PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

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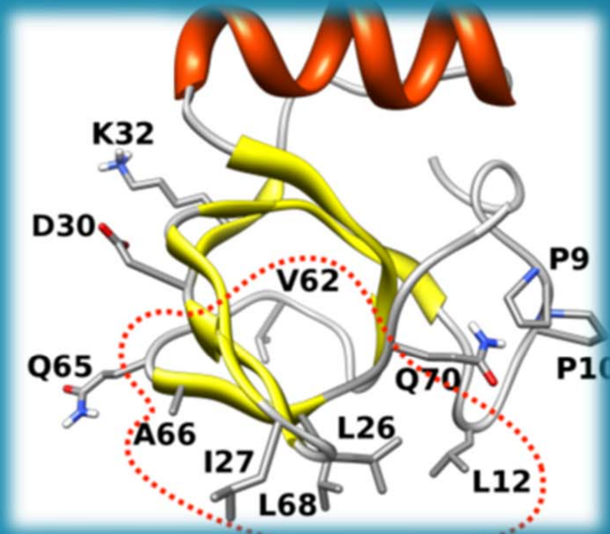
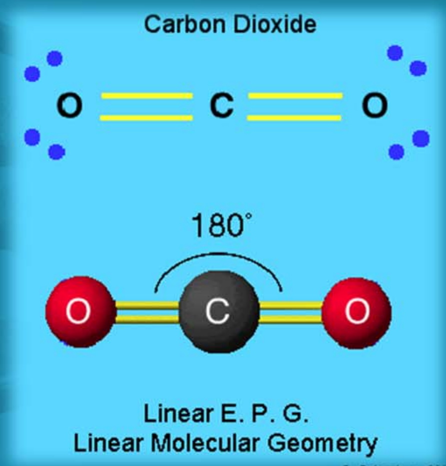
- WHY ?
- HOW TO DETECT ?
- IS IT POSSIBLE TO CURE ?





A trial...
to understand
by exact sciences !

KU LEUVEN

PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

INTRODUCTION

: Exact sciences

PARAMETERS

SEASONAL VARIABLES

DOMESTIC VARIABLES

CONSTANTS

NATURAL LAWS

THERMODYNAMICS

MICROBIOLOGY

CHEMISTRY

PHYSICS

LOCATIONS

FIELDS

MALTHOUSES

BREWERIES

DISPENSING PLACES

CONTAINERS

- GLASS BOTTLES
- PET BOTTLES
- CANS
- KEGS

: Exact sciences

MICROBIOLOGY | CHEMISTRY | PHYSICS | THERMODYNAMICS

LOCATIONS

FIELD

MALTHOUSE

BREWERY

DISPENSING PLACE

CONTAINER
- GLASS BOTTLE
- PET BOTTLE
- CAN
- KEG

PARAMETERS

SEASONAL VARIABLES
- GRAIN CONTAMINATION RATE
- GRAIN CONTAMINATION TYPE
- Class 2 hydrophobins content

DOMESTIC VARIABLES
- CO_2 content of beer
- BEER DISPENSING TEMPERATURE or ***CO_2 pressure in bottle by beer dispensing***
- Surface properties of intern wall of the container

CONSTANTS
- Physico- chemical properties of CO_2
- Specific surface properties of Class 2 hydrophobins (basic properties and functional consequences)

NATURAL LAWS

Water activity: a_w

Law of BOYLE-MARIOTTE

Law of HENRY

Law of YOUNG-LAPLACE

PHYSICAL INTERACTIONS

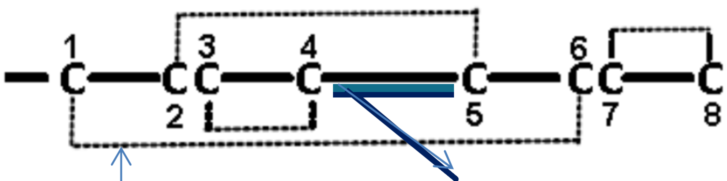
CHEMICAL BONDS

SURFACE PROPERTIES INVOLVED BY PRIMARY GUSHING :

1. Nanoscale approach

1.1. CLASS 2 Hydrophobins

Primary structure of CLASS 2 hydrophobins

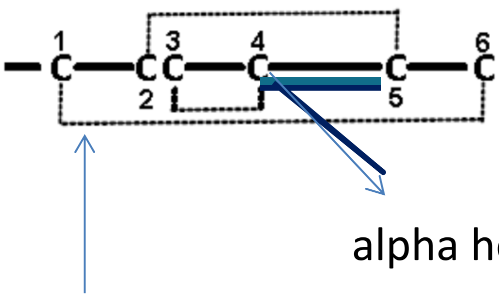


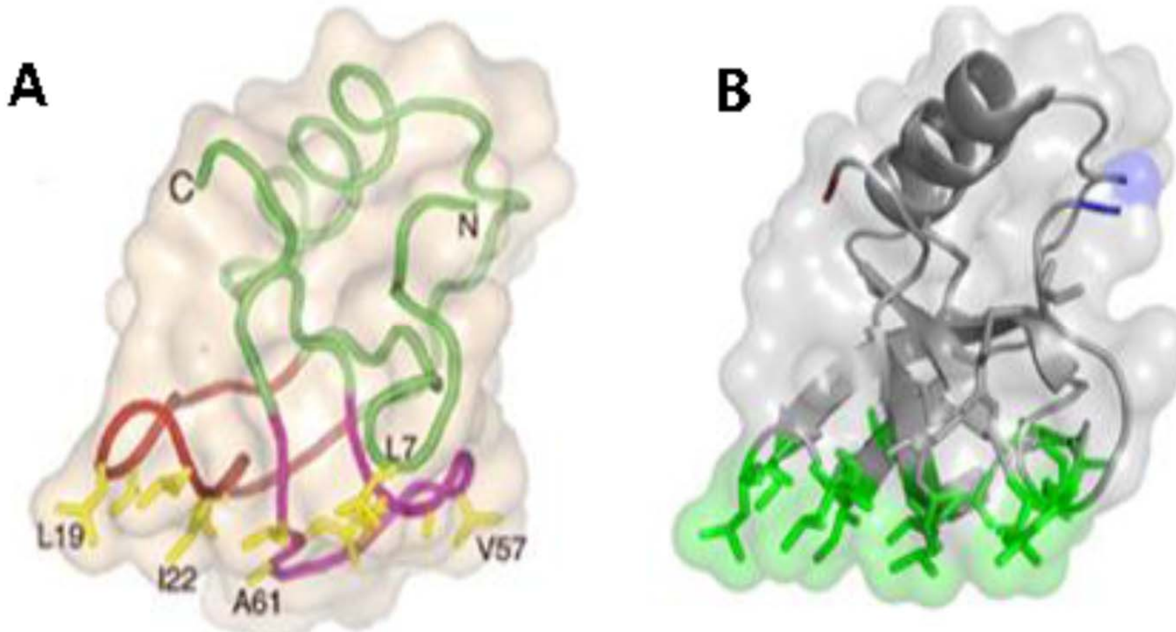
alpha helix

disulfide bridges

SURFACE CHEMISTRY OF CLASS 2 HYDROPHOBINS : NANOASPECTS

Primary and ternary structure of CLASS 2 hydrophobins





LEGEND:

A: X-Ray crystal structure of the Class 2 hydrophobin HFB II in which the **two hairpins** are shown in **red** and **purple**. Some aliphatic chains of hydrophobic amino acids of the hydophobic patch are shown in yellow.

B: X-Ra(Hakanpää *et al.*, 2004)f the Class 2 hydrophobin HFB II in which the **hydrophobic patch** is shown in green and the α-helix (spirale) and the b-sheets (arrow) are in cartoon representation.

(Szilvay, 2007)

SURFACE CHEMISTRY OF CLASS 2 HYDROPHOBINS : NANOASPECTS

SCIENTIFIC AND COMPREHENSIVE APPROACH

SPECIFIC physico-chemical properties of CLASS 2 HYDROPHOBINS

SPECIFIC PROPERTY OF CLASS 2 HYDROPHOBIN

Langmuir

Article

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Surface Pressure and Elasticity of Hydrophobin HFBII Layers on the Air–Water Interface: Rheology Versus Structure Detected by AFM Imaging

Rumyana D. Stanimirova,[†] Theodor D. Gurkov,[†] Peter A. Kralchevsky,[†,*] Konstantin T. Balashev,[‡] Simeon D. Stoyanov,[§,#] and Eddie G. Pelan[§]

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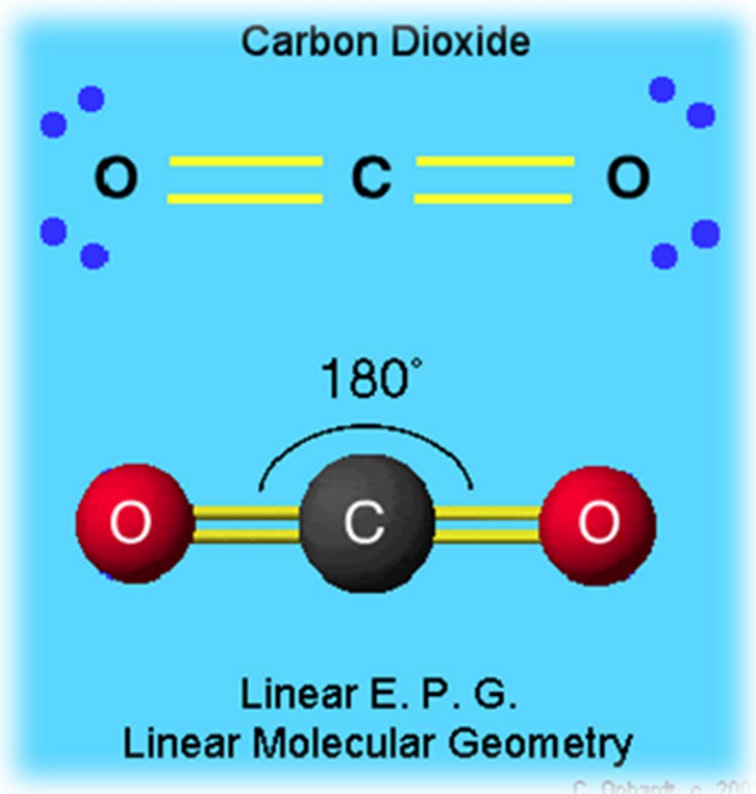
PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

SURFACE PROPERTIES INVOLVED BY PRIMARY GUSHING :
nanoscale approach

2. Gaseous CO_2

SURFACE PROPERTIES OF GASEOUS CARBONIC ACID : NANOASPECTS



Though the presence of two dipoles
Carbon dioxide is a <u>hydrophobic gas</u>
because…
both radicals face each other and
annihilate their “electron donor” properties

PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

SURFACE PROPERTIES INVOLVED BY PRIMARY GUSHING :
nanoscale approach

3. Hydrophobic interaction between gaseous CO_2 and the hydrophobic patch of CLASS 2 hydrophobins

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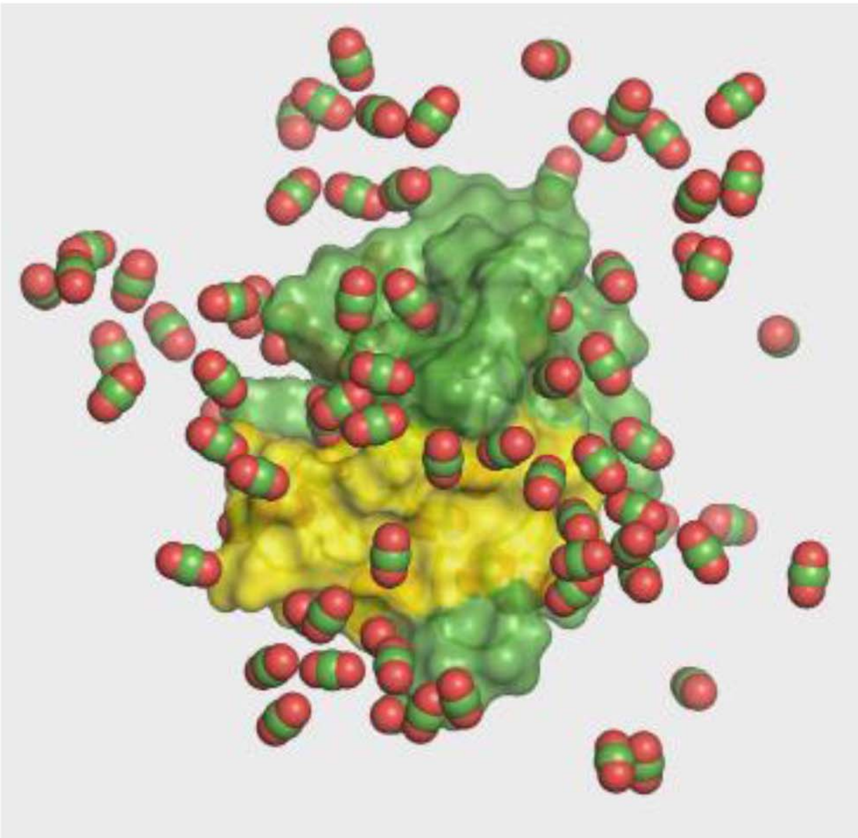

