ISLAB Physics and chemistry, Biotechnology and Maths work of the Class TSTL1
Lycée Saint Paul 4, Reunion Island

Physics and Chemistry Part

TITRATION OF SUCROSE IN CANE JUICE BY REFRACTOMETRY

1.A little history about sugar cane in Reunion Island

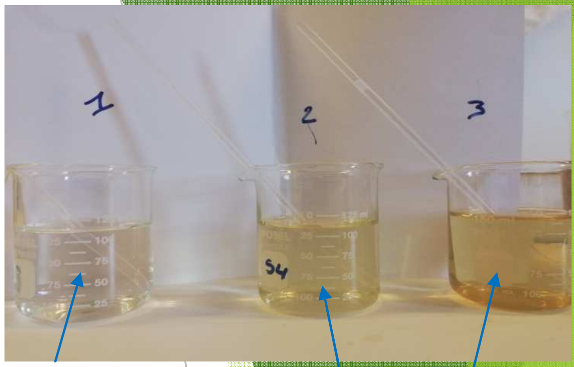
In Reunion Island , the sugar cane fields have been an integral part of the island's landscape and economy for over two hundred years:
Sugar, rum, but also animal feed, energy production, fertilizer, straw ...

How to extract the cane juice?

The cane juice obtained by crushing the sugar cane and passed through a press is succulent and fresh;

Its composition is as follows:
70% of water, 14% of sucrose,
14% of woody matter and 2% of impurities.

2. A physical property of light



First experiment: The broken straw experiment

What phenomenon is highlighted in this experiment?

The straw seems to be broken in the water (beaker 1). The break in water saturated with sugar (beaker 3) is more important compared to the two beakers.
The phenomenon highlighted in this qualitative experiment is :
The refraction of light : When the light passes through two media with different refractive index, it is deflected.

The refractive index of water relative to air is 1.330 at 20°C. If a substance is dissolved in water like sucrose, the refractive index increases.

3. Goals of the experiment

- First of all ,we will check whether the refractive index varies with the concentration of sucrose solutions at different mass concentrations.
- **We will measure the mass concentration of cane juice using the measurement of the refractive index of cane juice with a range of sugar solution calibrations.**
- Then , we will measure the BRIX degrees (percentage by mass of sucrose in 100 ml of water) using a refractometer of sucrose solutions at different mass concentrations.
- Finally, we will determine the mass concentration of sucrose in cane juice used to produce bioethanol by a calibration method.

4. Realisation of sugar solutions at different mass concentrations

Equipment: Electronic scale, weighing dish, spatula, funnel, 2 beakers of 100 mL, micro pipette, volumetric flask of 250 mL, distilled water, sugar cane.

Realisation of sugar solutions of different mass concentrations (50, 100, 150 , 200, 250, 300 g/L)

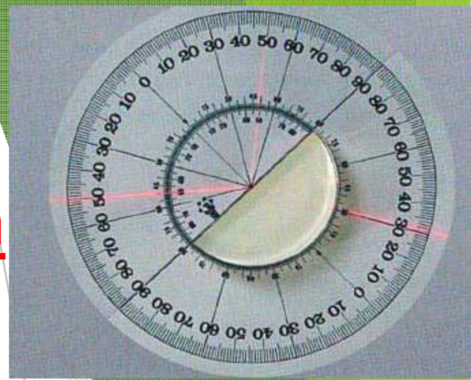
Using this formula : Cm (g/L)= m(g)/V(L)

1. Weighing of a given mass of sucrose

2. Dissolving the given mass of sugar in a 250 mL volumetric flask

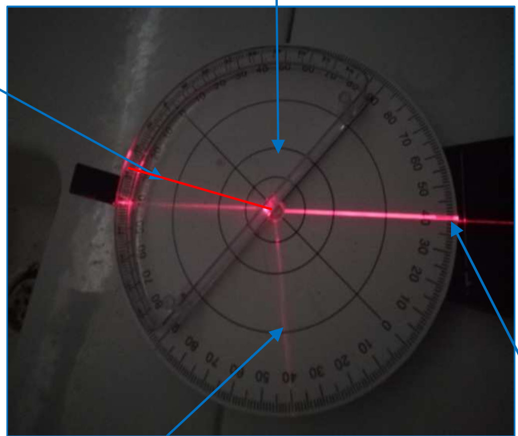
3. Realisation of 6 sucrose solutions of different mass concentrations

5.a Measurement of the refractive index of each sucrose solution at different mass concentration Cm



- Equipment: laser (λ= 650 nm), semi-cylinder containing liquid, disk degree scale
- For each sugar solution of different Cm, angle of refraction measurement (i_2),
- According to **Snell Descartes's law of refraction**, $n_1 \times \sin i_1 = n_2 \times \sin i_2$

  the refractive index n_2 is determined for each sugar cane solution and for cane juice (*table below*) :

