University Learning in Schools

Chemistry

The Engineer's Guide to Cleaning up an Oil Company's Mess: Final Project

Marks Available: 100

Part One: Theory of Chemical Process Design (50 Marks)

Part Two: Poster Presentation (50 Marks)

The Brilliant Club

Department for Education

SUPPORTED BY MAYOR OF LONDON

Part One: Problem Sheet

Questions from Lesson 1

1) Explain what a hydrocarbon is in your own words. Give two examples of hydrocarbons.

2) What is the difference between crude oil and other pure hydrocarbons?

3) How would you separate the hydrocarbons that are in crude oil? How does this separation mechanism work?

Questions from Lesson 2

1) Match the word from the left column with the correct statement from the right column.

Column A	Column B
Intermolecular Forces	In a fractional distillation column, petrol would exit the vessel at a higher point than diesel.
Because it has a lower density	It is a molecule that has only 1 carbon atom, and 4 hydrogen atoms.
Covalent bond	The reason as to why oil will float on water
Because it has a lower boiling point	The reason as to why longer chain carbons have a higher boiling point than
Methane	The bonds between the carbon and hydrogen atoms within a hydrocarbon.

2) Using your knowledge of intermolecular forces, can you predict which molecule in the pairs listed below will have the higher boiling point of the two?

a) CH_4 and C_3H_8

b) $C_{10}H_{22}$ and $C_{12}H_{26}$

c) H_2O and C_2H_6

3) How can we use the fact that oil and water have different densities to separate the two from each other?

Questions from Lesson 3

1) Why do we need to treat the wastewater from the fractional distillation process? Give two examples of problems that may occur if we do not treat this water.

2) List three ways in which we can treat the petroleum waste water. Give one advantage and one disadvantage in each of the processes.

3) Suppose we have a petroleum waste stream which contains 5987 mg/L of COD. Calculate the outlet COD concentration, and the COD removed by the following technologies:

a) A gravity separator with 20.4 % removal efficiency

b) An advanced oxidation unit which removes 90 % removal efficiency

c) A bioreactor with 70 % removal efficiency

d) A gravity separator with 60 % removal efficiency, followed by a bioreactor with 70 % removal efficiency

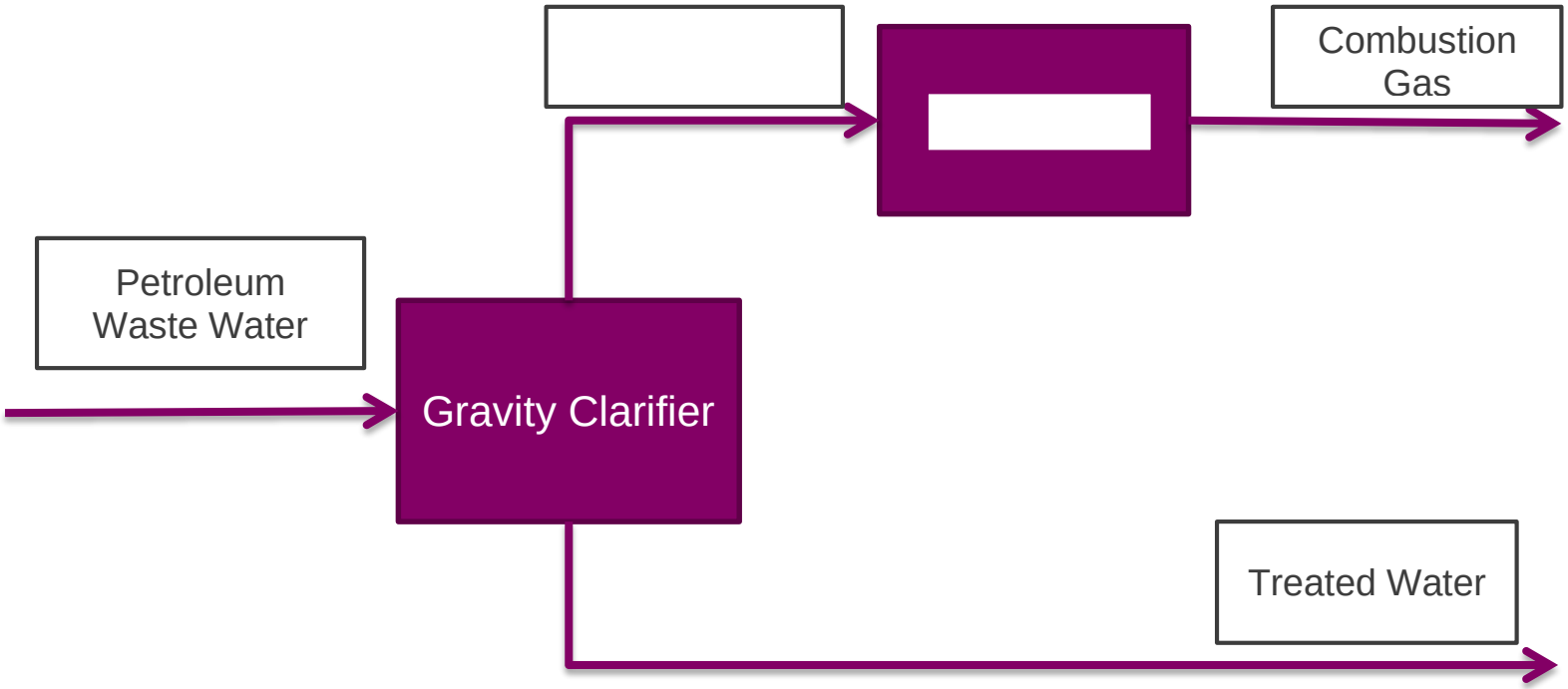
e) A gravity separator with 36 % removal efficiency, followed by the advanced oxidation unit with 94 % removal efficiency

