Grupo Especializado de Didáctica e Historia de la Física y la Química

Real Sociedad Española de Física (R.S.E.F.) · Real Sociedad Española de Química (RSEQ)

SCIENTIX — The community for science education in Europe

POLITÉCNICA

Context and inquiry-based chemistry teaching and learning for engineering students

Gabriel Pinto

Outline

- Introduction and goals.
- **Case 1**: Rate of melting ice cubes in different aqueous solutions.
- **Case 2**: Emission of CO_2 by cars.
- **Case 3**: Thermochemistry of self-heating beverages.
- **Case 4**: Why should we use domestic condensing boilers?
- **Case 5**: Critical analysis of pseudoscientific deceptive information.
- **Outcomes**.

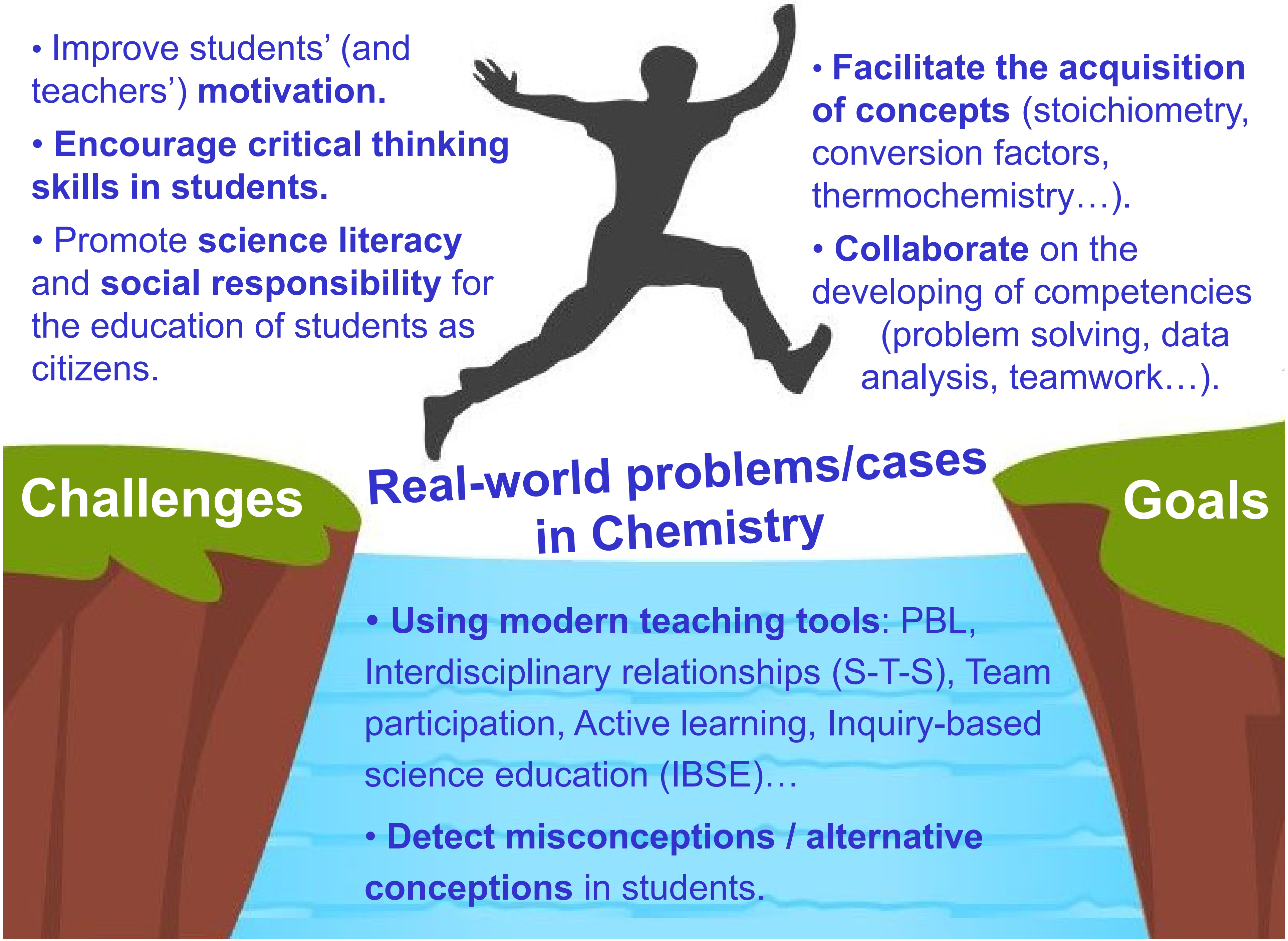
♦ “*Often* ***students are insufficiently interested by chemistry****, because they perceive science education as “irrelevant” both for themselves and for the society*”.

J. Dillon, *Int. J. Envir. Sci. Educ.*, 4, 201-213 (2009).

♦ This work is part of a program intended to help teachers include **connections between students’ daily experiences and chemical topics**.

