



## SECTION II: KINETICS AND BIOREACTOR DESIGN:

### LESSON 9.4. - Enzymatic kinetics, microbial kinetics and metabolic stoichiometry –Metabolic Stoichiometry

Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

UNIVERSIDAD FRANCISCO DE VITORIA

# AIMS FOR TODAY'S LESSON

- 1.- STOICHIOMETRY applied to bioprocesses with cells.
- 2.- ELEMENT BALANCE and stoichiometric coefficient obtaining.
- 3.- RESPIRATORY EXCHANGE RATIO and when can we use it.
- 4.- BALANCE of ELECTRONS and how we can take advantage of it
- 5.- YIELDS

Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid

**1.- STOICHIOMETRY**

**2.- ELEMENT BALANCE**

**3.- RESPIRATORY EXCHANGE RATIO**

**4.- BALANCE OF ELECTRONS**

**5.- YIELDS**

**6.- OTHER SITUATIONS**

**Cartagena99**

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid

# 1.- STOICHIOMETRY

**Cartagena99**

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid

# 1. PROCESS STOICHIOMETRY

---

Hundreds of reactions involved in metabolism:

- Growth.
- Generation of products.

➔ Transformations within cells present **great stoichiometric complexity.**

➔ **Mass Conservation Law** works.

➔ Simplification of reality is possible using **pseudo-reactions.**

How are these equations written?

The logo for Cartagena99, featuring the text "Cartagena99" in a stylized font with a blue and orange gradient background.

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 1. PROCESS STOICHIOMETRY... WHAT FOR?

---

- Outline **Mass and Energy Balances**.
- Compare **theoretical and real yields** of a bioprocess.
- Check **consistency of experimental bioprocess data**.
- Formulate **medium for growth and / or production** when living cells are used as biocatalysts.
- Obtaining **relationships between yields** based on matter and energy balances of microbial metabolism.

The logo for Cartagena99, featuring the text 'Cartagena99' in a stylized font with a blue and orange gradient background.

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid

**1.- STOICHIOMETRY**

**2.- ELEMENT BALANCE**

**3.- RESPIRATORY EXCHANGE RATIO**

**4.- BALANCE OF ELECTRONS**

**5.- YIELDS**

**6.- OTHER SITUATIONS**

**Cartagena99**

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 2.- ELEMENT BALANCE

**Cartagena99**

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70



Francisco de Vitoria  
**UFV Madrid**



## 2. STOICHIOMETRIC COEFFICIENTS FROM ELEMENT BALANCES

➤ ALONG GROWTH:

What elements to be considered?

- Those present in significant amounts → **C, H, O, N**
- Others particularly important to describe the process.

Components not included:

-**ATP** nor **NADH** ← not being exchanged with the outside, so they are included as biomass.

Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVIA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 2. STOICHIOMETRIC COEFFICIENTS FROM ELEMENT BALANCES

### ONE MOLE OF BIOLOGICAL MATERIAL:

Amount of biomass containing or being equivalent to one mole of carbon.



Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 2. STOICHIOMETRIC COEFFICIENTS FROM ELEMENT BALANCES

### ONE MOLE OF BIOLOGICAL MATERIAL:

TABLE 7.3 Date on Elemental Composition of Several Microorganisms

Microorganism	Limiting Nutrient	$\mu$ ( $h^{-1}$ )	Composition (% by wt)							Empirical Chemical Formula	Formula "Molecular" Weight	
			C	H	N	O	P	S	Ash			
Bacteria			53.0	7.3	12.0	19.0				8	$CH_{1.666}N_{0.20}O_{0.27}$	20.7
Bacteria			47.1	7.8	13.7	31.3					$CH_2N_{0.25}O_{0.5}$	25.5
<i>Aerobacter aerogenes</i>			48.7	7.3	13.9	21.1				8.9	$CH_{1.78}N_{0.24}O_{0.33}$	22.5
<i>Klebsiella aerogenes</i>	Glycerol	0.1	50.6	7.3	13.0	29.0					$CH_{1.74}N_{0.22}O_{0.43}$	23.7
<i>K aerogenes</i>	Glycerol	0.85	50.1	7.3	14.0	28.7					$CH_{1.73}N_{0.24}O_{0.43}$	24.0
Yeast			47.0	6.5	7.5	31.0				8	$CH_{1.66}N_{0.13}O_{0.40}$	23.5
Yeast			50.3	7.4	8.8	33.5					$CH_{1.73}N_{0.15}O_{0.5}$	23.9
Yeast			44.7	6.2	8.5	31.2	1.08	0.6			$CH_{1.64}N_{0.16}O_{0.52}P_{0.01}S_{0.005}$	26.9
<i>Candida utilis</i>	Glucose	0.08	50.0	7.6	11.1	31.3					$CH_{1.82}N_{0.19}O_{0.47}$	24.0
<i>C. utilis</i>	Glucose	0.45	46.9	7.2	10.9	35.0					$CH_{1.84}N_{0.2}O_{0.56}$	25.6
<i>C. utilis</i>	Ethanol	0.06	50.3	7.7	11.0	30.8					$CH_{1.82}N_{0.19}O_{0.46}$	23.9
<i>C. utilis</i>	Ethanol	0.43	47.2	7.3	11.0	34.6					$CH_{1.84}N_{0.2}O_{0.55}$	25.5

Web: [www.cartagena99.com](http://www.cartagena99.com) From: B. Adlauer and E. Marotta, *Biotechnical Engineering and Biotechnology Handbook*, Macmillan, Inc., New York, 1983.

CLASES PARTICULARES, TUTORIAS TECNICAS ONLINE  
LLAMA O ENVIA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Cartagena99

## 2. STOICHIOMETRIC COEFFICIENTS FROM ELEMENT BALANCES

ONE MOLE OF BIOLOGICAL MATERIAL:



CELLS	MICROORGANISM	EMPIRICAL CHEMICAL FORMULA
Prokaryote	<i>Escherichia coli</i>	$CH_{1,77}O_{0,49}N_{0,24}$
	<i>Klebsiella aerogenes</i>	$CH_{1,75}O_{0,43}N_{0,22}$
		$CH_{1,73}O_{0,43}N_{0,24}$
	<i>Pseudomonas C12 B</i>	$CH_{2,00}O_{0,52}N_{0,23}$
Eukariote	<i>Saccharomyces cerevisiae</i>	$CH_{1,64}O_{0,52}N_{0,16}$
		$CH_{1,81}O_{0,51}N_{0,17}$
		$CH_{1,82}O_{0,51}N_{0,18}$

Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Francisco de Vitoria  
UFV Madrid

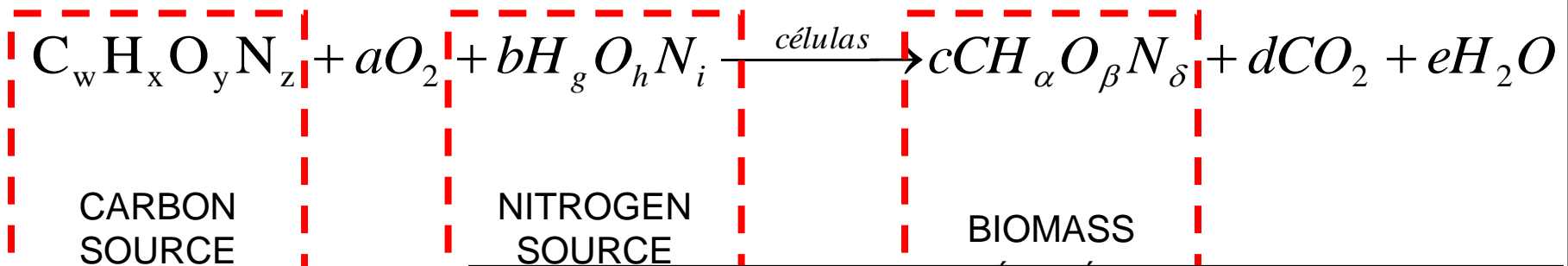
## 2. STOICHIOMETRIC COEFFICIENTS FROM ELEMENT BALANCES