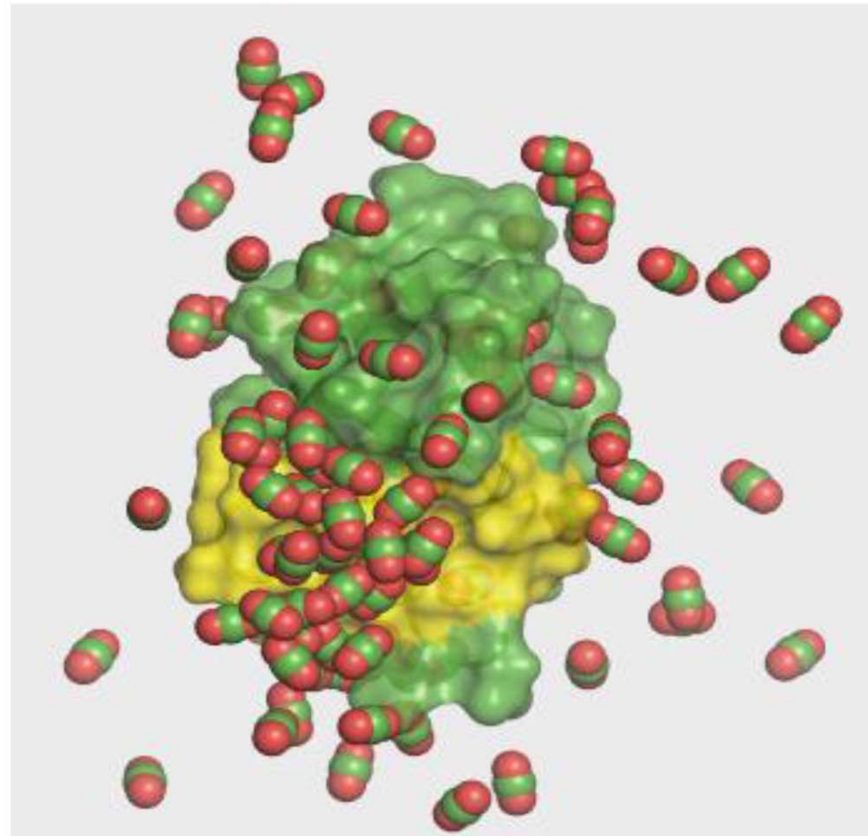

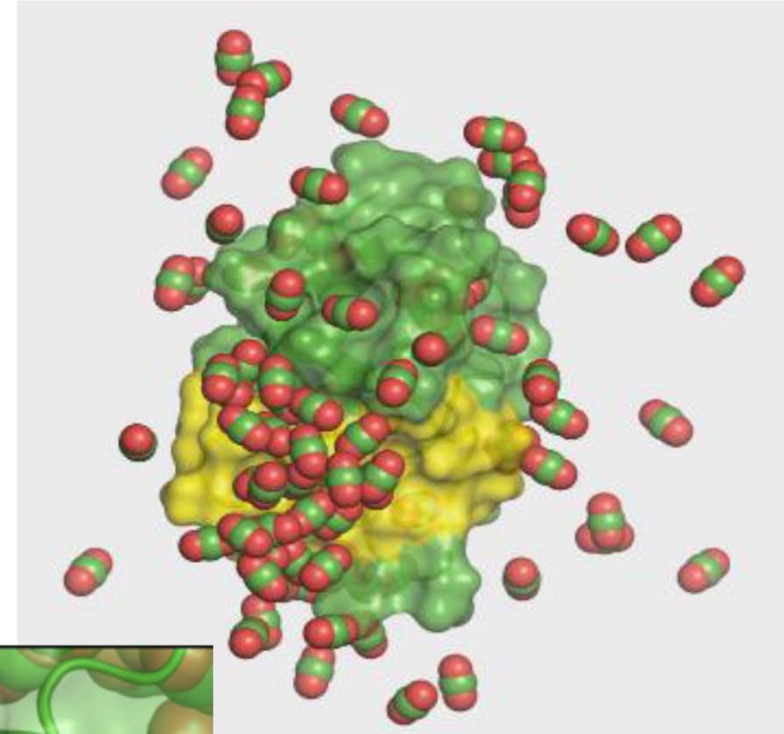

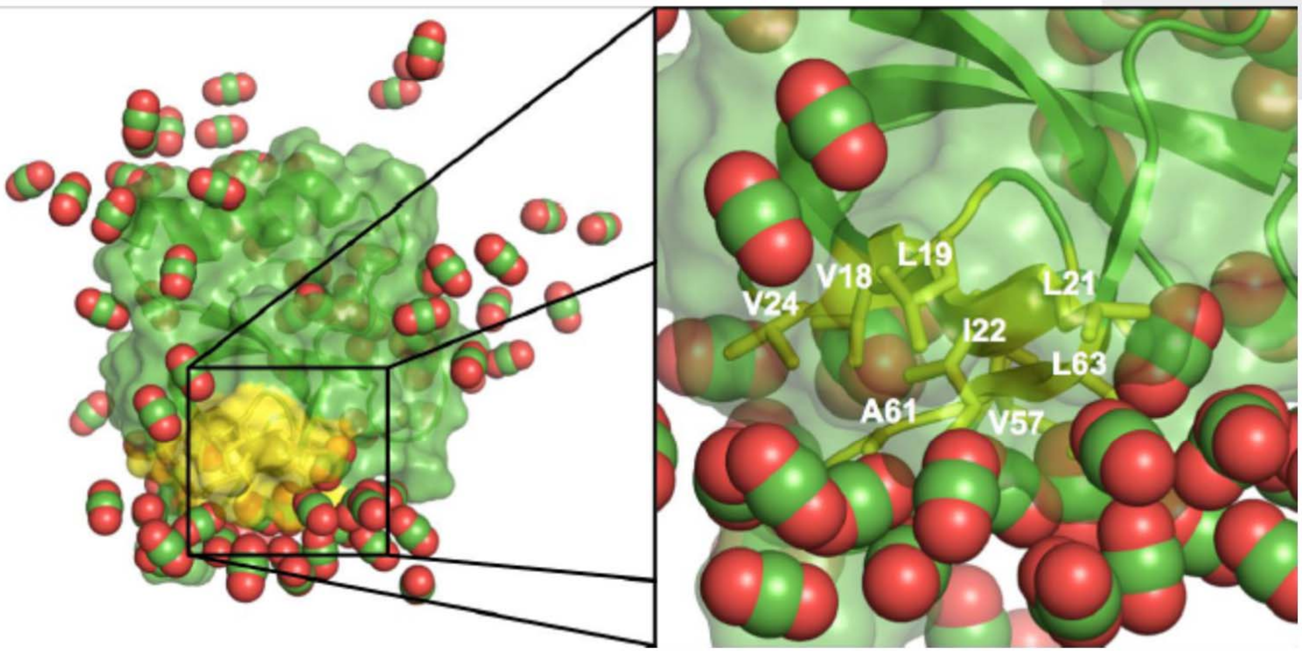

V24
V18
L19
L21
I22
L63
A61
V57

PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

SURFACE PROPERTIES INVOLVED BY PRIMARY GUSHING :
nanoscale approach

4. Nanobombs hypothesis

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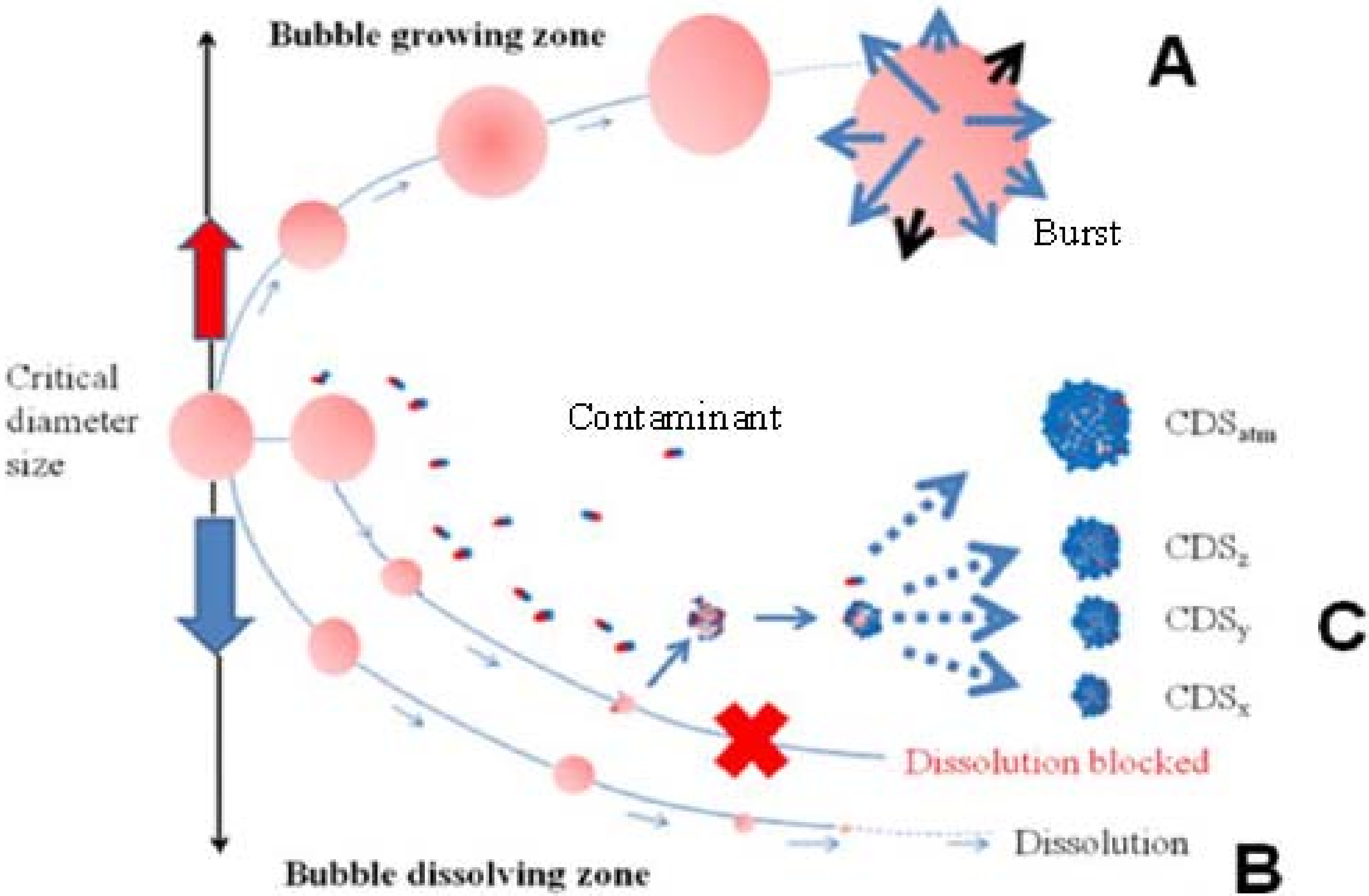

Bubble growing zone
A
Burst
Critical diameter size
Contaminant
CDS_{atm}
CDS_z
CDS_y
C
CDS_x
Dissolution blocked
Dissolution
B
Bubble dissolving zone

SURFACE PROPERTIES INVOLVED BY PRIMARY GUSHING :

2. From an hypothesis to a sustainable mechanism

EXACT ASPECTS OF PRIMARY GUSHING AND CURATIVE APPROACHES

Prerequesites

TO INDUCE PRIMARY GUSHING

Parameters

THAT INFLUENCE THE <u>ONSET</u> OF PRIMARY GUSHING

Parameters

THAT INFLUENCE THE <u>VOLUME EXPULSED</u> BY PRIMARY GUSHING

PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

SURFACE PROPERTIES INVOLVED BY PRIMARY GUSHING :