f) Calculate the overall removal efficiency of process D and E.

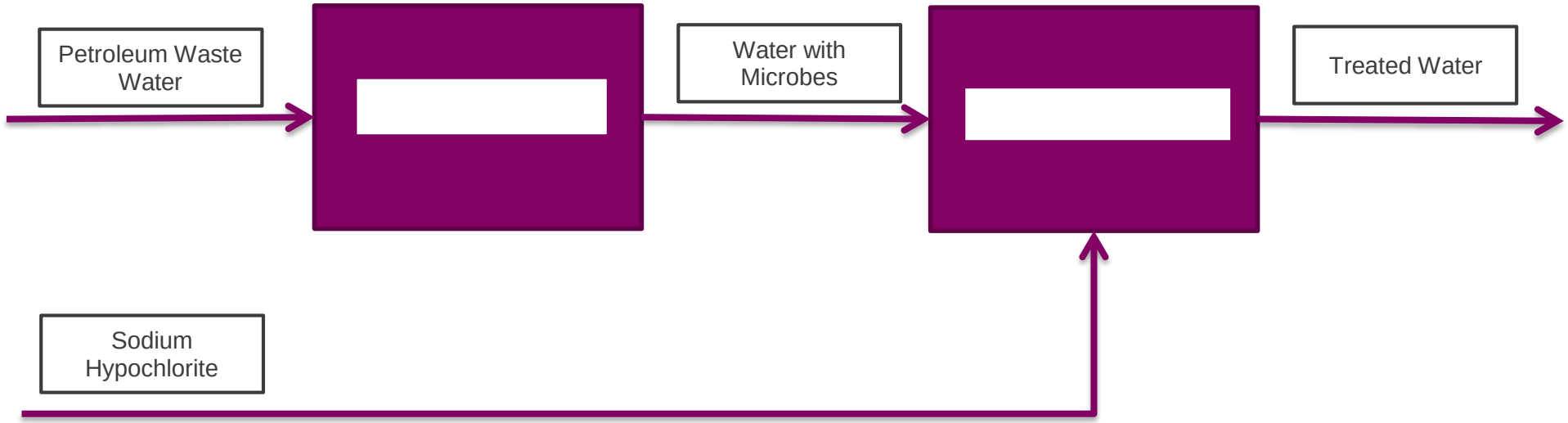
Questions from Lesson 4

Fill in the blanks for the following block flow diagrams:

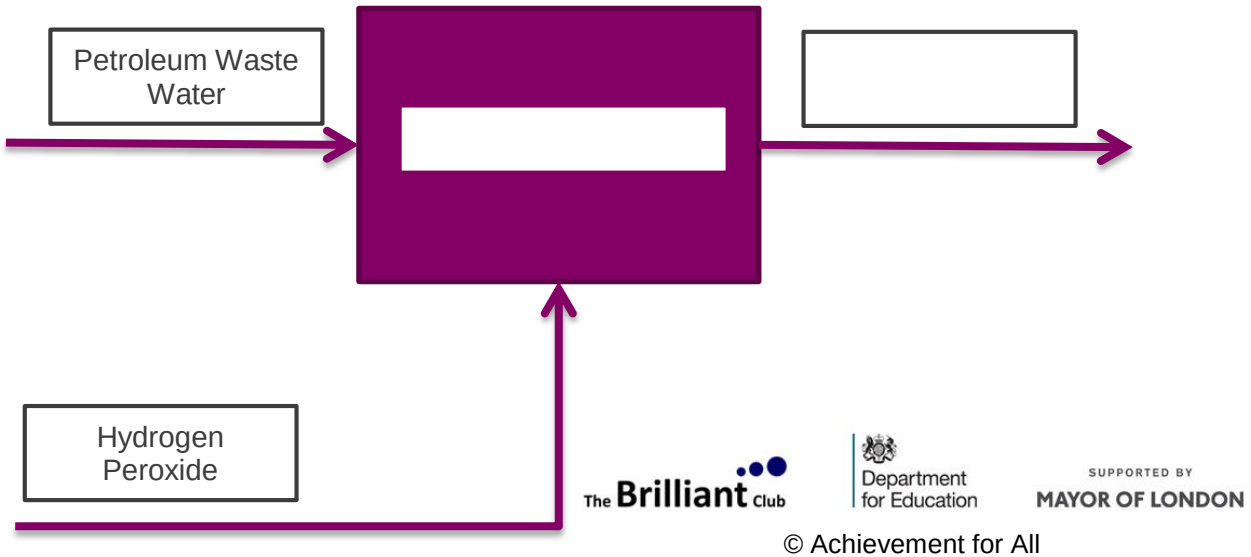
a)



b)



c)



Questions from Lesson 5

1) What is the difference between fixed costs and operational costs?

2) Give an example of a fixed cost and an operational cost for the physical process for treating petroleum waste water.

3) Suppose we are given a specification of treating 10 000 litres of waste over a year within a 100L bioreactor vessel.

- It is capable of removing 80 % of the COD within the waste
- The waste stream has a pollution level of 12 g/L COD.
- Our investors are willing to accept a cost of £8000 in the first year for the treatment facility to be built.
- The discharge limits require the streams leaving the process to have a COD of no more than 3.5 g/L.

a) Determine the amount of pollution removed in the reactor over the year (in grams COD)
b) Determine the cost of the bioreactor vessel if the following information is given to you.

Piece of Equipment	**Capital Cost**
AOP Reactor	£10 per litre
Bioreactor	£10 per litre
Gravity Clarifier	£30 per litre
UV Disinfection Vessel	£1000
Incinerator	£1500

c) Determine the operational costs if the following information is given to you. You would need to use the number of grams COD removed you calculated in 3a for this.

Operational Cost Name	**Cost**
Advanced oxidation (Using Hydrogen Peroxide)	£ 0.1 per g of COD removed
UV light for disinfection of microbes	£ 0.02 per g of COD removed
Physical process (Fuel for the incinerator)	£ 0.04 per g of COD removed

d) Determine the total cost of the process. Is this less than £8000?

Part Two- Poster Presentation

For part two of the assignment, you are required to pair up with 4 other pupils to come up with a feasible process for treating a stream of petroleum wastewater. You are required to choose a hybrid process (a combination of a physical, biological and chemical process) and then determine if the process is capable of reducing the pollution to below the discharge limits and the costs of the process in the first year. The details on how to go about doing this are provided on the next page.

Once you have determined the process, its ability to remove COD from the water, and its cost, you are then required to work with your team members to create a poster that can be used to convince your teacher as to why he/she should invest his/her money in your process other processes.

Each team will get 5 minutes to present their poster in front of the class.

For each team, you should have the following roles:

- A **process co-ordinator** and an **accountant** who will be working together to do the calculations in determining if the process treats the water to below the discharge specifications and its cost
- Two **graphical engineers** who will be responsible for coming up with the poster design (although everyone should contribute to the content)
- A spokesperson who will present the poster to the class (The entire team must participate in questions and answers.)