Average Empirical Chemical Formula:



Molecular weight: 24,6 g/mole dry biomass  
(5-10% ashes)

➤ General equation for aerobic process:



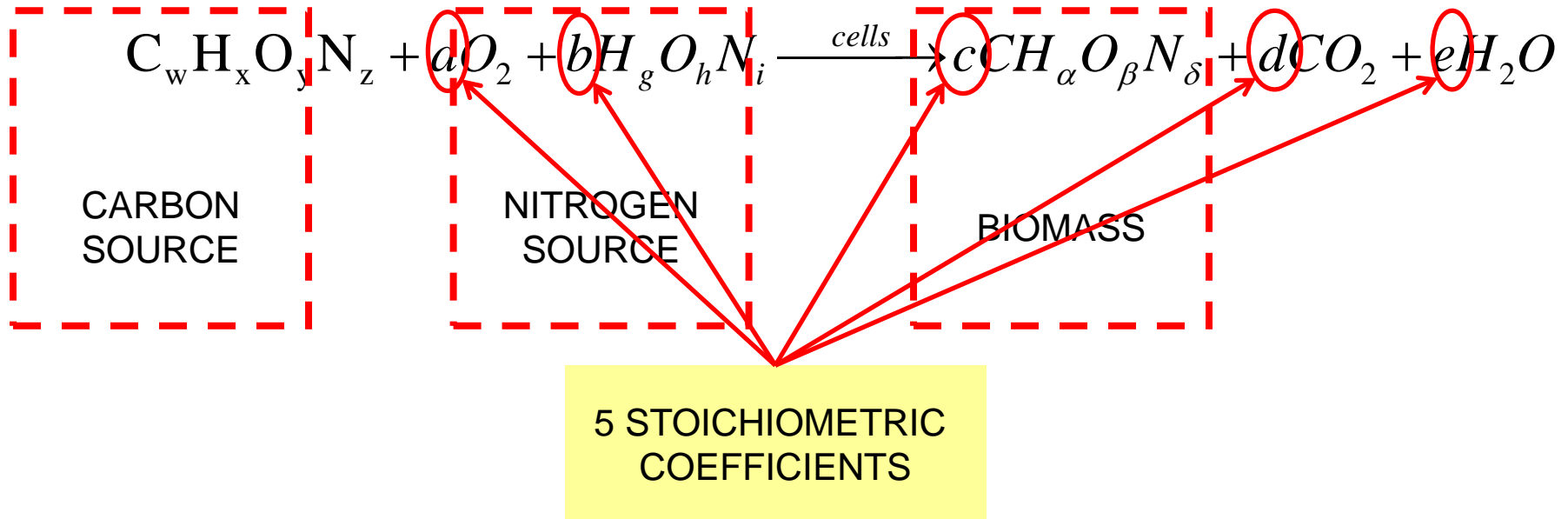
Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

## 2. STOICHIOMETRIC COEFFICIENTS FROM ELEMENT BALANCES



- Equation written on the basis of 1 mole of carbon substrate.
- Simplification of reality.
- Good tool for the thermodynamic analysis of the process.

Cartagena99

CLASES PARTICULARES, TUTORIAS TÉCNICAS ONLINE  
LLAMA O ENVIA WHATSAPP: 689 45 44 70

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 2. STOICHIOMETRIC COEFFICIENTS FROM ELEMENT BALANCES

---

- Microbial Composition ← elemental analysis.
- Material balance of the elements: C, H, O and N.