2. From an hypothesis till a sustainable mechanism

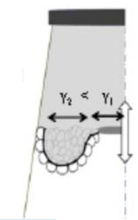
2.1. *PREREQUESITES*
TO <u>INDUCE</u> primary

EXACT ASPECTS OF PRIMARY GUSHING AND CURATIVE APPROACHES

Prerequesites

TO INDUCE PRIMARY GUSHING

HYDROPHILIC
SOLID SURFACE



GASEOUS CO_2
ATHMOSPHERE
(Hydrophobic gas)

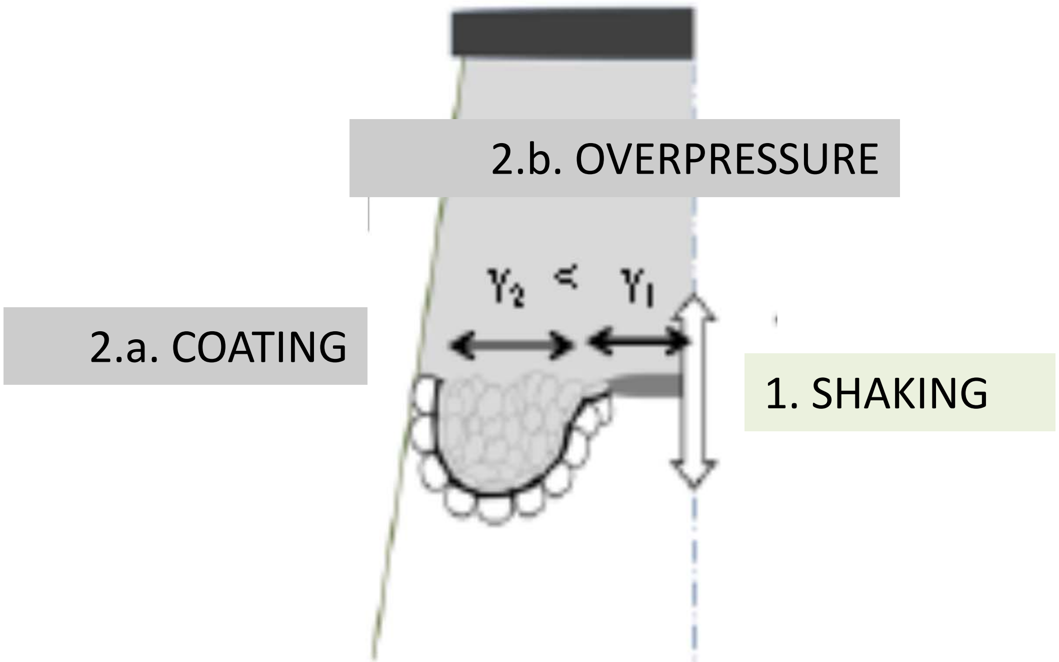
HYDROPHILIC
LIQUID SURFACE

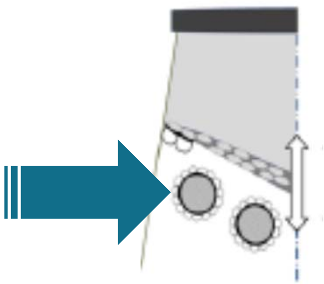
CRITICAL QUANTITY
OF CLASS 2 HYDROPHOBINS

EXACT ASPECTS OF PRIMARY GUSHING AND CURATIVE APPROACHES

Prerequesites

TO <u>INDUCE</u> PRIMARY GUSHING

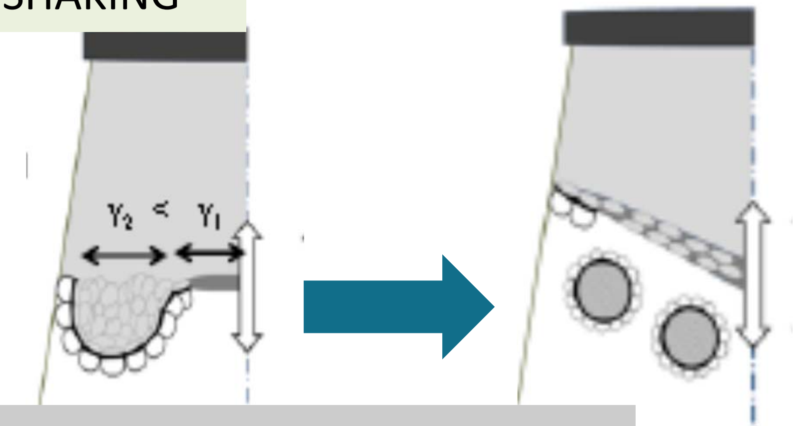




EXACT ASPECTS OF PRIMARY GUSHING AND CURATIVE APPROACHES

Prerequesites
TO INDUCE PRIMARY GUSHING

1. SHAKING



2.a. REDESOLVING OF CO_2

2.b.CLOSING OF CLASS 2 HYDROPHOBIN SHELL
Law of YOUNG-LAPLACE

PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

SURFACE PROPERTIES INVOLVED BY PRIMARY GUSHING :

2. From an hypothesis till a sustainable mechanism

2.2. PARAMETERS that INFLUENCE the ONSET of primary gushing

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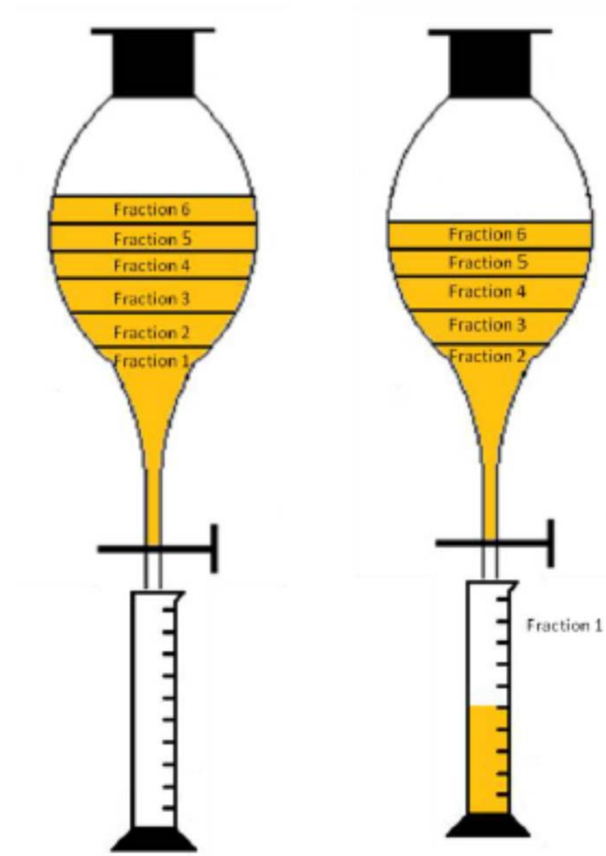
PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

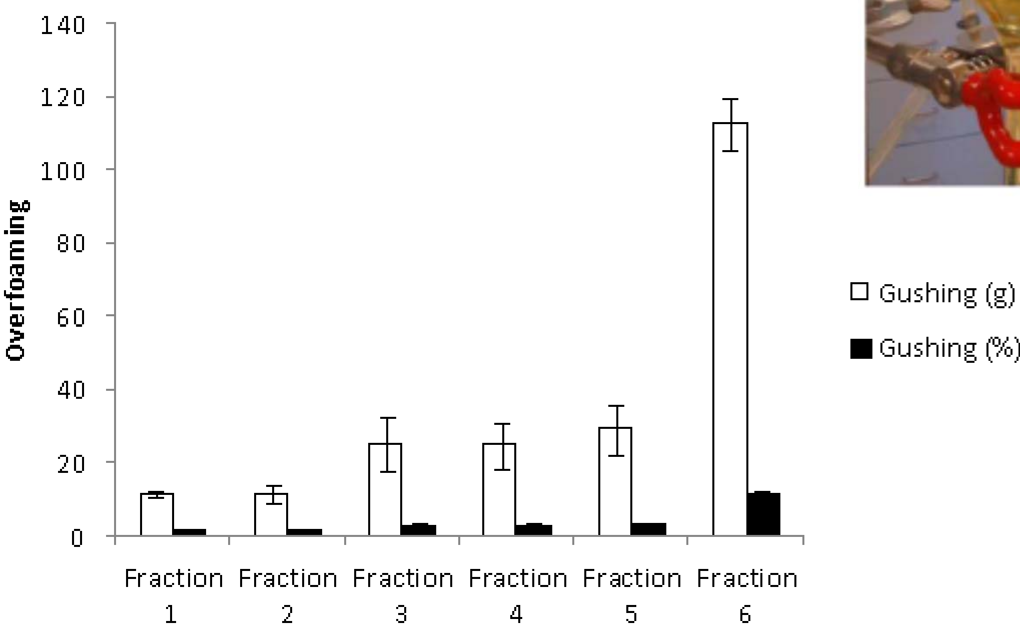
2. From an hypothesis till a sustainable mechanism

2.2. ***PARAMETERS*** ***that AFFECT the ONSET of primary gushing***

2.2.1. Where are the nanobubbles in non shaked bottles ?

Fraction	Volume
Fraction 1	70 mL
Fraction 2	50 mL
Fraction 3	50 mL
Fraction 4	50 mL
Fraction 5	50 mL
Fraction 6	50 mL