♦ Idea: by **bringing tangible examples we provide opportunities** for students to apply science to familiar contexts in hopes that they will appreciate chemistry more and will be motivated and encouraged to study concepts in greater detail.

♦ I summarize here 5 cases of **contextualized open-ended problems / cases** carried out with first-year engineering students in the last years, applicable to other educative levels.


• Improve students' (and teachers') **motivation.**
• **Encourage critical thinking skills in students.**
• Promote **science literacy** and **social responsibility** for the education of students as citizens.
Challenges
Real-world problems/cases in Chemistry
• **Using modern teaching tools**: PBL, Interdisciplinary relationships (S-T-S), Team participation, Active learning, Inquiry-based science education (IBSE)…
• **Detect misconceptions / alternative conceptions** in students.
Goals
• **Facilitate the acquisition of concepts** (stoichiometry, conversion factors, thermochemistry…).
• **Collaborate** on the developing of competencies (problem solving, data analysis, teamwork…).

Characteristics of suggested activities

- **Short class time** (< 5 min), and **~3 weeks** to solve each one.
- Groups of **3 students**.
- Account for 10% of the grade.
- **Open results** and **data mining.**

- General **rules for students:**

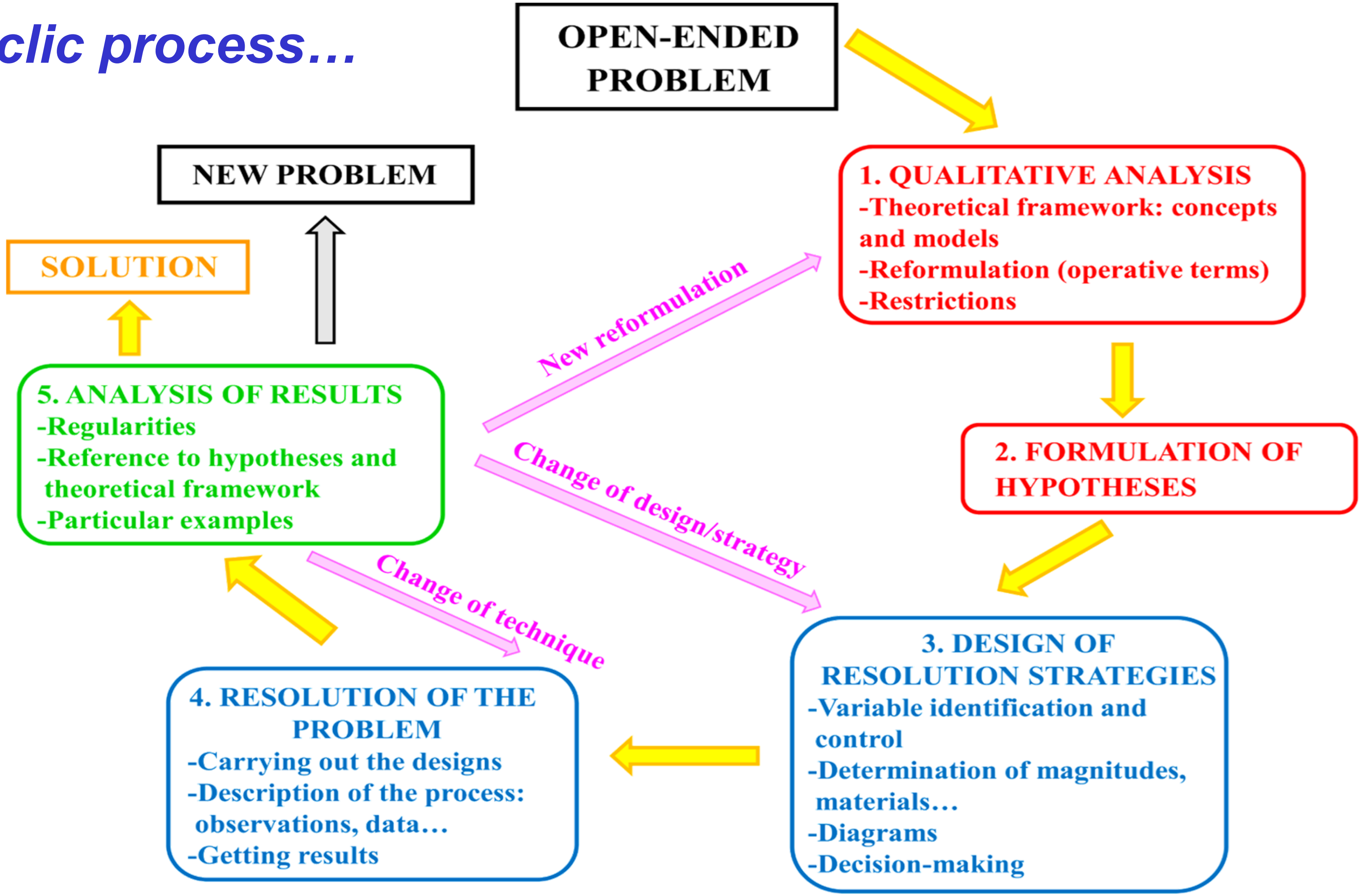
  - **Clearly written** (preparation of tables and drawings / graphics).