**PROBLEM:** Five unknowns and four balance equations → One more equation is needed.

Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid

**1.- STOICHIOMETRY**

**2.- ELEMENT BALANCE**

**3.- RESPIRATORY EXCHANGE RATIO**

**4.- BALANCE OF ELECTRONS**

**5.- YIELDS**

**6.- OTHER SITUATIONS**

**Cartagena99**

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid



### ***3.- RESPIRATORY EXCHANGE RATIO***

**Cartagena99**

**CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70**

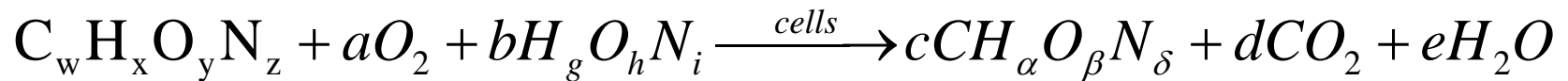
---

**ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70**



**Francisco de Vitoria  
UFV Madrid**

### 3. RESPIRATORY EXCHANGE RATIO



**C Balance:**  $w = c + d$

**H Balance:**  $x + b \cdot g = c \cdot \alpha + 2 \cdot e$

**O Balance:**  $y + 2 \cdot a + b \cdot h = c \cdot \beta + 2 \cdot d + e$

**N Balance:**  $z + b \cdot i = c \cdot \delta$

**RESPIRATORY EXCHANGE RATIO** ← microorganism composition ←

← elemental analysis.

$$RER = \frac{\text{generated } CO_2}{\text{consumed } O_2} = \frac{d}{a}$$

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

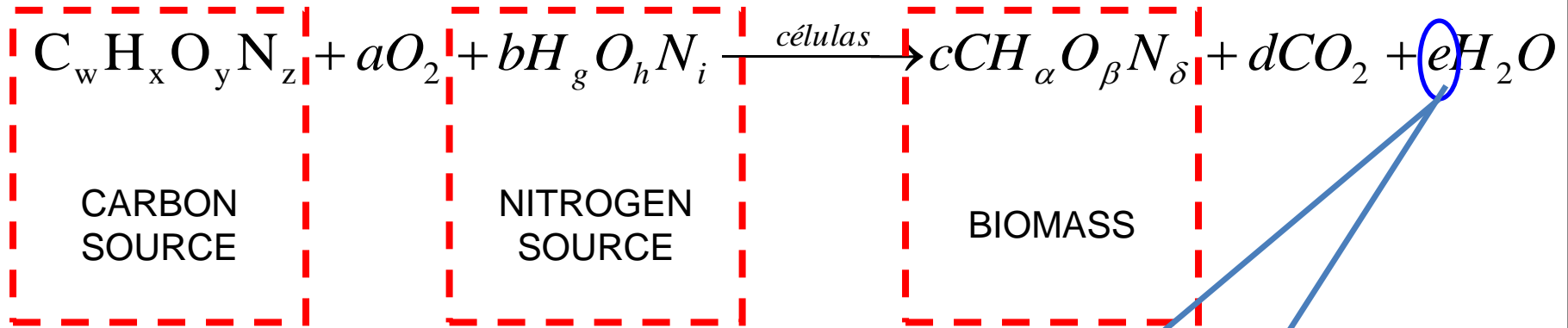
---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Cartagena99

Francisco de Vitoria  
UFV Madrid

### 3. RESPIRATORY EXCHANGE RATIO



**C Balance:**             $w = c + d$

**H Balance:**             $x + b \cdot g = c \cdot \alpha + 2 \cdot e$

**O Balance:**             $y + 2 \cdot a + b \cdot h = c \cdot \beta + 2 \cdot d + e$

**N Balance:**             $z + b \cdot i = c \cdot \delta$

➤ **PROBLEM:** water within the medium ➔ hydrogen and oxygen

Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Francisco de Vitoria  
UFV Madrid

**1.- STOICHIOMETRY**

**2.- ELEMENT BALANCE**

**3.- RESPIRATORY EXCHANGE RATIO**

**4.- BALANCE OF ELECTRONS**

**5.- YIELDS**

**6.- OTHER SITUATIONS**

**Cartagena99**

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 4.- BALANCE OF ELECTRONS

**Cartagena99**

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

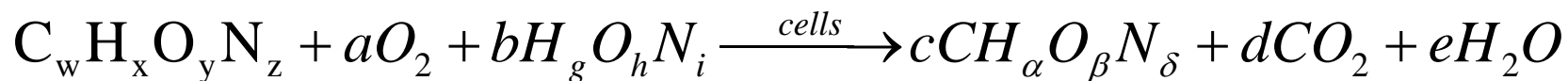
---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70