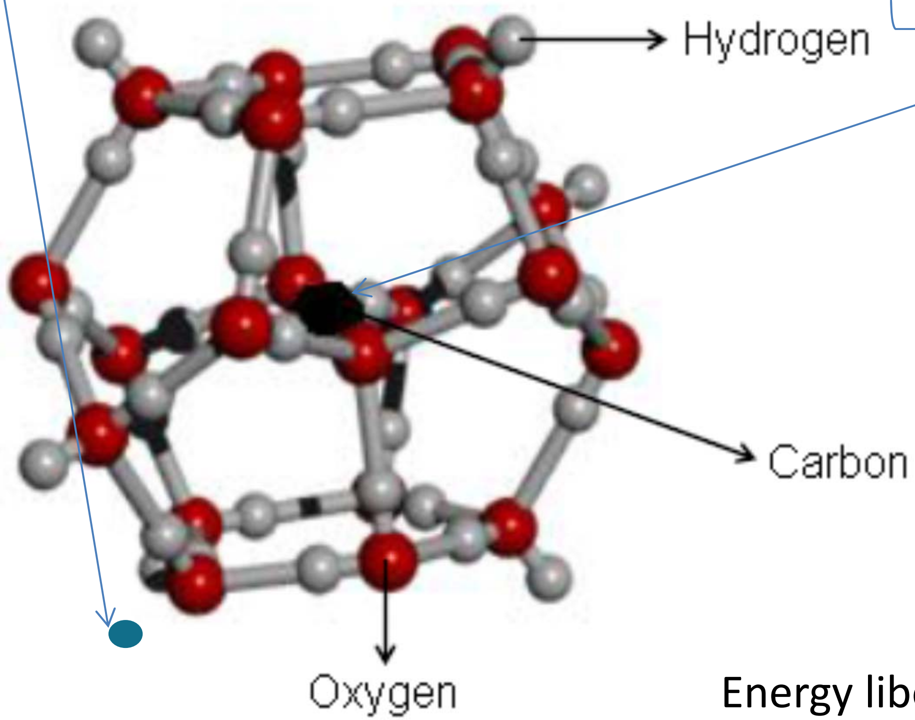
Parameters that

INFLUENCE THE ONSET OF PRIMARY GUSHING

ENERGY THAT PROVOKES
ONSET NUCLEATION

QUANTITY OF NANOBOMBS REQUIRED TO START THE
DISRUPTION OF THE BONDS
BETWEEN **CO_2 and WATER**

Volume of liquid expulsed



Energy liberated by CO_2 release

EXACT ASPECTS OF PRIMARY GUSHING AND CURATIVE APPROACHES

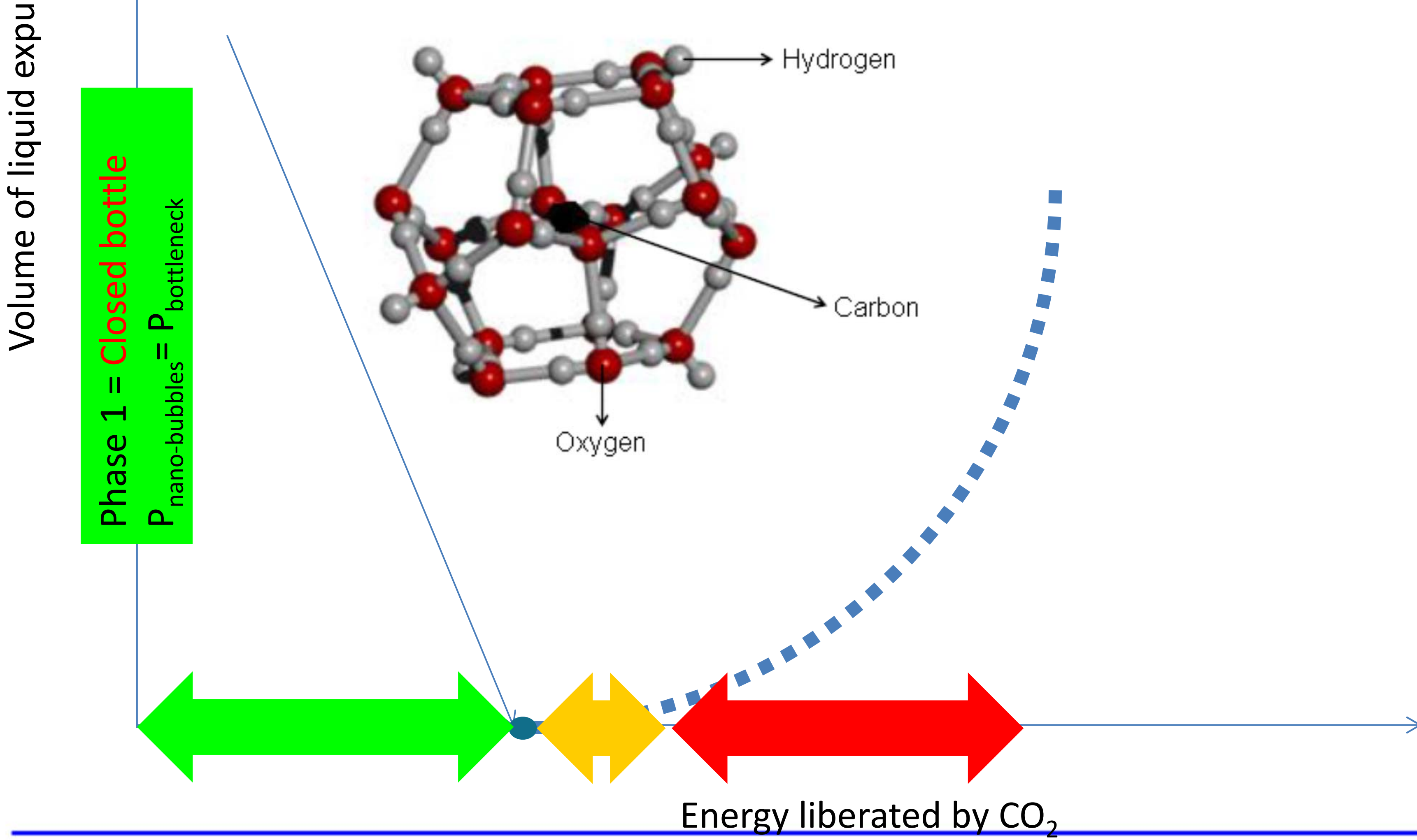
Parameters that *AFFECT THE ONSET OF PRIMARY GUSHING*

explosion

Parameters that

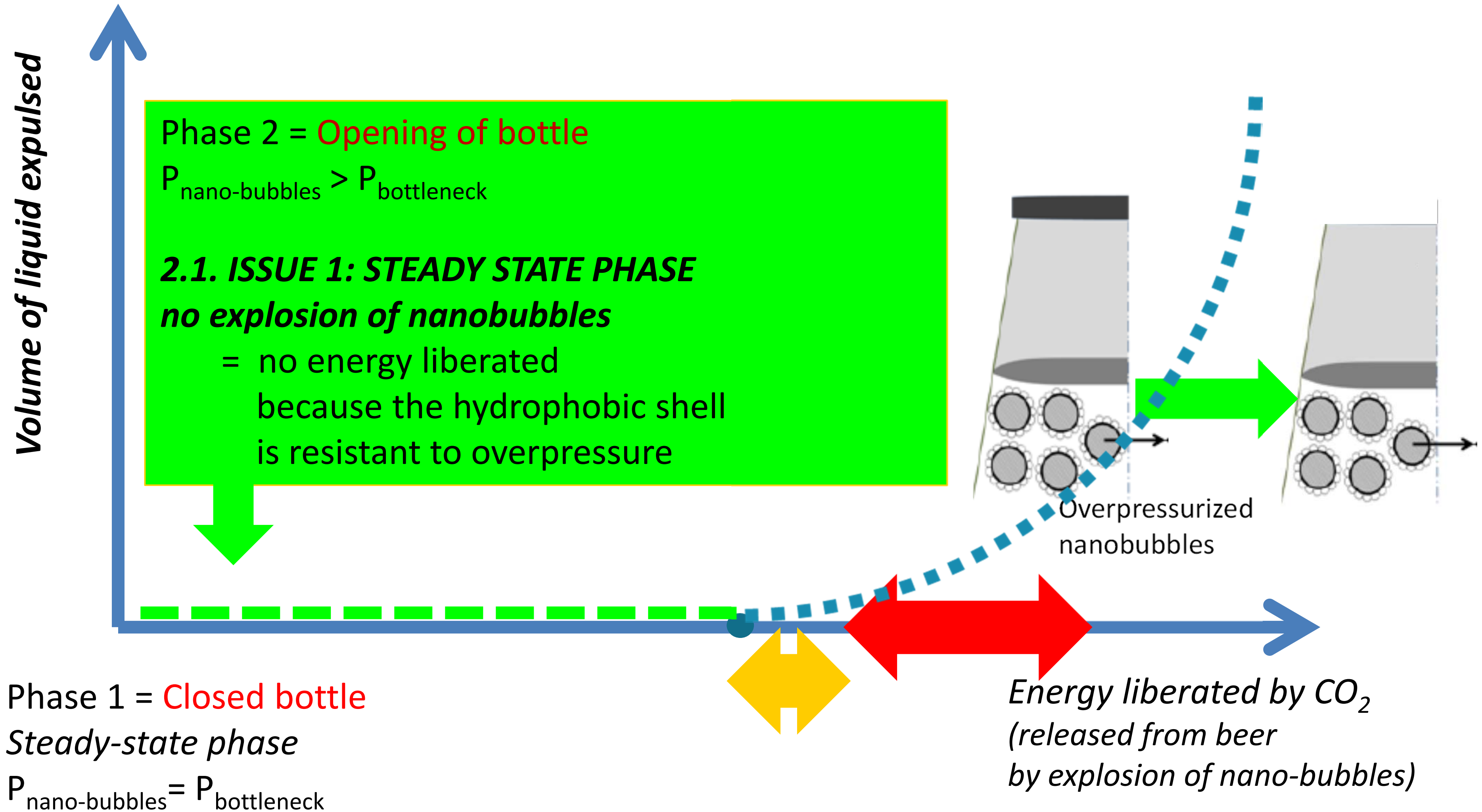
AFFECT THE ONSET OF PRIMARY GUSHING

In practice, **three issues** are possible after opening a CONTAMINATED beer bottle :



Parameters that

INFLUENCE THE ONSET OF PRIMARY GUSHING



PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

SURFACE PROPERTIES INVOLVED BY PRIMARY GUSHING :

2. From an hypothesis till a sustainable mechanism

2.3. ***PARAMETERS that INFLUENCE the VOLUME EXPULSED by primary gushing***

Parameters that
INFLUENCE THE ONSET OF PRIMARY GUSHING

Volume of liquid expulsed

Phase 2 = Opening of bottle

$P_{nano\text{-}bubbles} > P_{bottleneck}$

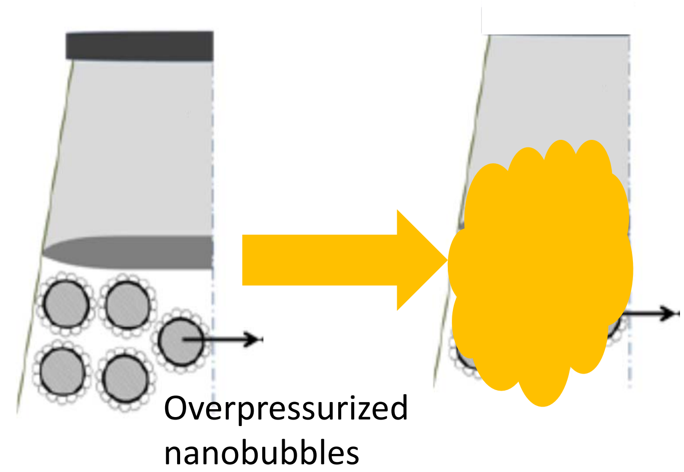
2.2. CASE 2: RAISE IN NECK

= energy liberated

because the hydrophobic shell is not resistant to overpressure

BUT

hydrogen bonds between CO_2 and water are strong enough to limit gaseous CO_2 escape



Energy liberated by CO_2
(released from beer
by explosion of nano-bubbles)

Parameters that

INFLUENCE THE ONSET OF PRIMARY GUSHING

Phase 2 = Opening of bottle

$P_{nano\text{-}bubbles} > P_{bottleneck}$

2.3. CASE 3: STRONG GUSHING

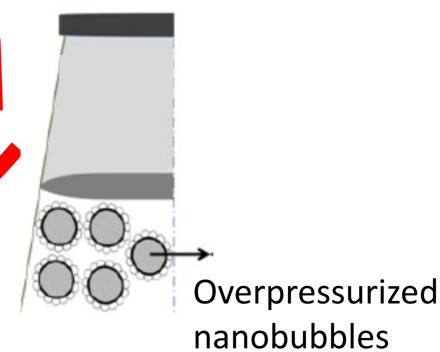
explosion of nanobubbles

= strong quantity of energy liberated because the hydrophobic shell is NOT resistant to overpressure

AND

hydrogen bonds between CO_2 and water are **no longer strong enough** to prevent STRONG gaseous CO_2 escape from the liquid

Volume of liquid expulsed



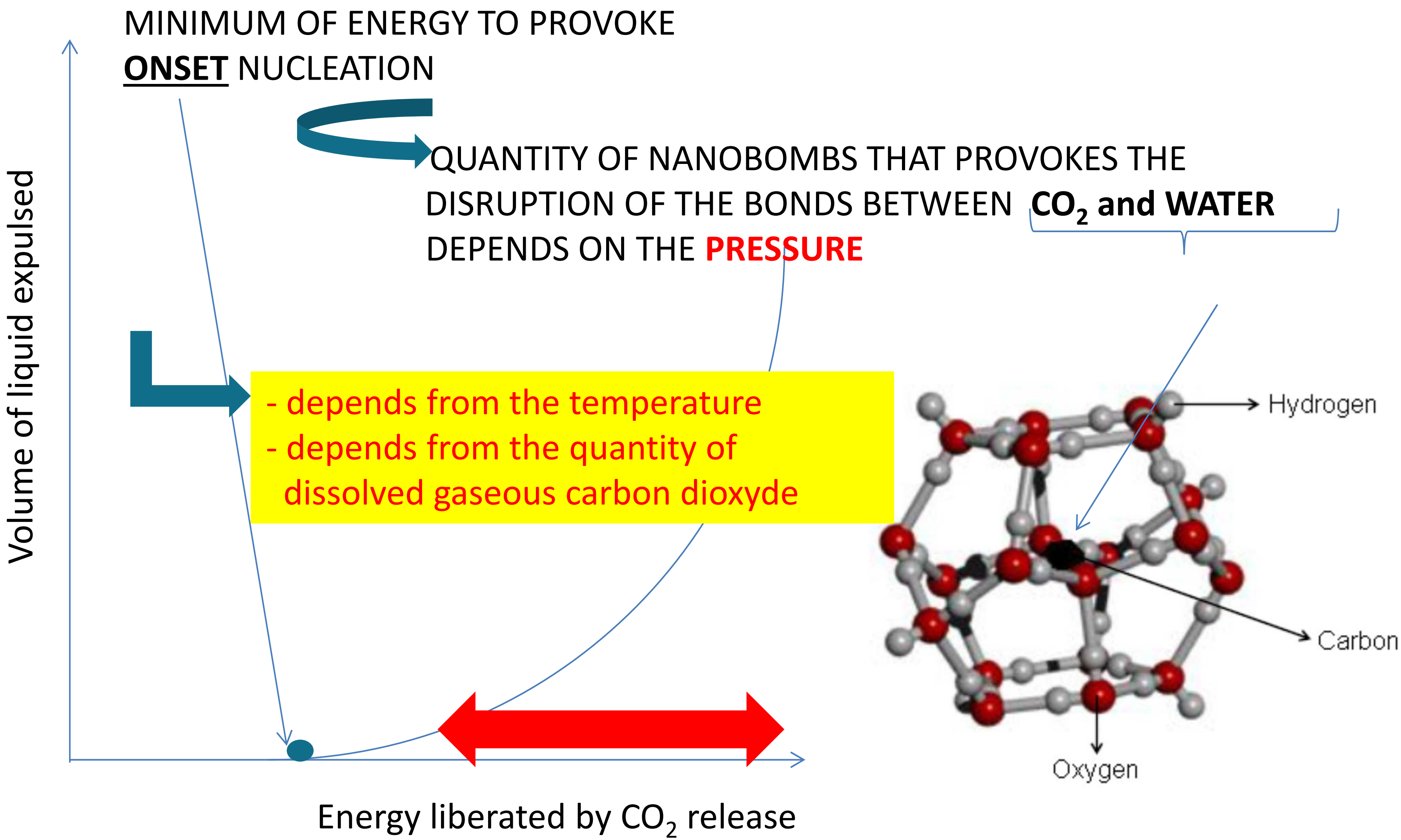
Phase 1 = Closed bottle

Steady-state phase

$P_{nano\text{-}bubbles} = P_{bottleneck}$

Energy liberated by CO_2 (released from beer by explosion of nano-bubbles)

