a way that the needs of future generations are not compromised.		
Briefly define system thinking. [1]	System thinking is a way of approaching issues or problems by investigating the factors, relationships and interactions between and within components of a system.		
Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important.	<input checked="" type="checkbox"/> Source of raw materials	<input checked="" type="checkbox"/> Solvents	
	<input checked="" type="checkbox"/> Energy used	<input checked="" type="checkbox"/> Catalysts	
	<input checked="" type="checkbox"/> Amounts of reactants used	<input checked="" type="checkbox"/> Amounts products formed	
	<input checked="" type="checkbox"/> Waste management	<input checked="" type="checkbox"/> Byproducts	

**Question 4**

What kind of engineer will you be? Civil. As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]

By developing ways to reduce waste, for example or purification systems, for example water purification systems to decrease contamination etc

**Question 5**

Do you give consent for your submission to be used for research purposes? Yes or No.

Yes  No

If your answer is **yes**, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is **No**.

The University of Pretoria Ethics Board has approved this research.

## Question 2

Refer to the procedure for the synthesis of **aspirin from salicylic acid and acetic anhydride in the laboratory on page 3 of the information document**. In the table below, three inputs and three outputs of aspirin synthesis are listed. The three processes that requires energy during the synthesis of aspirin are also listed.

Indicate the impact (environmental, social or economic) that each input, output and energy usage will have during aspirin synthesis. Briefly explain each impact.

Use **methanol** in row 1 as an example.

Refer to the table below as guidance:

ENVIRONMENTAL IMPACT	ECONOMIC IMPACT	SOCIAL IMPACT
Over extraction of raw materials Land pollution Air and water pollution Land degradation Global warming and climate change	Demand and supply Profits Prices of chemicals and drugs Employment Tax contribution	Job creation Longevity of life Quality of life Drug dependency and abuse Human rights

Table of inputs, outputs and energy used during aspirin synthesis.			
	List	Impact	Explain the impact
Example	Methanol	Environmental Social Economic	Methanol exposure may affect animals, birds and fish, leading to their death. Methanol can cause low growth rate in plants. Methanol can be an alternative to conventional transportation fuels because it is cheap to produce and has a lower risk of flammability compared to gasoline.
Inputs	Salicylic acid	Social Environmental Economic	<ul style="list-style-type: none"> <li>• Used as <sup>form of</sup> a dermatology on skin defects like warts and acne.</li> <li>• Harmful to <del>developing plants and</del> toxic to marine life by affecting reproduction</li> <li>• Used as an ingredient in many chemical <sup>compounds</sup></li> </ul>
	Acetic anhydride	Economic Environment Social	<ul style="list-style-type: none"> <li>• Key ingredient in the production of cellulose acetate</li> <li>• Causes water pollution by damaging the quality of marine ecosystems.</li> <li>• Acetic anhydride can be used to convert morphine into heroin.</li> </ul>
	Sulfuric acid	Social Economic Environmental	<ul style="list-style-type: none"> <li>• Can cause health hazards to individuals who are handling, producing and using it.</li> <li>• Used to produce fertilizer</li> <li>• Significantly lowers the pH of the soil when used as fertilizer</li> </ul>

Outputs	Aspirin	Environmental Social Economic	<ul style="list-style-type: none"> <li>• If its not properly disposed it will contribute to air &amp; water pollution.</li> <li>• <del>Pain killer</del> used as a pain killer for common ailments like muscle aches, headaches and minor pain</li> <li>• contributes to the income of the pharmaceutical market.</li> </ul>
	Water	Social <del>Environmental</del> Economic Environmental	<ul style="list-style-type: none"> <li>• Needed to survive as a human</li> <li>• Is need for the production of almost everything</li> <li>• Can cause habitat destruction if a flood or tsunami occurs</li> </ul>
	Acetic acid	Social Environmental Economic	<ul style="list-style-type: none"> <li>• used <del>as a</del> for cooking</li> <li>• can contribute to water pollution</li> <li>• High demand <del>exists</del> in the chemical industry as its used to produce many thing such as <del>ant</del> vinegar. This creates jobs.</li> </ul>
Energy	Weighing Heating Boiling	Economic Social	<ul style="list-style-type: none"> <li>• Used in the production of almost everything such as chemicals, processed food and materials...</li> <li>• We use it in everyday life, <del>as a</del></li> </ul>

**Question 3**

Briefly define sustainability. [1]	Sustainability is the ability to fulfill our needs as human beings while being able to ensure that the generations of humans that follow us will be able to meet their own needs.			
Briefly define system thinking. [1]	A tactic that views <del>the</del> problem solving for problems and phenomena as <sup>an</sup> interconnected <del>system</del> system through feedback loops, and consideration of relationships.			
Tick (✓) the factors that are important in the choice of the drug synthesis route. [1] Do not tick if NOT important.	✓ ✓ ✓ ✓	Source of raw materials Energy used Amounts of reactants used Waste management	✓ ✓ ✓ ✓	Solvents Catalysts Amounts products formed Byproducts

**Question 4**

What kind of engineer will you be? Civil . As this engineer, what could you contribute to make a drug synthesis route more sustainable? [2]

I would help with the factory design of the facility to make it more energy efficient.

**Question 5**

Do you give consent for your submission to be used for research purposes? Yes or No.

Yes	No
-----	----

If your answer is **yes**, your submissions will be used as data to evaluate how effective this teaching design is. Your anonymity will be protected and codes will be assigned to all documents received.

You will not be penalized or be disadvantaged in anyway if your answer is **No**.

The University of Pretoria Ethics Board has approved this research.