Poster Details

Your poster should contain the following:

- A team name
- A block flow diagram of your chosen process (drawn neatly in the way that was taught to you). You may start with the stream of petroleum wastewater.
- The fixed cost of the process (in £), the operational costs for the process (in £) and the total cost in the first year. You do not have to show your calculations, but you should display this information in a neat table outlining where all the costs come from.
- The overall removal efficiency of the process, as well as the concentration of the treated water in grams COD. Again, you do not have to show your calculations.
- Reasons as to why the teacher, or anyone for that matter, should invest in your process.
- Your poster should be neat and presentable so that everyone can follow what you are saying; but feel free to be creative!

Spokesperson Details

- During the 5-minute presentation, the spokesperson should describe their chosen process, the removal ability and the cost associated with it.
- They should also describe why it is important to treat petroleum wastewater, and why their process is better than others in treating it.

Treatment Process Details

You are provided with the following information:

- You are required to treat 20 000 litres of petroleum wastewater a year
- The wastewater has a COD of 20 g/L
- You have the option to choose one of the following treatment options:
    - A physical process followed by a biological process
    - A physical process followed by a chemical process
    - A biological process followed by a chemical process
    - A chemical process followed by a biological process

- **Table 1:** The COD removal efficiency of the units is listed below:

Gravity clarifier	50 %
Bioreactor	80 %
Advanced oxidation reactor	95 %

- **Table 2:** The size of the units in the processes are as follows:

Gravity clarifier	200 L
Bioreactor	150 L
Advanced oxidation reactor	80 L

- **Table 3:** The fixed costs for the units are as follows:

Gravity clarifier	£20 per litre
Bioreactor	£10 per litre
Advanced oxidation reactor	£10 per litre

- **Table 4:** The operational costs for the processes are as follows

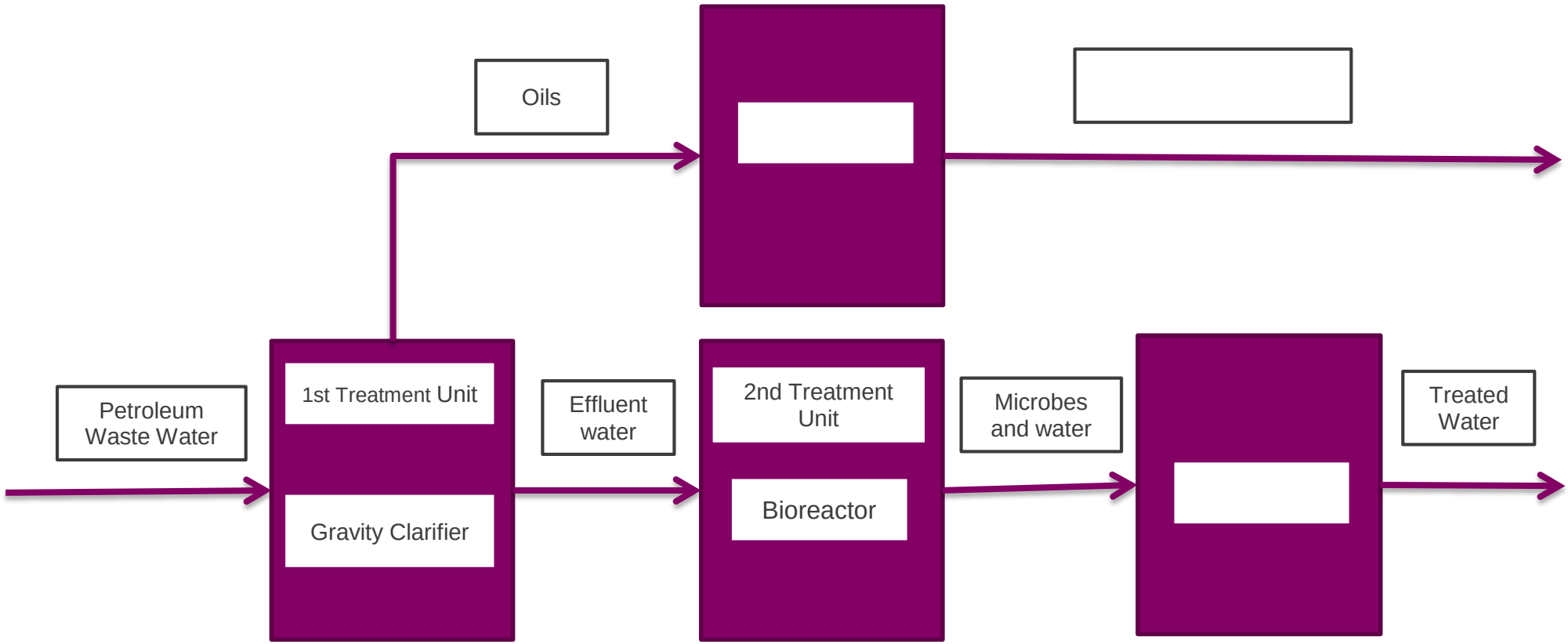
Incinerator fuel	£ 0.04 per g of COD removed by clarifier
UV Light for disinfection of microbes	£ 0.02 per g of COD removed by bioreactor
Use of hydrogen peroxide for advanced oxidation	£ 0.1 per g of COD removed by advanced oxidation reactor