Francisco de Vitoria  
**UFV Madrid**

## 4. BALANCE OF ELECTRONS



➤ **SOLUTION:**

Perform an **ELECTRONIC BALANCE**

(or balance of degree of reduction  $\gamma$ )

**DEGREE OF REDUCTION  $\gamma$**  is the number of equivalents of electrons per mole of carbon.

➔ number of electrons that can be transferred to oxygen by combustion

Cartagena99

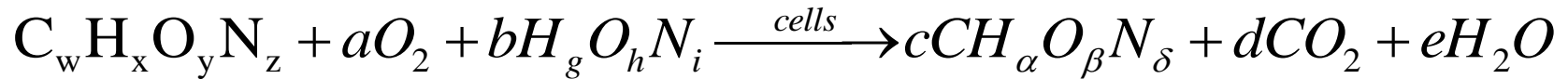
CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 4. BALANCE OF ELECTRONS



### VALENCES:

C → 4; H → 1; N → (0 (N<sub>2</sub>); -3 (ammonium); 5 (nitrate)); O → -2; P → 5;...

### DEGREE OF REDUCTION:

- For an **element** its degree of reduction is **its valence**.
- Within a molecule the degree of reduction need to be referred to its

number of carbon atoms

Cartagena99

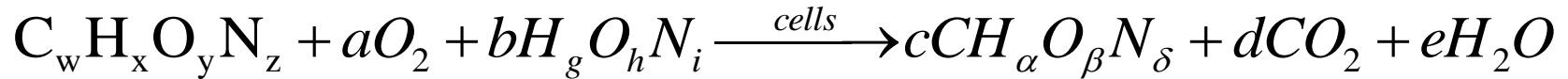
CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 4. BALANCE OF ELECTRONS



### DEGREE OF REDUCTION:

-Methane  $CH_4 \gamma_{met} = \frac{1(4) + 4(1)}{1} = 8$

-Glucose  $C_6H_{12}O_6 \gamma_{glu} = \frac{6(4) + 12(1) + 6(-2)}{6} = 4$

- Ethanol  $C_2H_5OH \gamma_{EtOH} = \frac{2(4) + 6(1) + 1(-2)}{2} = 6$

- Substrate  $C_w H_x O_y N_z \gamma_S = \frac{w(4) + x(1) + y(-2) + z(-3)}{w}$

$$(4) + \alpha(1) + \beta(-2) + \delta(-3)$$

CLASES PARTICULARES, TUTORIAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Cartagena99



## 4. BALANCE OF ELECTRONS

**TABLE 7.4** Degree of Reduction and Weight of One Carbon Equivalent of One Mole of Some Substrates and Biomass

Compound	Molecular Formula	Degree of Reduction, $\gamma$	Weight, $m$
Biomass	$\text{CH}_{1.64}\text{N}_{0.16}\text{O}_{0.52}$ $\text{P}_{0.0054}\text{S}_{0.005}^a$	4.17 ( $\text{NH}_3$ )	24.5
		4.65 ( $\text{N}_2$ )	
		5.45 ( $\text{HNO}_3$ )	
Methane	$\text{CH}_4$	8	16.0
<i>n</i> -Alkane	$\text{C}_{15}\text{H}_{32}$	6.13	14.1
Methanol	$\text{CH}_3\text{O}$	6.0	32.0
Ethanol	$\text{C}_2\text{H}_5\text{O}$	6.0	23.0
Glycerol	$\text{C}_3\text{H}_8\text{O}_3$	4.67	30.7
Mannitol	$\text{C}_6\text{H}_{14}\text{O}_6$	4.33	30.3
Acetic acid	$\text{C}_2\text{H}_4\text{O}_2$	4.0	30.0
Lactic acid	$\text{C}_3\text{H}_6\text{O}_3$	4.0	30.0
Glucose	$\text{C}_6\text{H}_{12}\text{O}_6$	4.0	30.0
Formaldehyde	$\text{CH}_2\text{O}$	4.0	30.0
Gluconic acid	$\text{C}_6\text{H}_{12}\text{O}_7$	3.67	32.7
Succinic acid	$\text{C}_4\text{H}_6\text{O}_4$	3.50	29.5
Citric acid	$\text{C}_6\text{H}_8\text{O}_7$	3.0	33.5
Formic acid	$\text{CH}_2\text{O}_2$	2.0	46.0

Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

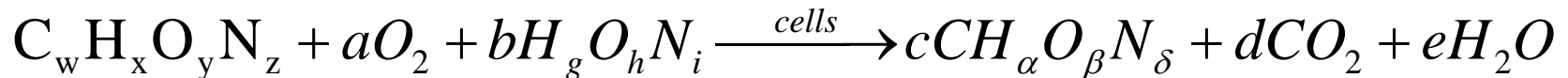
Francisco de Vitoria  
UFV Madrid

## 4. BALANCE OF ELECTRONS

### DEGREE OF REDUCTION:

$$\text{- Substrate } C_w H_x O_y N_z \gamma_s = \frac{w(4) + x(1) + y(-2) + z(-3)}{w}$$

$$\text{- Biomass } C H_\alpha O_\beta N_\delta \gamma_b = \frac{(4) + \alpha(1) + \beta(-2) + \delta(-3)}{1}$$



-As a result:

$$w \cdot (\gamma_s) + 2a(-2) = c \cdot (\gamma_b)$$

Cartagena99

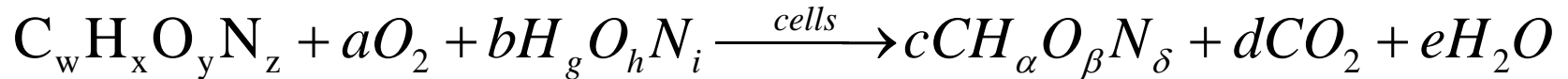
CLASES PARTICULARES, TUTORIAS TECNICAS ONLINE  
LLAMA O ENVIA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 4. BALANCE OF ELECTRONS



**FIVE UNKNOWN; How many equations?**

1

**C Balance:**  $w = c + d$

2

**N Balance:**  $z + b \cdot i = c \cdot \delta$

3

**RESPIRATORY EXCHANGE RATIO:**  $RQ = \frac{d}{a}$

4

**REDUCTION POWER BALANCE:**  $w \cdot (\gamma_s) + 2 \cdot a(-2) = c \cdot (\gamma_b)$

Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Francisco de Vitoria  
UFV Madrid

**1.- STOICHIOMETRY**

**2.- ELEMENT BALANCE**

**3.- RESPIRATORY EXCHANGE RATIO**

**4.- BALANCE OF ELECTRONS**

**5.- YIELDS**

**6.- OTHER SITUATIONS**

**Cartagena99**

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 5.- YIELDS

**Cartagena99**

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

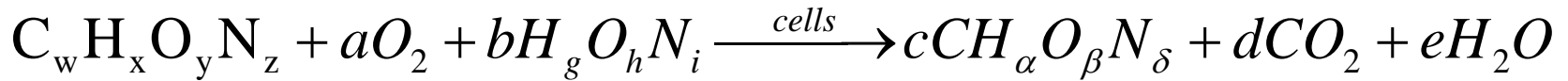
---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70



Francisco de Vitoria  
**UFV Madrid**

## 5. YIELD FROM SUBSTRATE TO BIOMASS



**FIVE UNKNOWN; How many equations?**

1 **CARBON BALANCE:**  $w = c + d$

2 **NITROGEN BALANCE:**  $z + b \cdot i = c \cdot \delta$

3 **RESPIRATORY EXCHANGE RATIO:**  $RQ = \frac{d}{a}$

4 **REDUCTION POWER BALANCE:**  $w \cdot (\gamma_s) + 2 \cdot a(-2) = c \cdot (\gamma_b)$