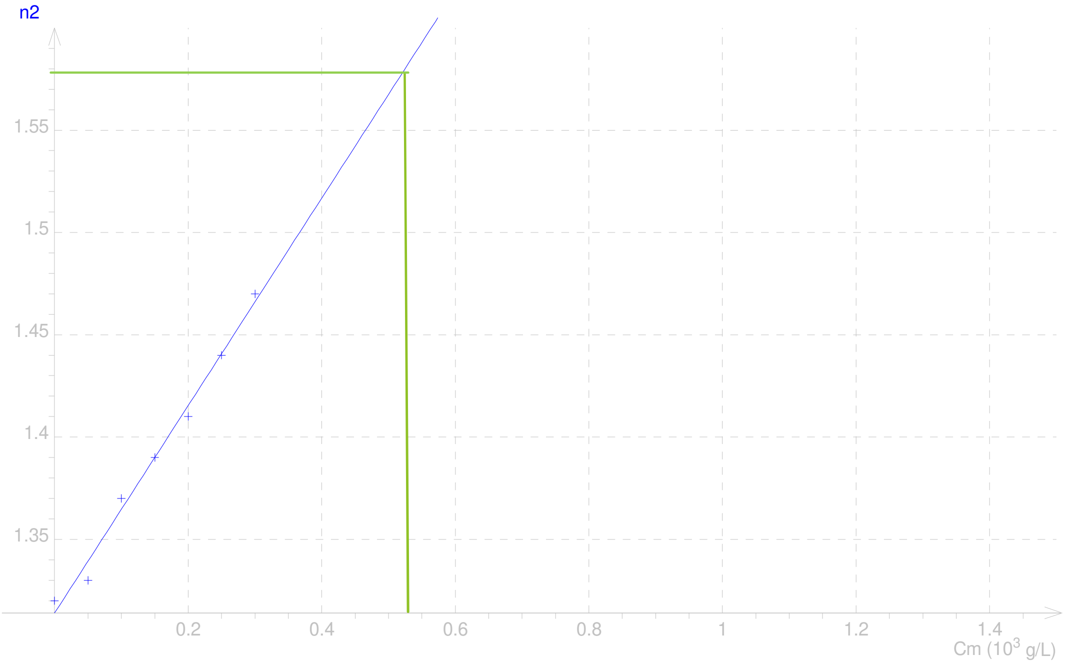


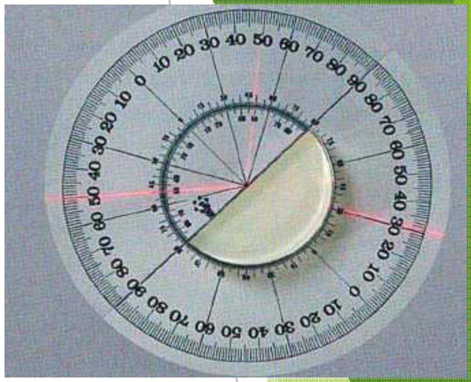
n_1 (air) = 1.0 ; i_1 =40°

Cm (g/L)	0	50	100	150	200	250	Juice cane
m (g)	0	12.5	25	37.5	50	62.5	
i_2(°)	29.1	28.8	28	27.5	27	26.5	24
n2	1,32	1,33	1,37	1,39	1,42	1,44	1,58

5.b Determination of the mass concentration of cane juice by a calibration line

n2 =1,58



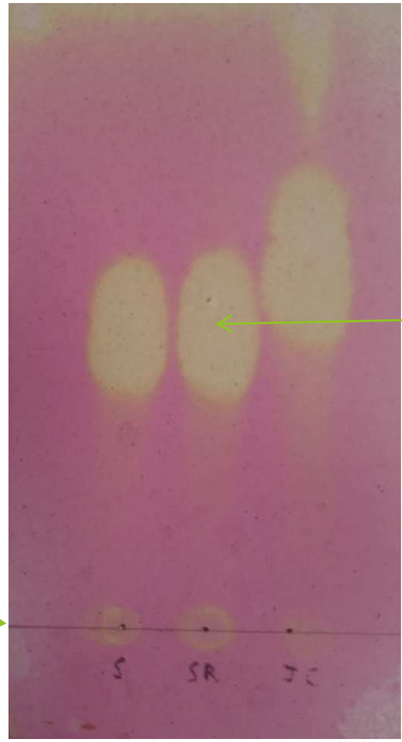


Cm(cane juice) = 523 g/L

6.What about the sugar contained in sugar solutions of different mass concentrations Cm ?

We know that sucrose ($C_{12}H_{22}O_{11}$) hydrolyses into glucose and fructose ($C_6H_{12}O_6$) at 37°C .
So, we performed a thin-layer chromatogram .

Front line



On the front line of the chromatogram, we have deposited pure glucose , pure fructose , pure sucrose , sugar cane solutions and cane juice .

Results : we can see that the sugar solution contains only pure sucrose .
So all the sugar solutions of different Cm realised before contains pure sucrose .
The cane juice also contains sucrose.

7.a Measurement of the mass concentration of sucrose in cane juice with a refractometer:

In this experiment a small portable refractometer specially calibrated for sucrose is used.
This device is graduated in degrees BRIX (° B).
But how do you relate the degrees BRIX (°B) to the mass concentration of sucrose?

The BRIX degree represents the percentage of sucrose in the solution, i.e. the mass of sucrose in 100g of water or 100 ml of water.

How does the refractometer work ?