- The treatment specification states that the final concentration of the waste water should be less than 2.5 g/L of COD.

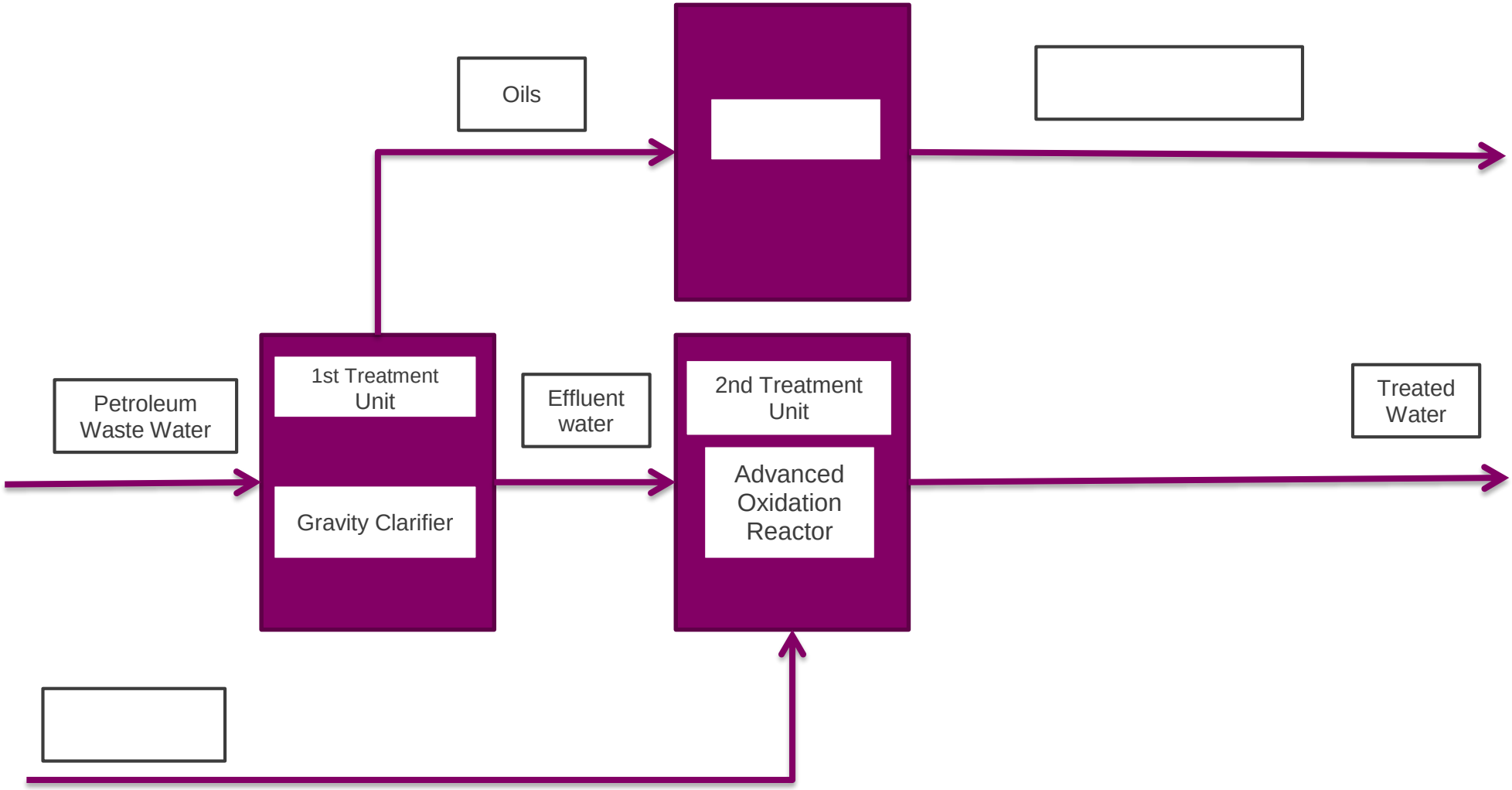
Tips for completing the project

- Discuss with your team as to which of the options you would like to pursue. Remember, you might not want to go for a very costly option!
- Choose the Block Flow Diagram Template on the next page given to you and fill in the blanks. You can then copy this diagram onto your poster.
- Calculate the COD removed by the first unit in your process using the efficiency and the inlet COD of 20 g/L. Also calculate COD of the water after the first unit of treatment.
- The outlet COD from your first unit of treatment is the inlet COD to the second unit of treatment. Using this, and the treatment unit efficiency given in the first table above, calculate the COD removed by the second