5 **YIELD FROM SUBSTRATE TO BIOMASS,  $Y_{x/s}$**

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

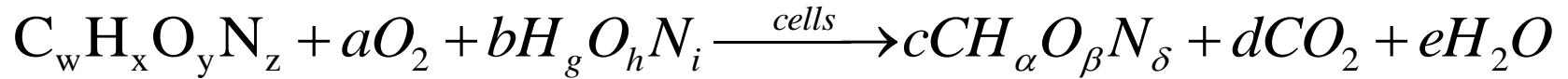
---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Cartagena99

Francisco de Vitoria  
UFV Madrid

## 5. YIELD FROM SUBSTRATE TO BIOMASS



### YIELD FROM SUBSTRATE TO BIOMASS, $Y_{x/s}$

It depends on:

- The composition of the culture medium.
- The nature of the carbon source and the source of nitrogen.
- The operating variables: pH, T, aeration, ...
- $Y_{x/s}$  is bigger under aerobiosis than under anaerobiosis

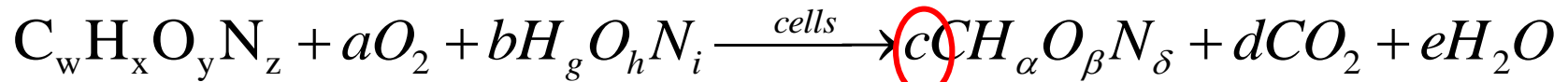
Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

## 5. YIELD FROM SUBSTRATE TO BIOMASS



### YIELD FROM SUBSTRATE TO BIOMASS, $Y_{x/s}$

- If biomass yield can be considered constant during growth.
- If we know the molecular mass of the substrate.
- If we know the average molecular mass of biomass.

$$Y_{x/s} = \frac{g \text{ biomass}}{g \text{ substrate}} = \frac{c Mm_{(Biomass)}}{w Mm_{(Substrate)}}$$

Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

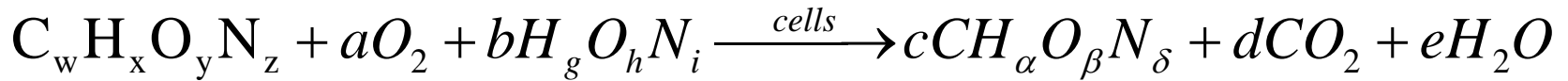
---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Francisco de Vitoria  
UFV Madrid



## 5. YIELD FROM SUBSTRATE TO BIOMASS



**FIVE UNKNOWN; How many equations?**

1 **CARBON BALANCE:**  $w = c + d$

2 **NITROGEN BALANCE:**  $z + b \cdot i = c \cdot \delta$

3 **RESPIRATORY EXCHANGE RATIO:**  $RQ = \frac{d}{a}$

4 **REDUCTION POWER BALANCE:**  $w \cdot (\gamma_s) + 2 \cdot a(-2) = c \cdot (\gamma_b)$

5 **YIELD FROM SUBSTRATE TO BIOMASS,  $Y_{x/s}$**   $Y_{x/s} = \frac{c \cdot Mm_{(Biomass)}}{w \cdot Mm_{(Substrate)}}$

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Cartagena99

Francisco de Vitoria  
UFV Madrid

**1.- STOICHIOMETRY**

**2.- ELEMENT BALANCE**

**3.- RESPIRATORY EXCHANGE RATIO**

**4.- BALANCE OF ELECTRONS**

**5.- YIELDS**

**6.- OTHER SITUATIONS**

**Cartagena99**

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 6.- OTHER SITUATIONS

**Cartagena99**

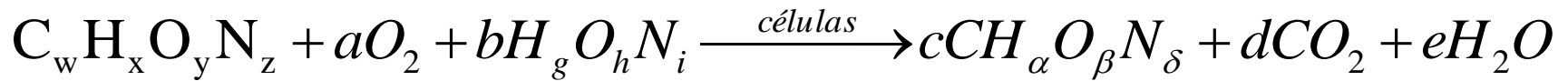
CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