Cane juice


Fig1 : refractometer

Fig 2 : a drop of solution is deposited

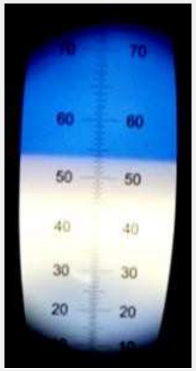



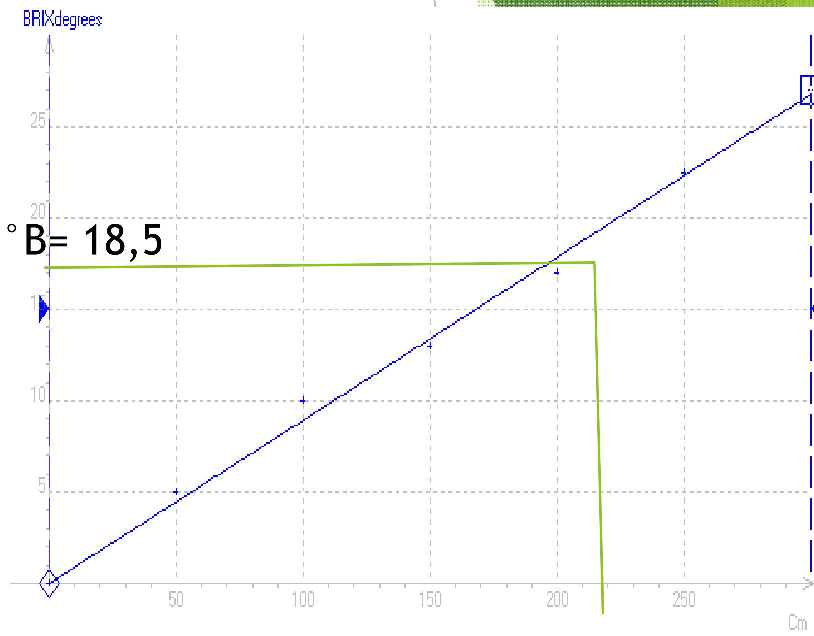
fig 3 : measurement

7.b Determination of the mass concentration of sucrose contained in cane juice by a calibration line

1.Measurement of the degrees BRIX of each sucrose solution at different mass concentrations and of cane juice using a refractometer (table below).

Cm (g/L)	0	50	100	150	200	250	300	Cane juice
n2	1,32	1,33	1,37	1,39	1,41	1,44	1,47	1,58
°BRIX	0	5	10	13	17	22,5	27	18,5

2. Determination of Cm(sucrose) in cane juice by a calibration line



Cm = 204,9 g/L of **sucrose**

Due to its ease of use, refractometric measurement is commonly used in the sugar industry to directly measure **the brix degrees of cane juice** .
The refractometer is then directly graduated in sucrose concentration.

Biotchnology Part

BIOETHANOL PRODUCTION
Saint-Paul 4 HighSchool

1. PRESENTATION OF BIOFUELS AND THEIR INTERESTS

✓Biofuels are energy sources made from recently grown biomass (plant or animal matter).
✓Biofuels are a renewable resource because they are continually replenished. Fossil fuels on the other hand are not renewable since they require millions of years to form.

Different types and generation of biofuels

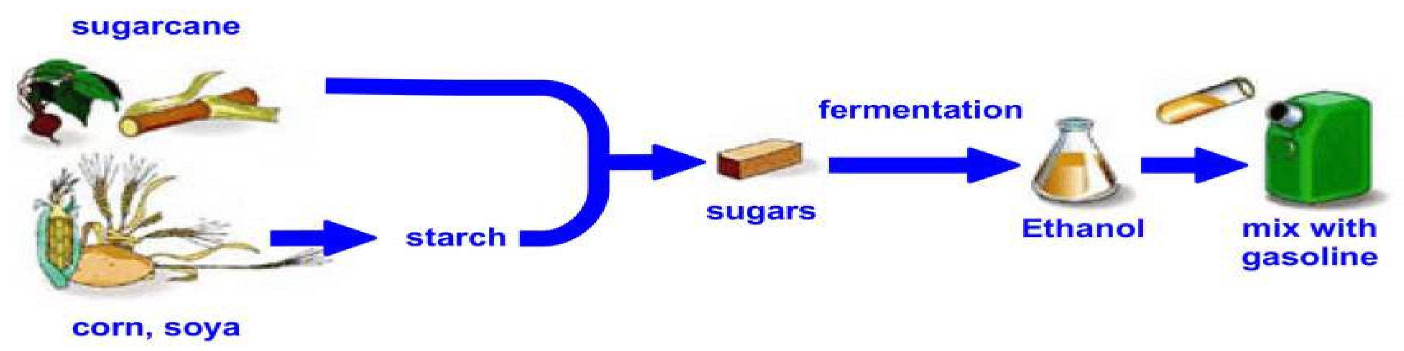
1. Biodiesel

Produced from vegetable oil, biodiesel is obtained by reacting lipids with an alcohol, so as to obtain methyl ester. Biodiesel will not be study in this lab work.