unit. Also calculate the COD of the water leaving the second treatment unit. This is the final COD of the water. Does this meet specifications?
- Using the size of the first and second treatment units in your process (given in table 2 above) and the equipment costs (given in table 3). Calculate the fixed cost for the process.
- Using the COD removed from the first treatment unit, and the COD removed from the second treatment unit, and the operational costs given in table 4, calculate the total operational costs for the process.
- Add the total fixed cost, and total operational costs to determine the total cost for your process in a year.

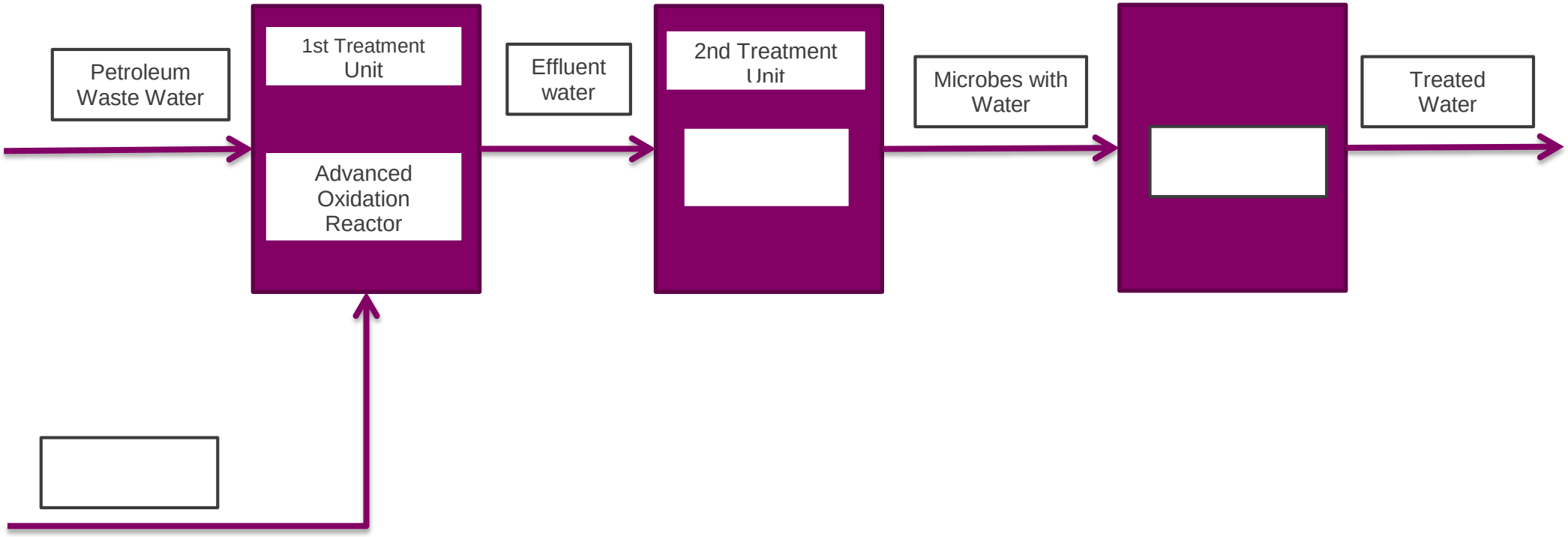
Template for Physical and Biological Process



Template for Physical and Chemical Process



Template for Chemical and Biological Process



Template for Biological and Chemical Process