Francisco de Vitoria  
**UFV Madrid**

## 6. AEROBIOSIS



1 **C BALANCE:**  $w = c + d$

2 **N BALANCE:**  $z + b \cdot i = c \cdot \delta$

3 **RER:**  $RQ = \frac{d}{a}$

4 **REDUCTION POWER BALANCE:**  $w \cdot (\gamma_s) + a(-2) = c \cdot (\gamma_b)$

5 **BIOMASS YIELD,  $Y_{x/s}$**   $Y_{x/s} = \frac{c \cdot Mm_{(Biomass)}}{Mm_{(Substrate)}}$

Cartagena99

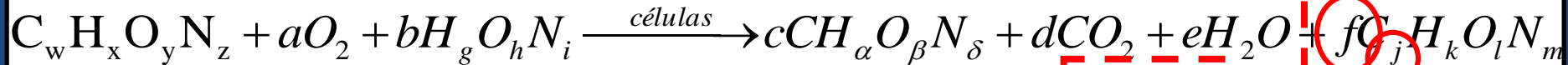
CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 7. PRODUCTION DURING AEROBIOSIS



1 **C BALANCE:**

$$w = c + d + f \cdot j$$

2 **N BALANCE:**

$$z + b \cdot i = c \cdot \delta + f \cdot m$$

3 **RER:**

$$RQ = \frac{d}{a}$$

4 **REDUCTION POWER BALANCE:**

$$w \cdot (\gamma_s) + 2 \cdot a(-2) = c \cdot (\gamma_b) + f \cdot j \cdot (\gamma_p)$$

5 **BIOMASS YIELD,  $Y_{x/s}$**

$$Y_{x/s} = \frac{c \cdot Mm_{(Biomass)}}{Mm_{(Substrate)}}$$

6 **PRODUCT YIELD,  $Y_{p/s}$**

$$Y_{p/s} = \frac{f \cdot Mm_{(Product)}}{Mm_{(Substrate)}}$$

PRODUCT

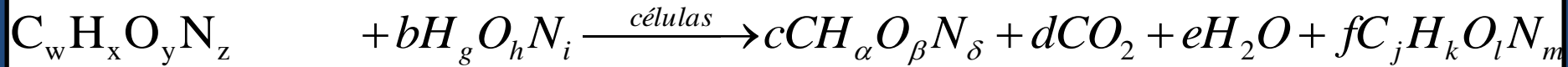
Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Francisco de Vitoria  
UFV Madrid

## 8. GROWTH AND PRODUCTION DURING ANAEROBIOSIS



1 **C BALANCE:**  $w = c + d + f \cdot j$

2 **N BALANCE:**  $z + b \cdot i = c \cdot \delta + f \cdot m$

3 **REDUCTION POWER BALANCE:**  $w \cdot (\gamma_s) + 2 \cdot a \cdot (-2) = c \cdot (\gamma_b) + f \cdot j \cdot (\gamma_p)$

4 **BIOMASS YIELD,  $Y_{x/s}$**   $Y_{x/s} = \frac{c \cdot Mm_{(Biomass)}}{Mm_{(Substrate)}}$

5 **PRODUCT YIELD,  $Y_{p/s}$**   $Y_{p/s} = \frac{f \cdot Mm_{(Product)}}{Mm_{(Substrate)}}$

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---  
ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP: 689 45 44 70

Cartagena99

Francisco de Vitoria  
UFV Madrid

**ANY QUESTION?**

**Cartagena99**

**CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70**

---

**ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70**



**Francisco de Vitoria  
UFV Madrid**



## SECTION II: KINETICS AND BIOREACTOR DESIGN:

### LESSON 9.4. - Enzymatic kinetics, microbial kinetics and metabolic stoichiometry –Metabolic Stoichiometry

Cartagena99

CLASES PARTICULARES, TUTORÍAS TÉCNICAS ONLINE  
LLAMA O ENVÍA WHATSAPP: 689 45 44 70

---

ONLINE PRIVATE LESSONS FOR SCIENCE STUDENTS  
CALL OR WHATSAPP:689 45 44 70

UNIVERSIDAD FRANCISCO DE VITORIA