2. Bioethanol

1. PRESENTATION OF BIOFUELS AND THEIR INTERESTS

•*First generation of bioethanol:*



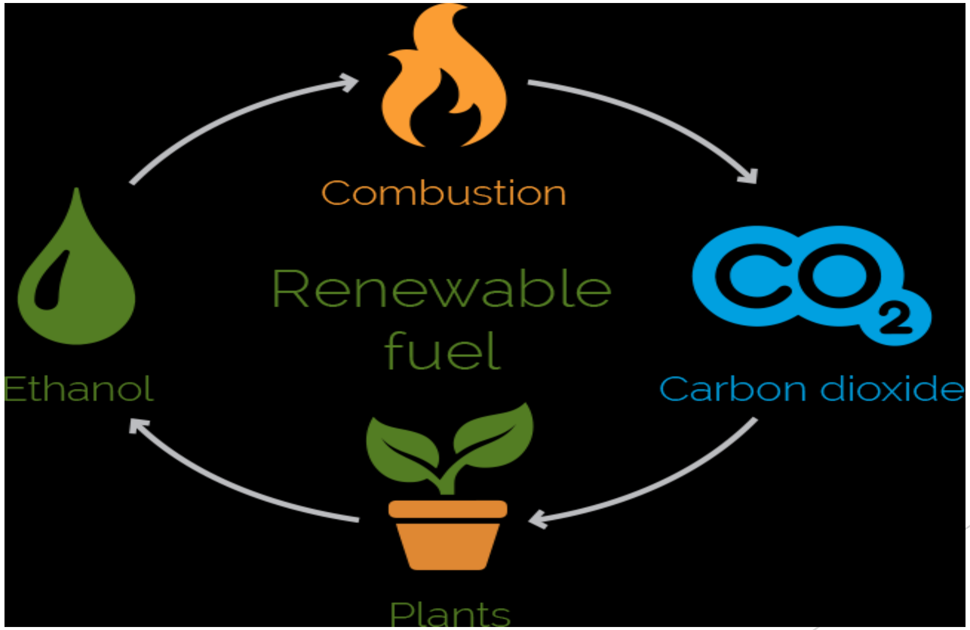
This first generation use as major glucose source crop products like corn, soya bean, sugarcane, and beet. The sugars can be fermented to bioethanol which is added in gasoline.

•*Second generation of bioethanol*

The biomass sources for 2nd generation biofuels include wood, organic waste, food waste and specific biomass crops.

1. PRESENTATION OF BIOFUELS AND THEIR INTERESTS

Bioethanol is a substitute for conventional fuel sources such as petrol and other gasoline used for road transport vehicles owing to its low greenhouse gas emissions.
Bioethanol has a carbon balance of neutral production since the plants at its origin consume CO2 during their shoots; this absorbed CO2 makes it possible to balance the carbon balance when the gas is then rejected with the gasoline engine.



2. OVERVIEW OF THE LAB WORK

Fermentation

- The yeasts will transform the sucrose from cane juice into ethanol

Distillation

- Will separate the ethanol from the water and therefore concentrate the ethanol

Quantify ethanol

- Determination of ethanol concentration by indirect volumetric metering

3. SUGARCANE FERMENTATION

Cane juice extraction :

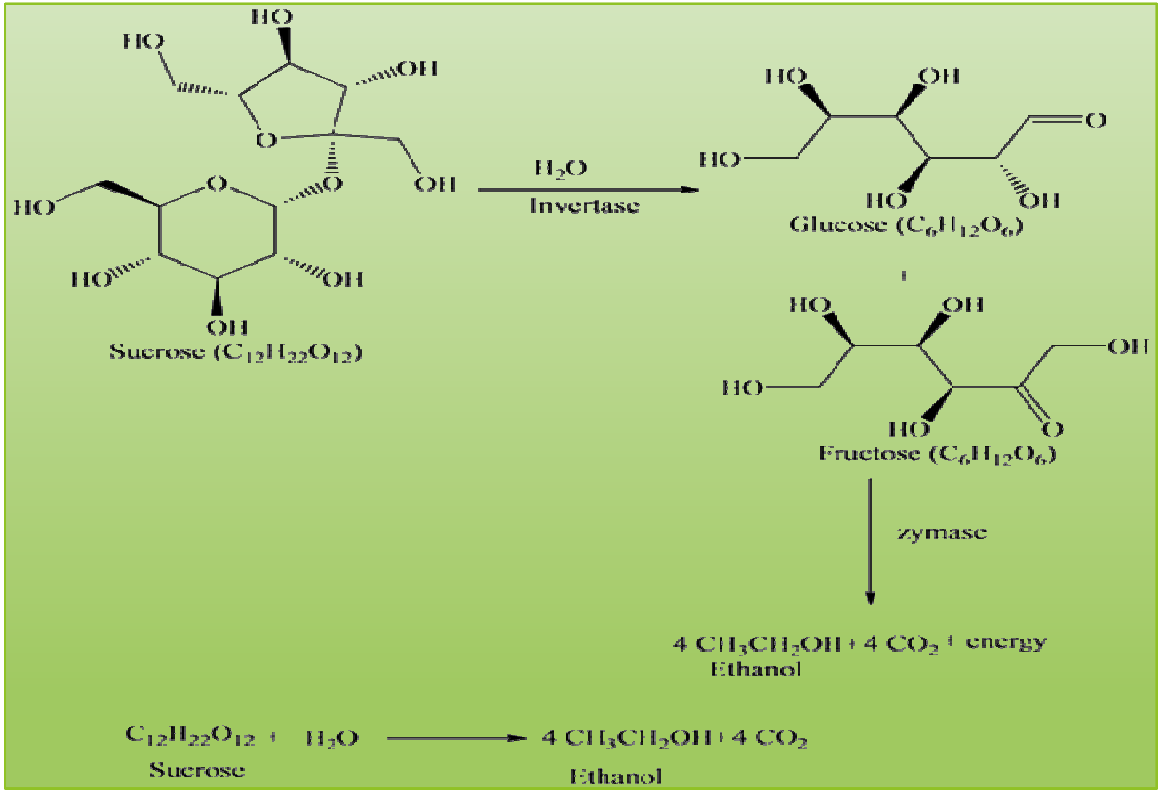
Procedure:

•Put in an Erlenmeyer flask:

- 90 mL of cane juice
- 10 mL of a 24 hour yeast culture.