Parameters that
INFLUENCE THE ONSET OF PRIMARY GUSHING



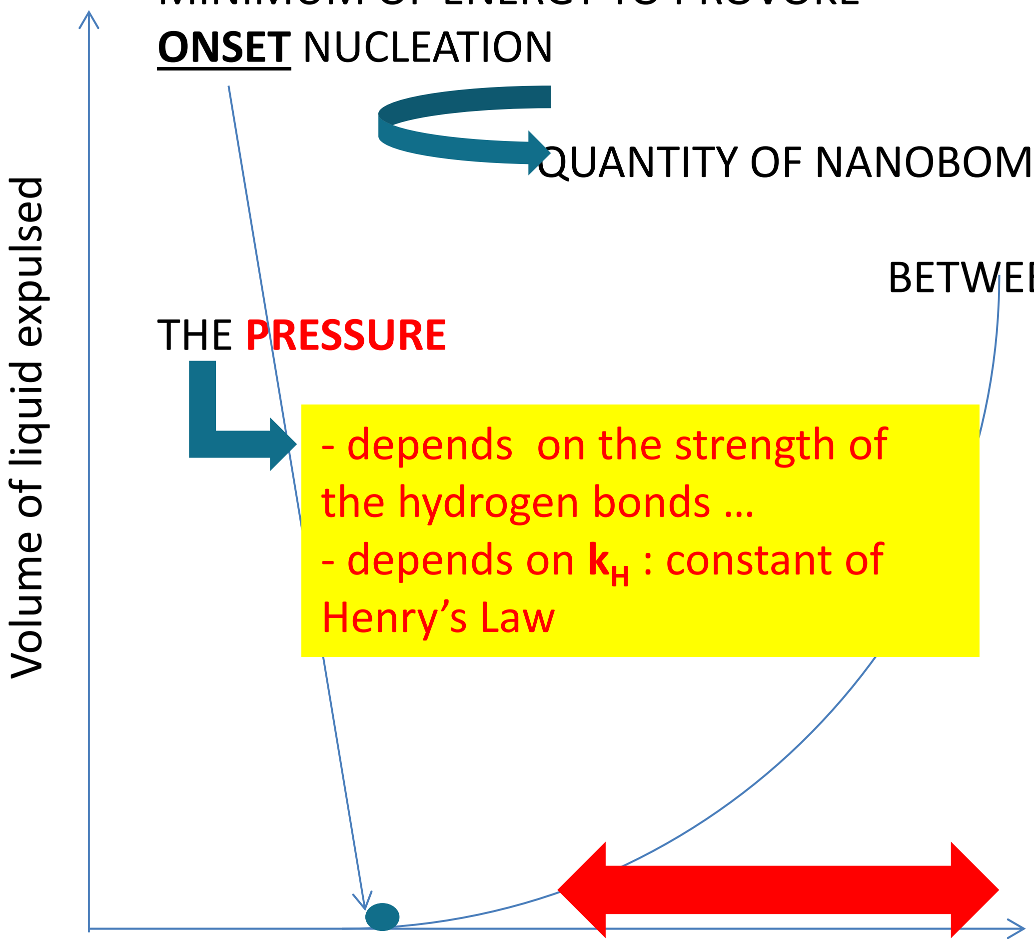
Parameters that
INFLUENCE THE ONSET OF PRIMARY GUSHING

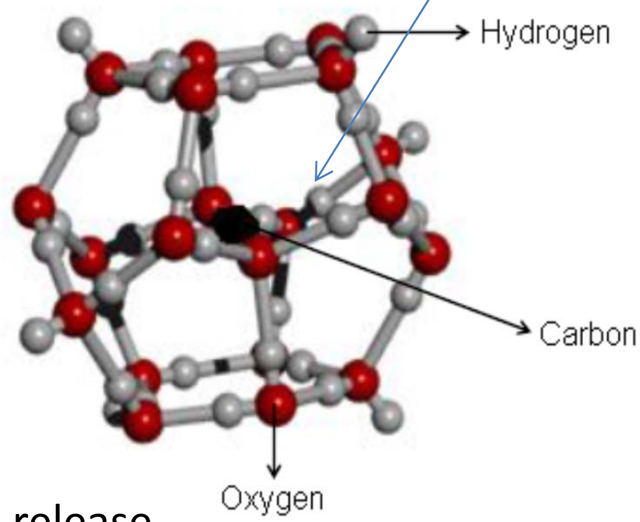
MINIMUM OF ENERGY TO PROVOKE
ONSET NUCLEATION

QUANTITY OF NANOBOMBS THAT PROVOKES THE DISRUPTION OF THE BONDS BETWEEN **CO_2 and WATER** DEPENDS ON

THE **PRESSURE**

- depends on the strength of the hydrogen bonds …
- depends on **k_H** : constant of Henry's Law

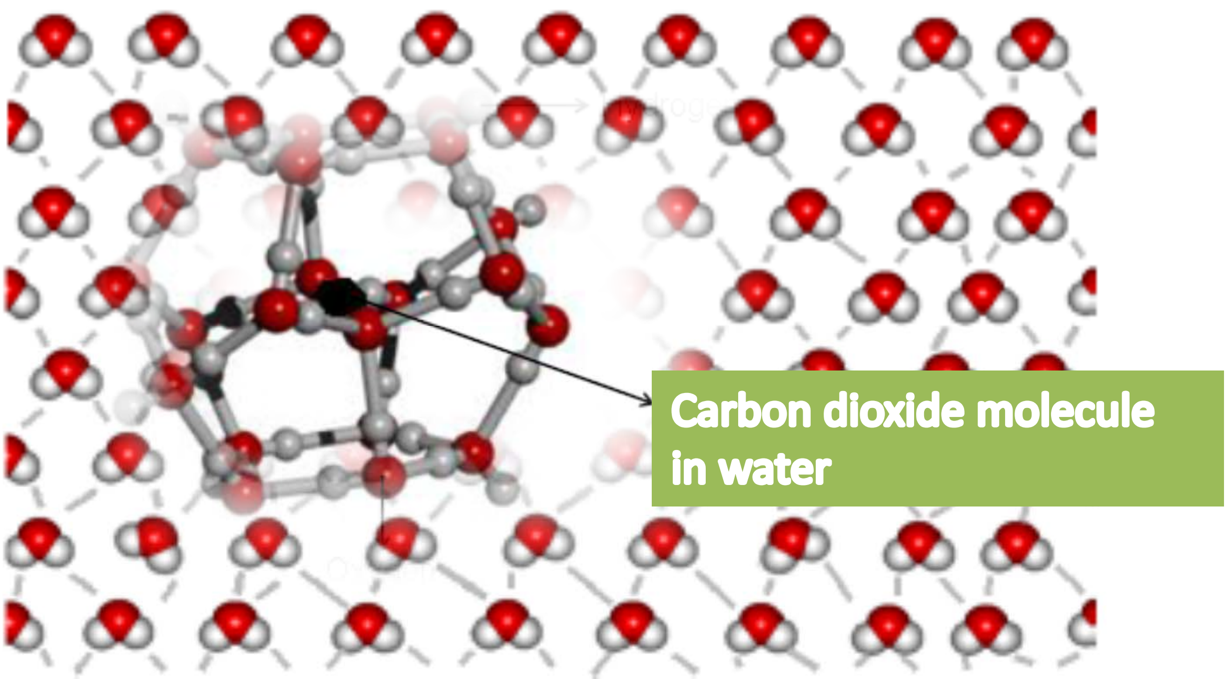


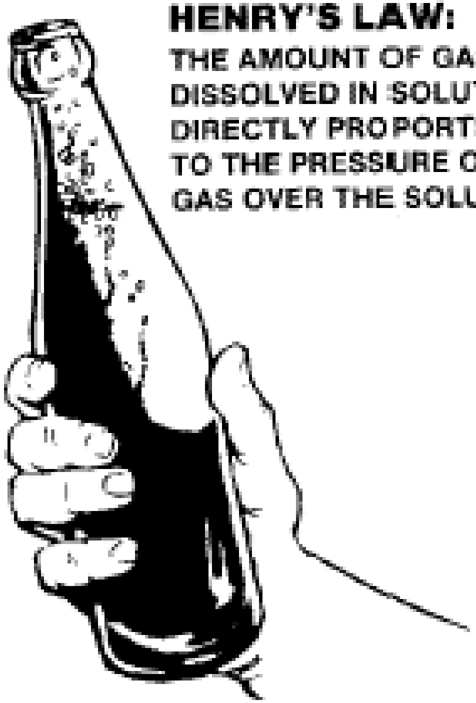


EXACT ASPECTS OF PRIMARY GUSHING AND CURATIVE APPROACHES

Parameters

THAT INFLUENCE THE VOLUME EXPULSED BY PRIMARY GUSHING



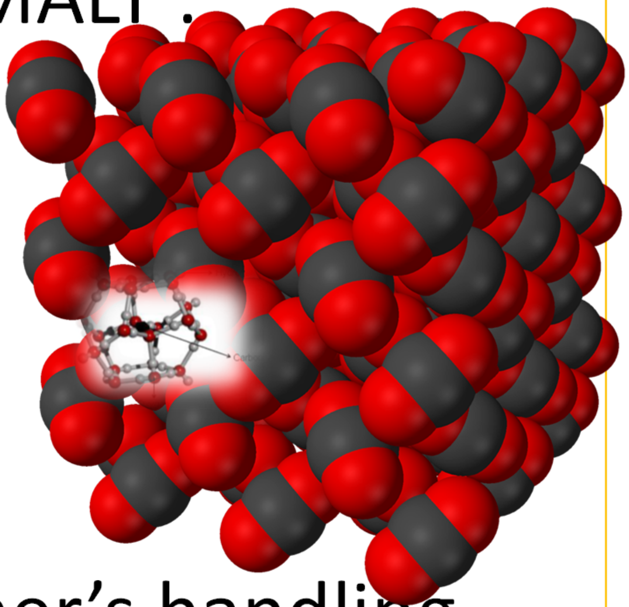


PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

CONCLUSIONS

RISK MANAGEMENT
BY PRIMARY GUSHING

- AN **IDENTIC** CONTAMINATED MALT :



- depending on the brewery,
- depending on the beer type,
- depending on the beer pub,
- depending on the beer consumer's handling,
- depending on the container can provoke :
- **no**, poor, or **severe** primary gushing and desastrous financial damages.

PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

Nanoscale approach

RISK MANAGEMENT
BY
PRIMARY GUSHING

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PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

THANKS
FOR YOUR ATTENTION …

CHEERS !!!

PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

Nanoscale approach

RISK MANAGEMENT
BY
PRIMARY GUSHING

PREDICTION methods
CURATIVE practices

KU LEUVEN

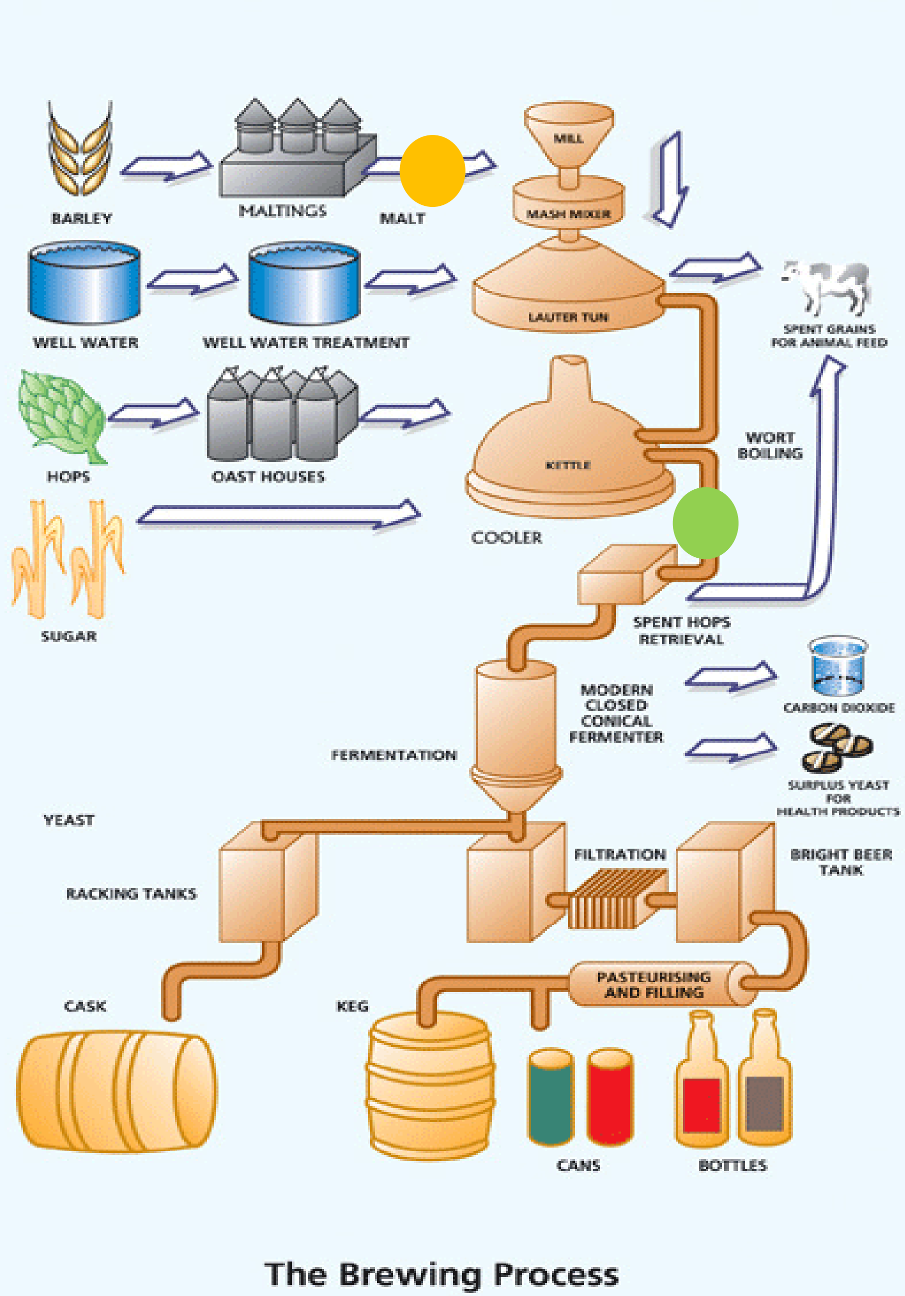

STAN DARD

PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

Nanoscale approach

RISK MANAGEMENT
BY
PRIMARY GUSHING

PREDICTION methods



PREVENTIVE MANAGEMENT

- normal QC :

  microbial detection

  contaminant identification

  lab-scale brews or **better** ,

  Single malt brews at industrial scale

  - **Qualitative presence of Class 2 hydrofobines by ELISA (*VTT - Finland*)**
  - **Primary gushing assessment by MC-*t* and confirmation by DLS**

PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

Nanoscale approach

RISK MANAGEMENT
BY
PRIMARY GUSHING

PREDICTION methods

CONDITIONS TO OBSERVE OVERFOAMING BY M*Carlsberg*-t :

- **Hydrophilic surface of container**
- **Energy liberated by nucleation of CO_2**
  - **explosion of nanobombs**
  - **rupture of hydrogen bonds**

PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

Nanoscale approach

RISK MANAGEMENT
BY
PRIMARY GUSHING

PREDICTION methods

MCarlsberg-t :

<u>overfoaming volumes</u> of sparkling water are
"in some cases" <u>disputable values</u> between
malsters and brewers

Report of collaborative trial held by EBC Analysis Committee in 2003 concerning evaluation of **MCarlsberg-t**

Table 1: Original data from the collaborative trial. All the results are expressed in grams.

Laboratory	Sample			
	Malt A	Malt B	Malt C	Malt D
	Weight of beer lost on opening (g)			
1	0	58	65	107
2	0	22	0	1
3	0	94	9	60
4	0	13	8	37
5	0	80	3	63
6	0	95	0	13
7	0	28	27	24
8	0	22	0	3
9	3	80	0	113
10	0	150	103	124
Average	0	64	22	55
Min.	0	13	0	1
Max.	3	150	103	124
Std Dev	0.95	43.8	35.1	46.6

P. Vaag, P. Riis, A-D. Knudsen, S. Pedersen & E. Meiling. A simple and rapid test for gushing tendency in brewing materials, Proceedings 24th EBC Congress, Oslo 1993, IRL Press, 155-162.

PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

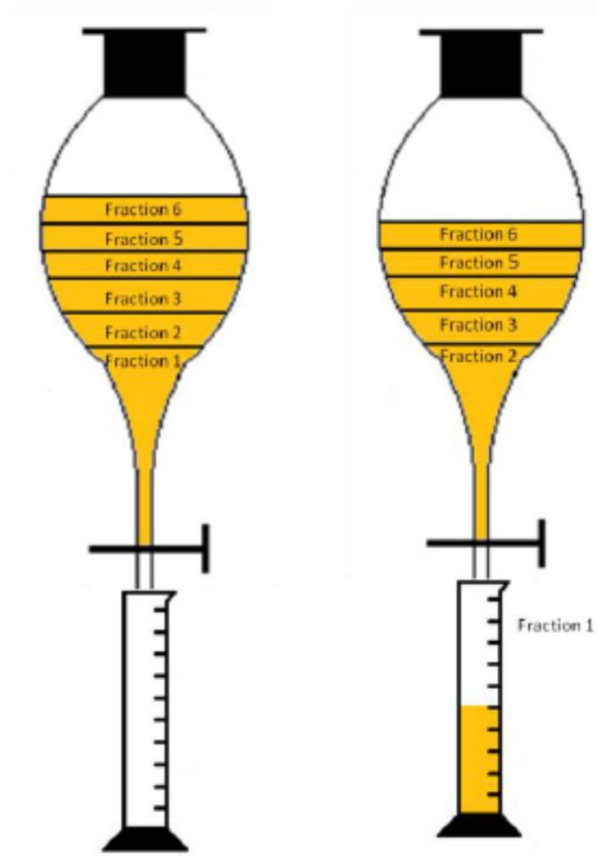
Nanoscale approach

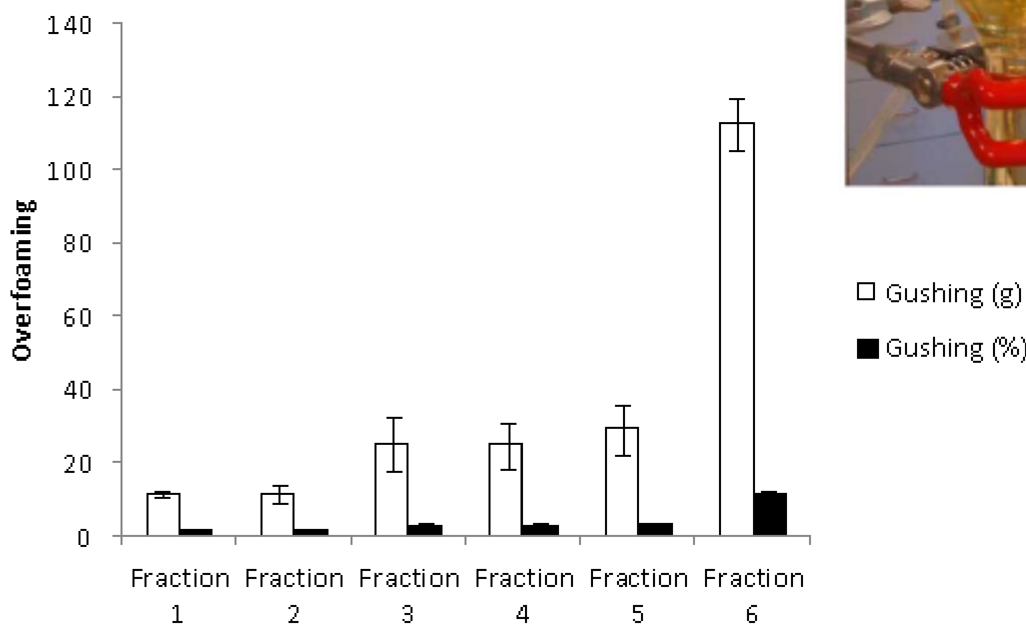
RISK MANAGEMENT
BY
PRIMARY GUSHING

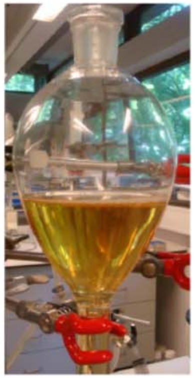
PREDICTION methods

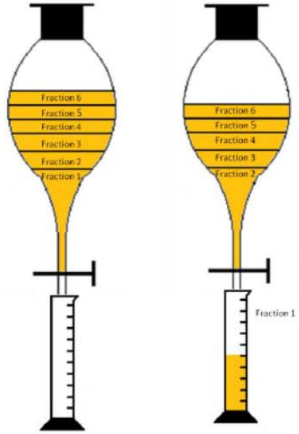
M*Carlsberg*-t (MC-*t*)
<u>checked</u> (*confirmed*) by the DLS detection

Fraction	Volume
Fraction 1	70 mL
Fraction 2	50 mL
Fraction 3	50 mL
Fraction 4	50 mL
Fraction 5	50 mL
Fraction 6	50 mL









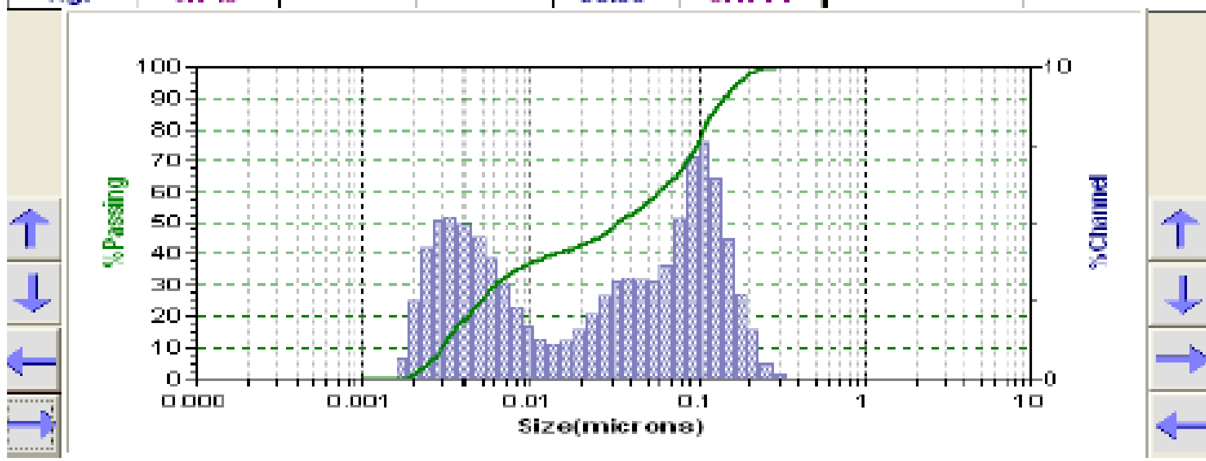
NANOFLEX
Microtrac Gmbh

OVERFOAMATE OF M*Carlsberg*-t (MC-*t*) confirmed by the DLS detection

Beer with high gushing:

Flaschenbier 214 — S/N: U2343ES

- Summary -		- Size % -		- Percentiles -		- Peaks Summary -		
Data	Value	Size(um)	%Tile	%Tile	Size(um)	Dia(um)	Vol%	Width
MI(um):	0.0567			10.00	0.00294	0.0859	60.9	0.11
MN(um):	0.00282			20.00	0.00411	0.00405	39.1	0.00
MA(um):	0.00877			30.00	0.00607			
CS:	684.5			40.00	0.01399			
SD:	0.0587			50.00	0.0338			
MW:	1.22E+07			60.00	0.0584			
Mz:	0.0528			70.00	0.0870	UDef Name	UDef Data	
σι:	0.0549			80.00	0.1103			
Ski:	0.557			90.00	0.1419			
Kg:	0.740			95.00	0.1714			



Particle Metrix GmbH Am Latumer See 13, 40668 Meerbusch, Tel.: 02150-6347, boeck@particle-metrix.de

PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

Nanoscale approach

RISK MANAGEMENT
BY
PRIMARY GUSHING

CURATIVE aspects

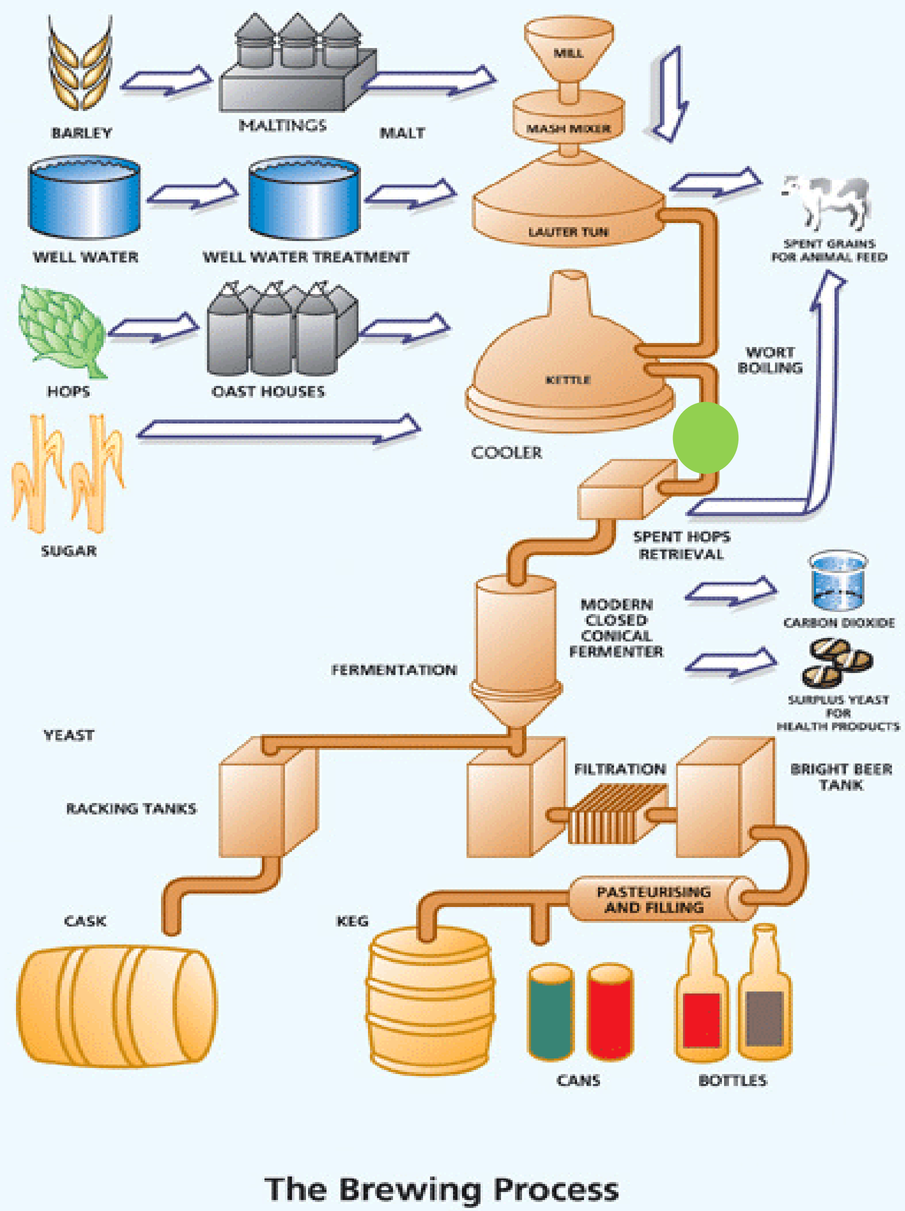
PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