•Incubate at 30 ° C for 24 hours with a CO_2 evacuation system.

3. SUGARCANE FERMENTATION



The sucrose in cane juice is hydrolyzed to glucose and fructose. These will be fermented by ethanol yeasts.

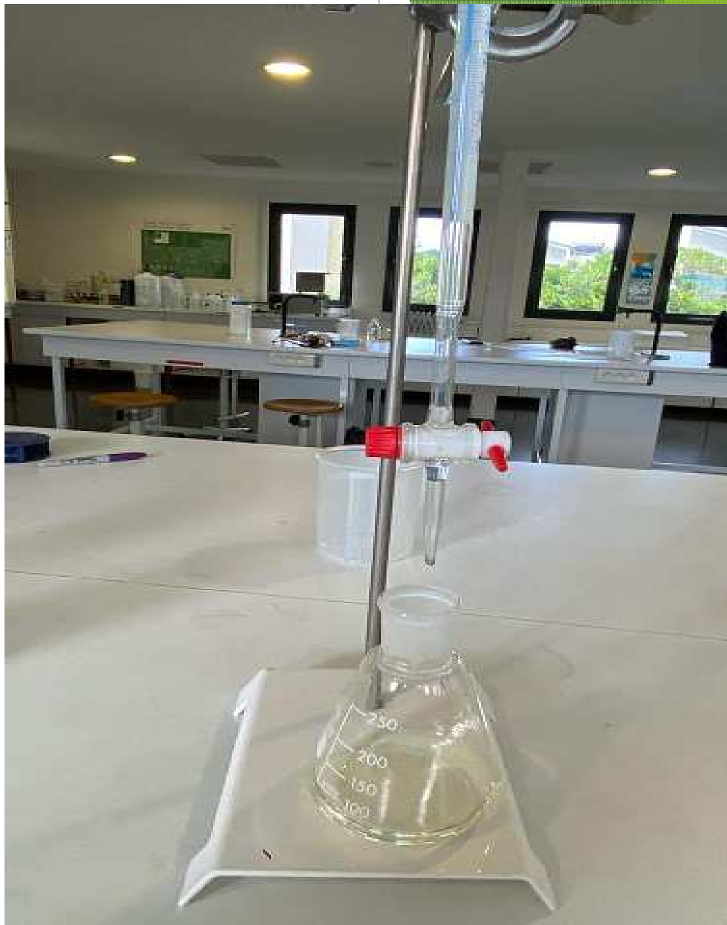
After fermentation : separation between the fermentation products and the yeasts

4. DISTILLATION

The distillation system :

Definition of distillation :
Molecule separation technique based on their difference in boiling point.
→***Allows ethanol to be separated from other constituents of fermentation products.***

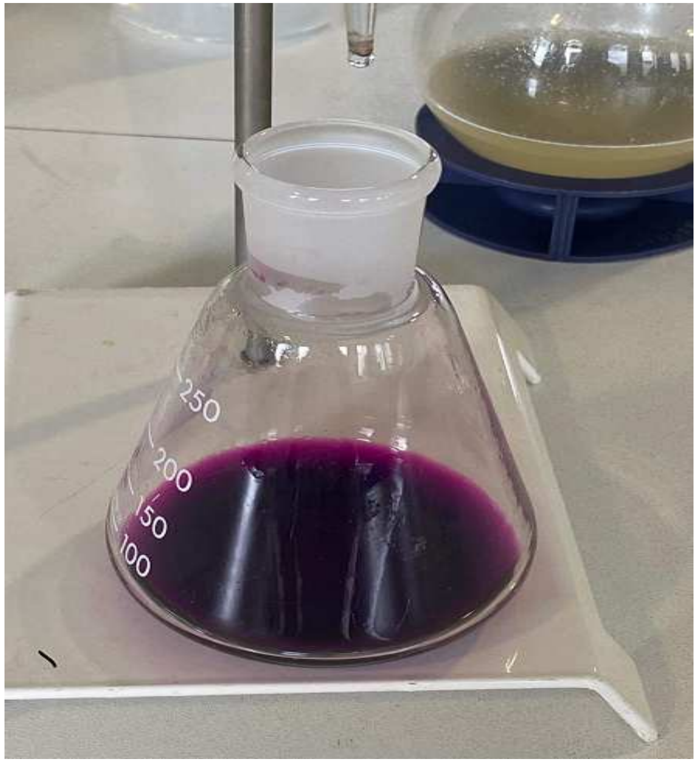
5. DETERMINATION OF ETHANOL CONCENTRATION IN THE DISTILLATE



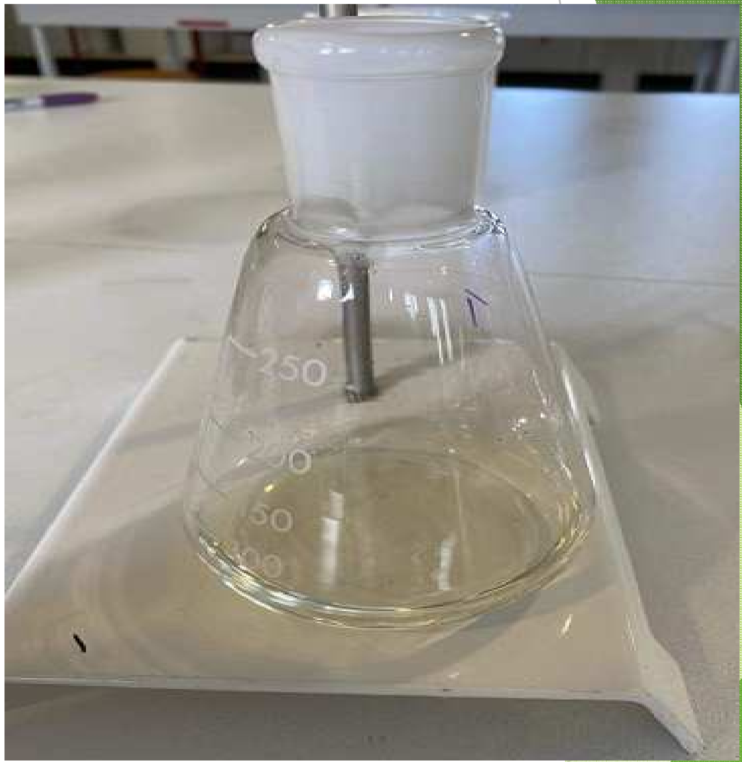
It is a volumetric dosing in return: the ethanol of the distillate is oxidized by an excess of potassium permanganate;

then the excess potassium permanganate is determinate by a calibrated solution of Mohr salt (which contains Fer^{2+} ions).

5. DETERMINATION OF ETHANOL CONCENTRATION IN THE DISTILLATE



Erlenmeyer flask before ethanol measuring



Erlenmeyer flask after ethanol measuring

5. DETERMINATION OF ETHANOL CONCENTRATION IN THE DISTILLATE

Calculations :

$$\rho_{(ethanol,distillate)} = \frac{c_{fer} * (V_T - V_E)}{4 * V_{ethanol}} * Fd * M_{ethanol}$$