Nanoscale approach

RISK MANAGEMENT
BY
PRIMARY GUSHING

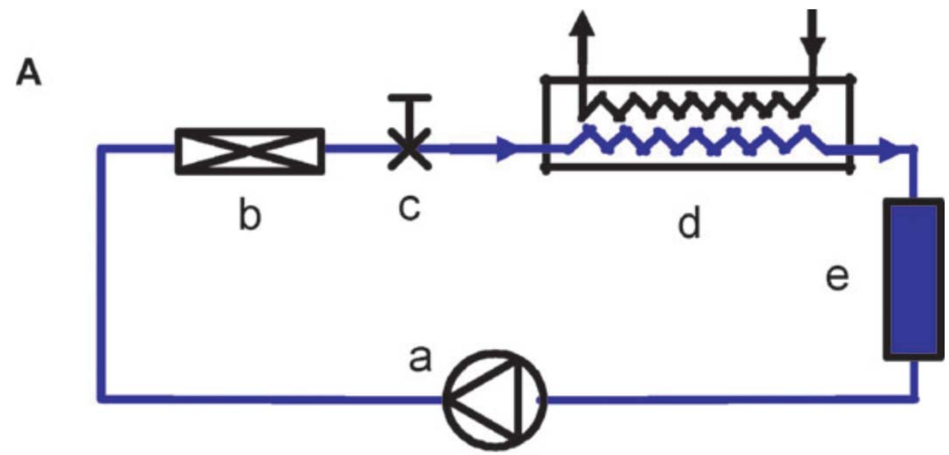
CURATIVE aspects

Inactivation of the hydophobic patch

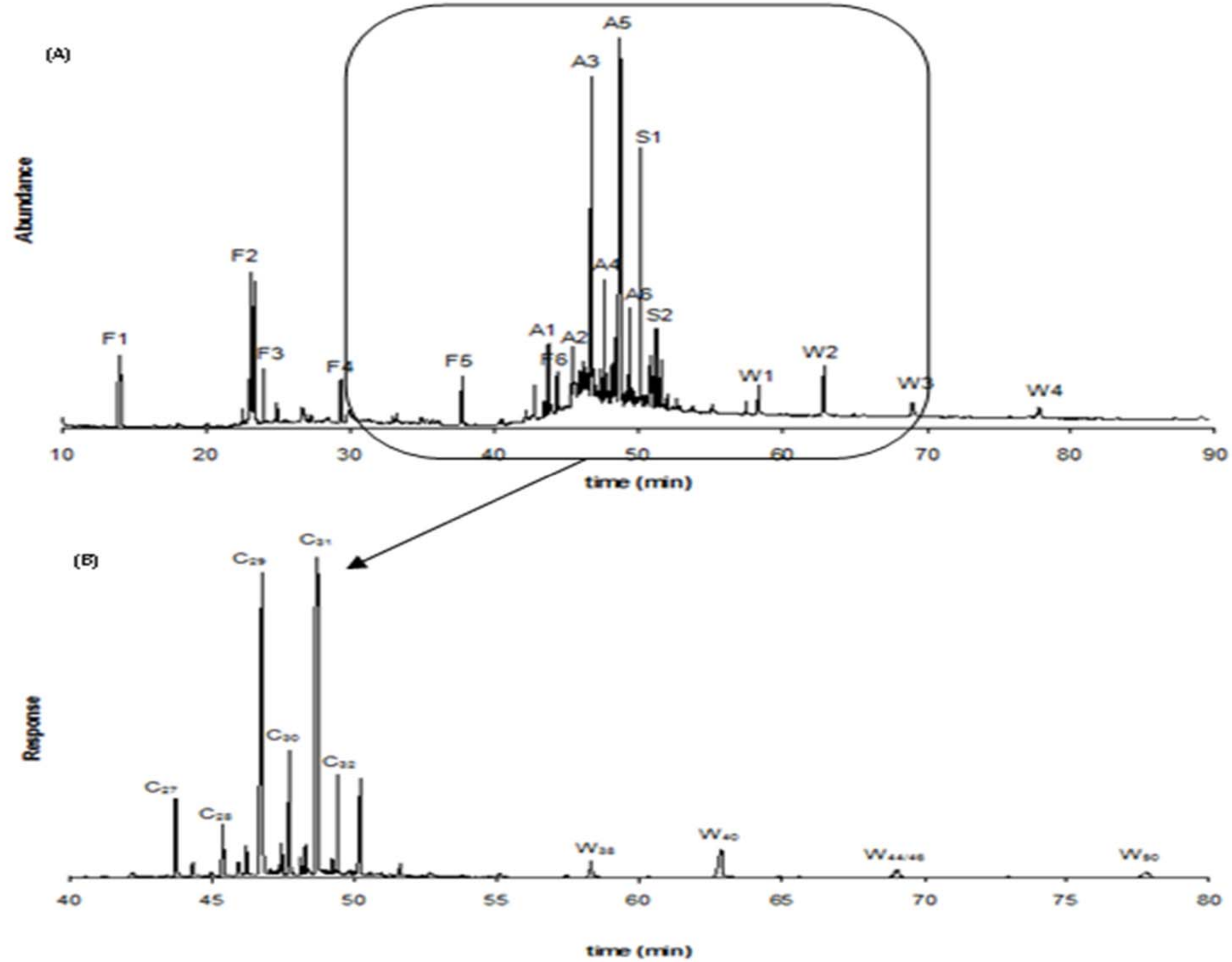


CURATIVE METHODS

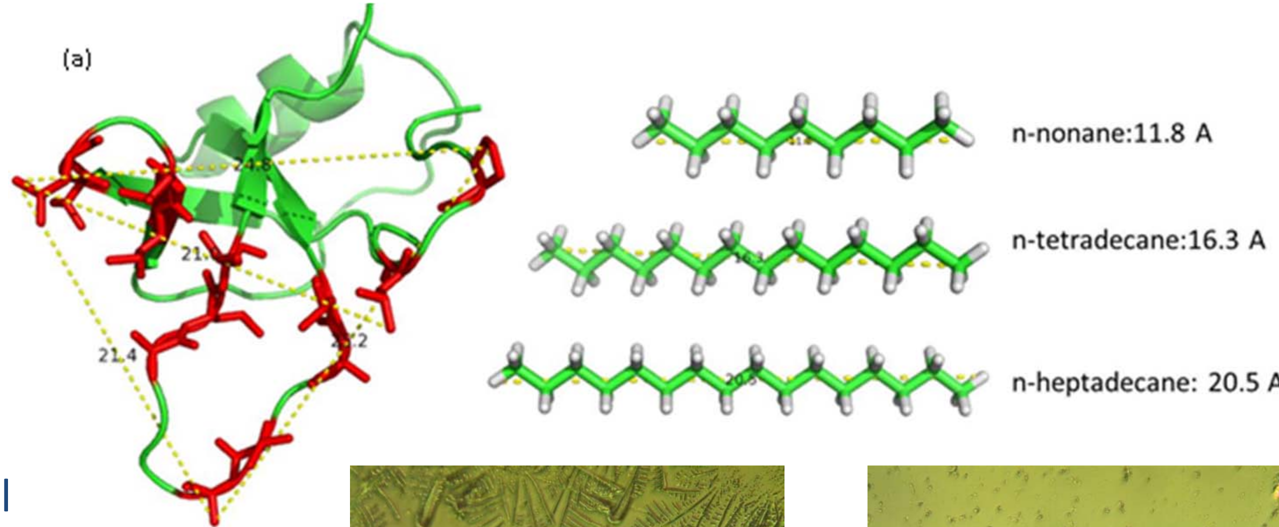
USE OF DISPERSED HOP ANTI-FOAM

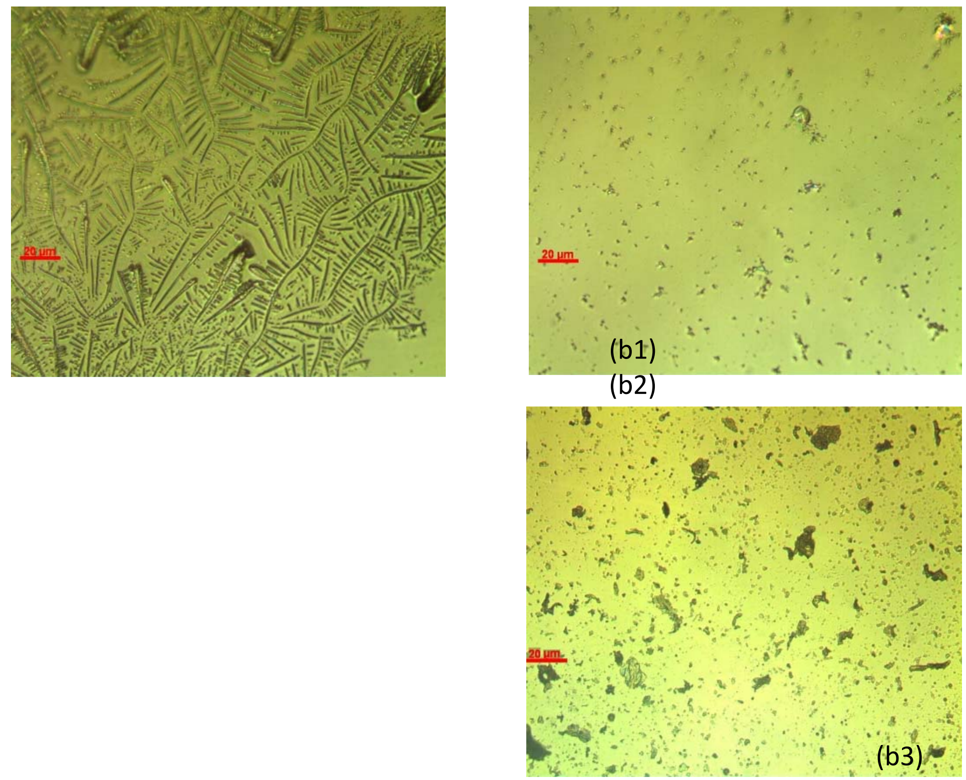


Magnetic field assisted nanoparticle dispersion (*Chem. Commun.*, 2009, 47-49)

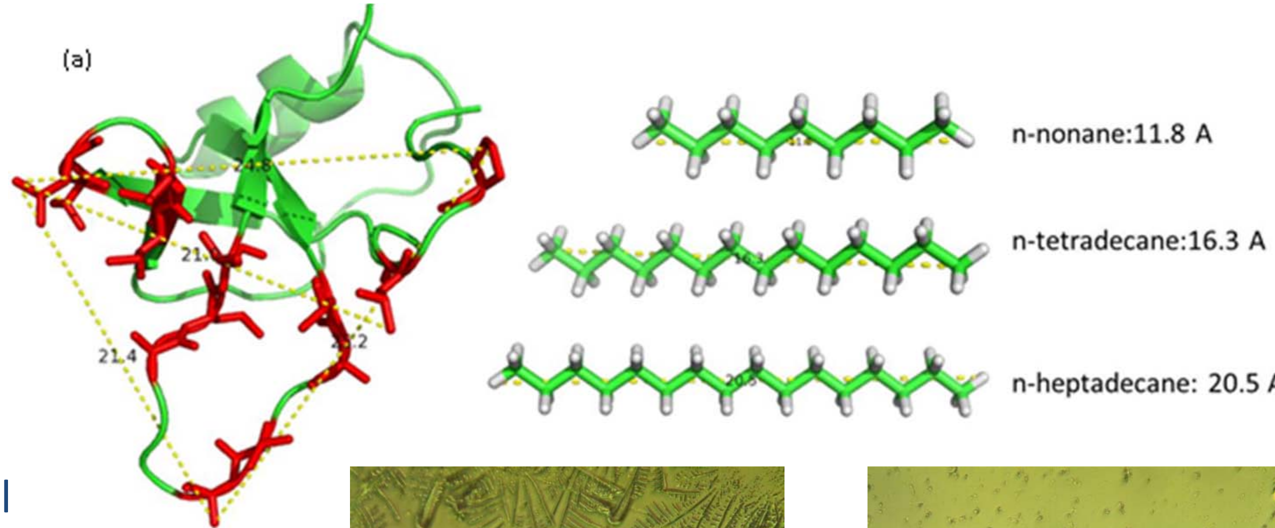


GC/MS chromatogram of the methanolyzed lipid extracts from hop antifoam: F = fatty acid methyl ester; A = n-alkane; W= wax ester; S = steroid compounds (A). Ion extraction of GC-MS spectrum (m/z = 57), characteristic for alkanes and wax esters (B).





. (a) Comparing the l hydrophobic patch of hydrophobin HFBI with n-nonane (decreases gushing of HFBI) and n-tetradecane and n-heptadecane (suppress gushing of HFBI); Microscopic image of crystals formed by (b1) HFBI (0.15 mg/mL) in distilled water, oleic acid (5 µL/mL) in distilled water (b2) and mixture of HFBI with oleic acid (b3). All images are taken by reflected light and the scale bar indicates 20 µm.



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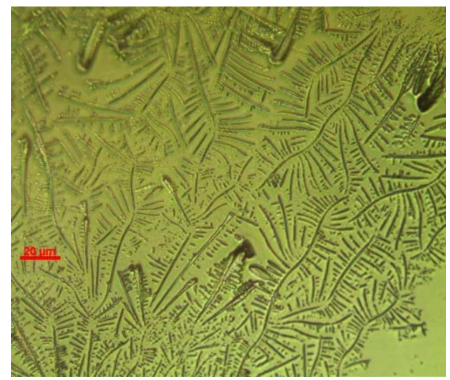
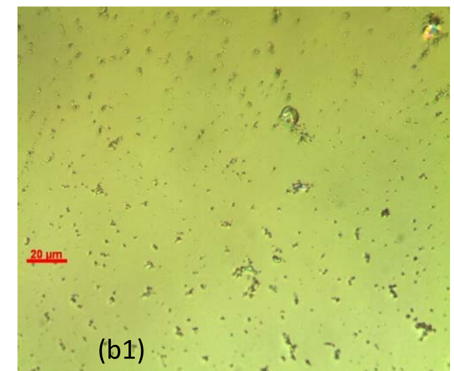
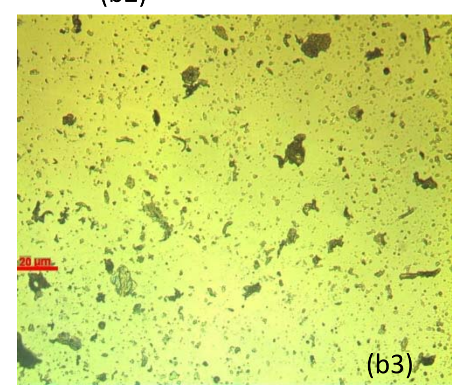
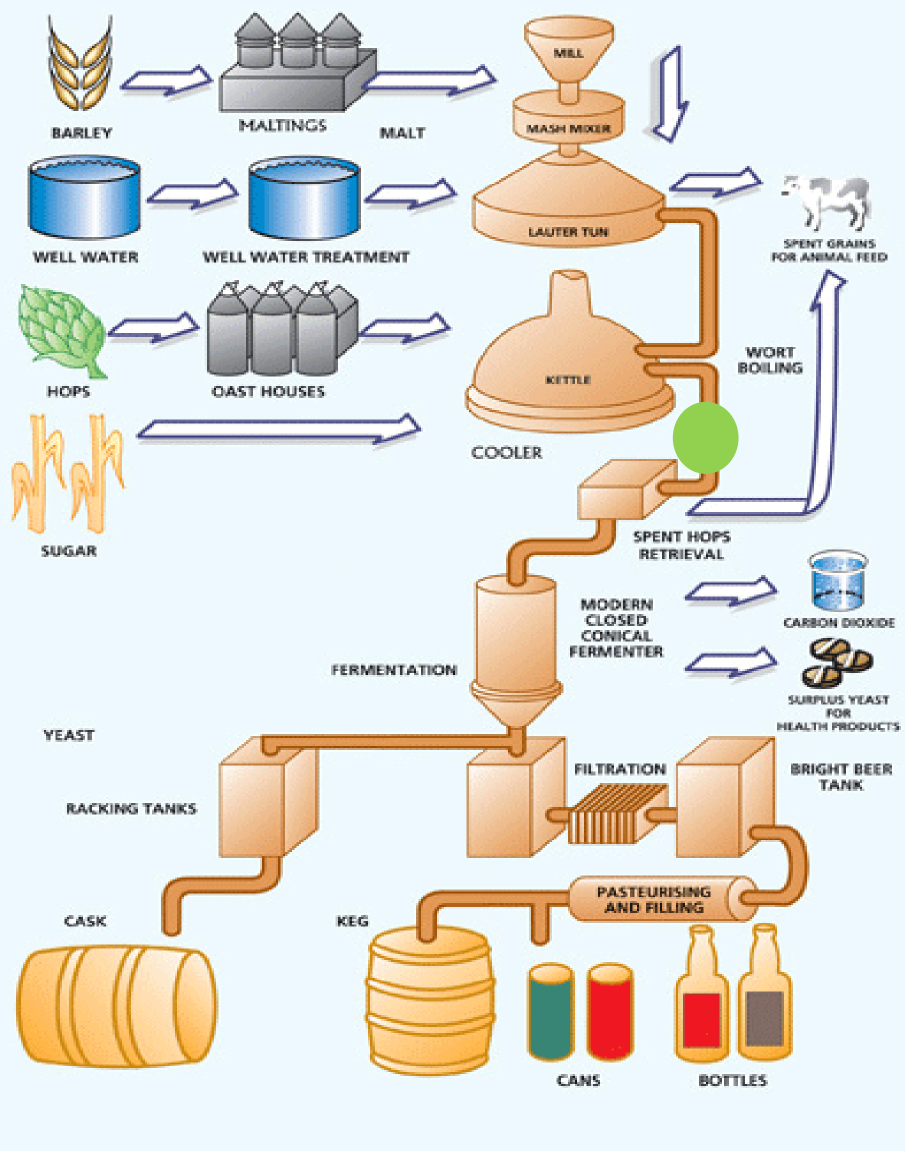




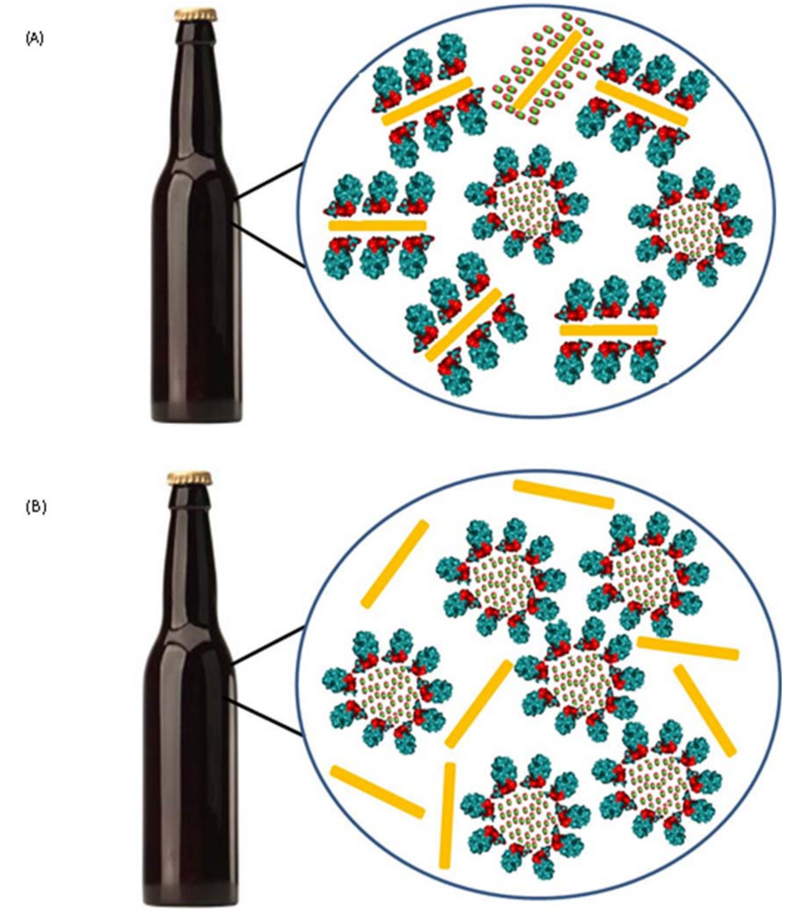
(b1)
(b2)





The Brewing Process

CURATIVE METHODS



PRIMARY GUSHING UNDER THE MAGNIFYING GLASS OF EXACT SCIENCE

THANKS
FOR YOUR ATTENTION …

CHEERS !!!