$$\rho_{(ethanol,distillate)} = \frac{0.100 * (10.55 - 7.15)}{4 * 5} * 50 * 46$$

$$\rho_{(ethanol,distillate)} = 39.1\ g.L^{-1}$$

This concentration corresponds to 4.9% of ethanol

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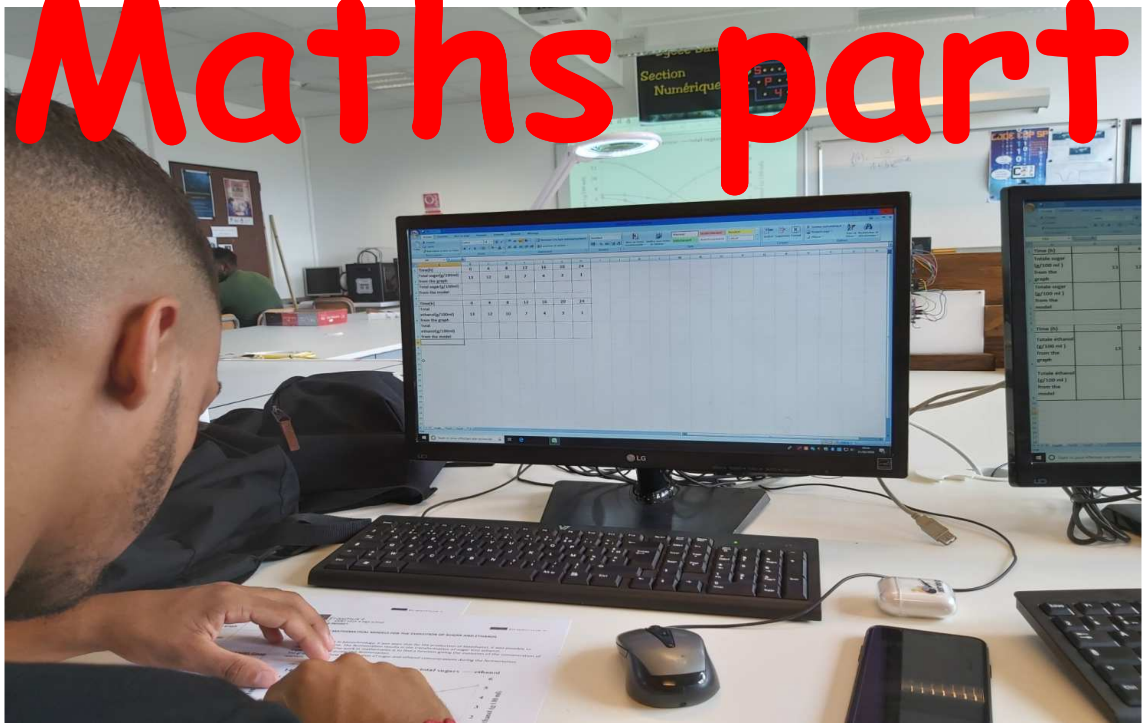
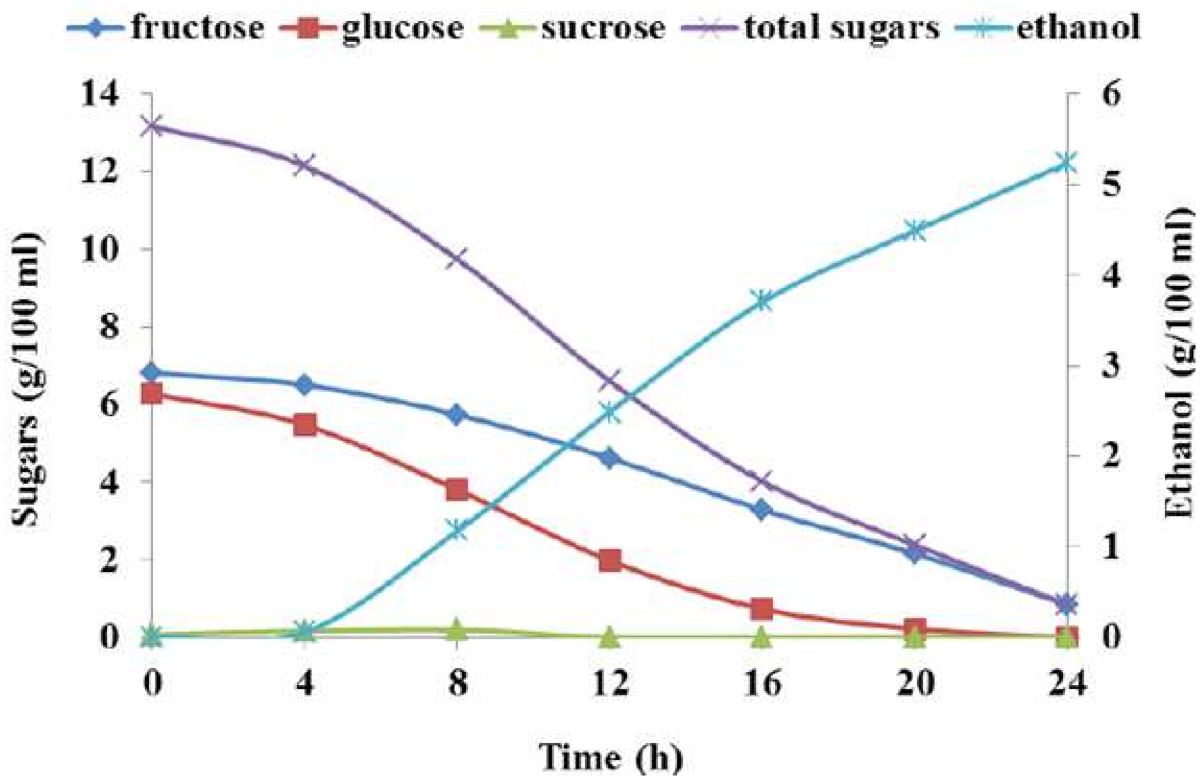
Erasmus+

Maths part

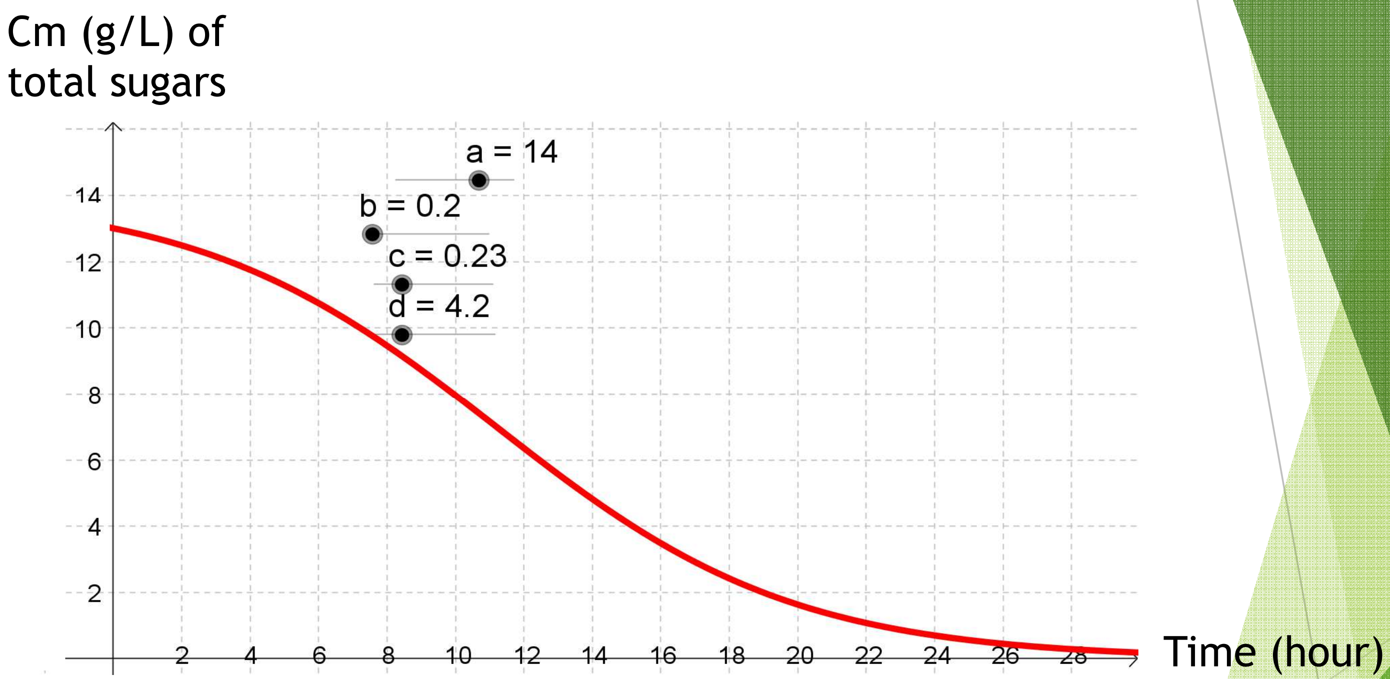




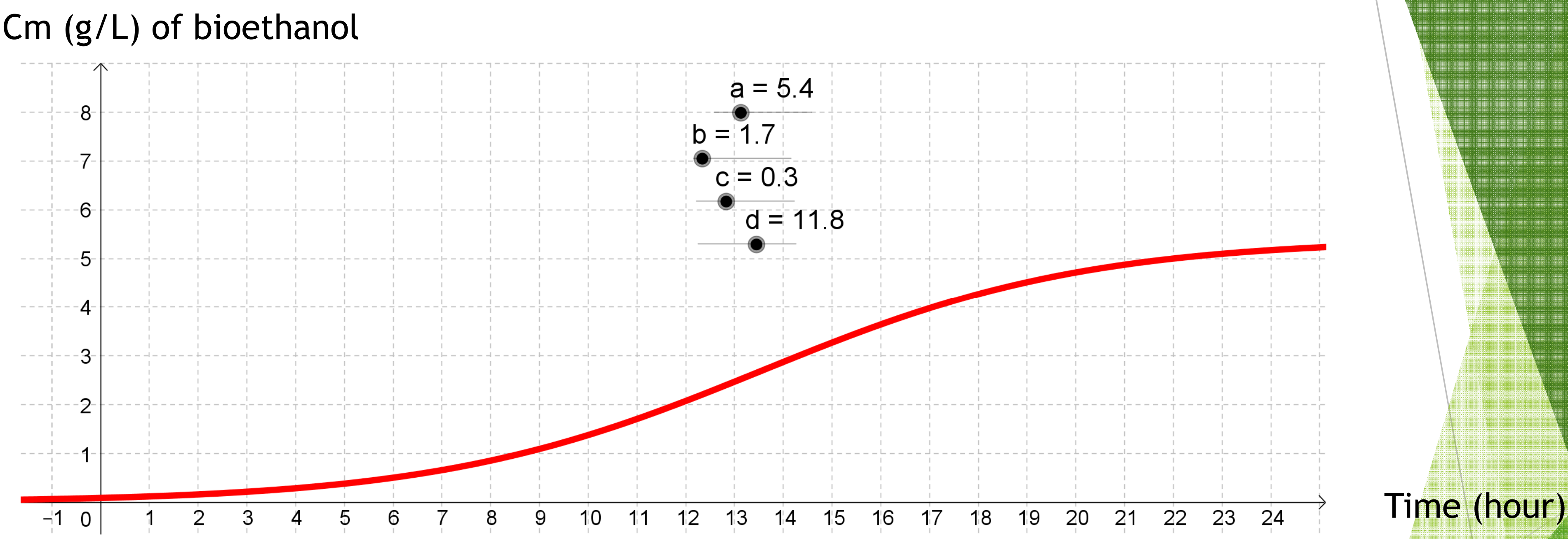
These are measurements during the fermentation of sugar cane

Our goal in maths is to find a function to model the evolution of sugars and ethanol.

The type of function is $f(t) = a/(1+be^{c(t-d)})$.



In Geogebra, we set a function with 4 parameters (4 sliders) to model the evolution of sugars concentration



We did the same thing for the ethanol concentration.

Finally, we found for the sugars concentration as a function of the time:

$$f(t) = \frac{14}{1+0.2e^{0.23(t-4.2)}}$$

And for the ethanol concentration:

$$g(t) = \frac{5.4}{1+1.7e^{0.3(t-11.8)}}$$

Comparison between the measurements and the models:

Time (h)	0	4	8	12	16	20	24
Total sugar (g/100 ml) **from the graph**	13	12	9,5	6,5	4	3	1
Total sugar (g/100 ml) **from the model**	13,0	11,8	9,5	6,4	3,5	1,6	0,7

Time (h)	0	4	8	12	16	20	24
Ethanol (g/100 ml) **from the graph**	0	0,2	1	2,5	3,5	4,5	5,25
Ethanol (g/100 ml) **from the model**	0,1	0,3	0,9	2,1	3,6	4,7	5,2

Chemistry, Biotechnology and Mathematics Labwork realised by students of TSTL1 *Lycée Saint Paul 4* (Reunion Island) in February 2020 presented by :

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