  - Results must be clearly indicated (**appropriate units** and care in the **significant digits**).

  - **Proper citation** of references and sites visited.

  - **Discussion of the activity with the teacher.**

A cyclic process…



Stages and characteristics of the methodology of problem solving as an investigation, in: "Introducing Inquiry-Based Methodologies during Initial Secondary Education Teacher Training Using an Open-Ended Problem about Chemical Change", I. Rodríguez-Arteche, M. M. Martínez-Aznar, *J. Chem. Educ.* 93(9), 1528-1535 (2016).

Case 1: Ice melting rate in various liquids

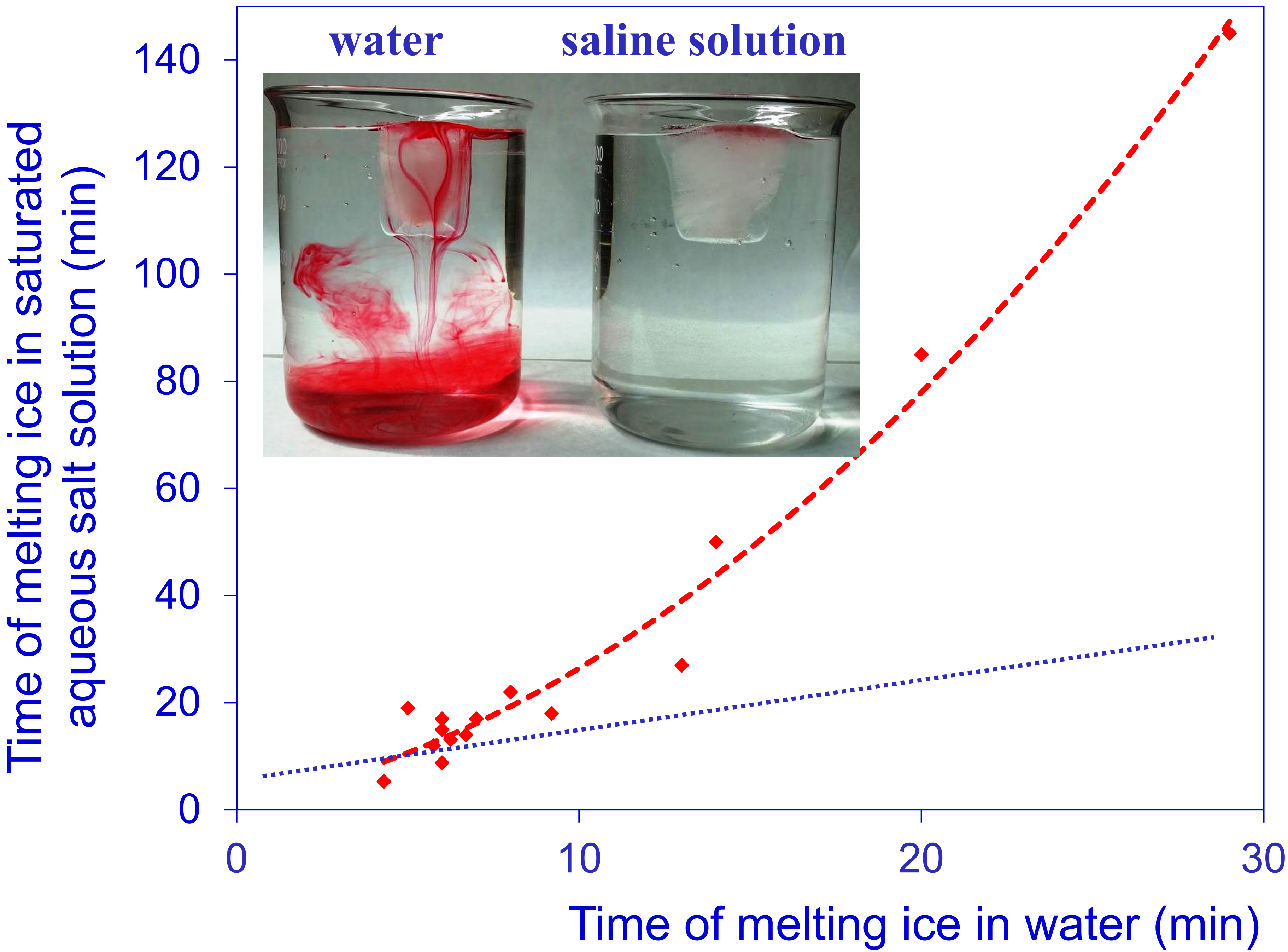
Where will melt before an ice cube in water or in saturated salt water?

It melts before in:	water	water with salt	practically equal	I don’t know
Individual analysis	8	43	7	2
Group (3 students)	4	48	4	4

Two days after the proposed experimental work…

It melts before in:	water	water with salt	practically equal	I don’t know
49 said they did	32	14	2	1
11 said they did not	1	8	1	1

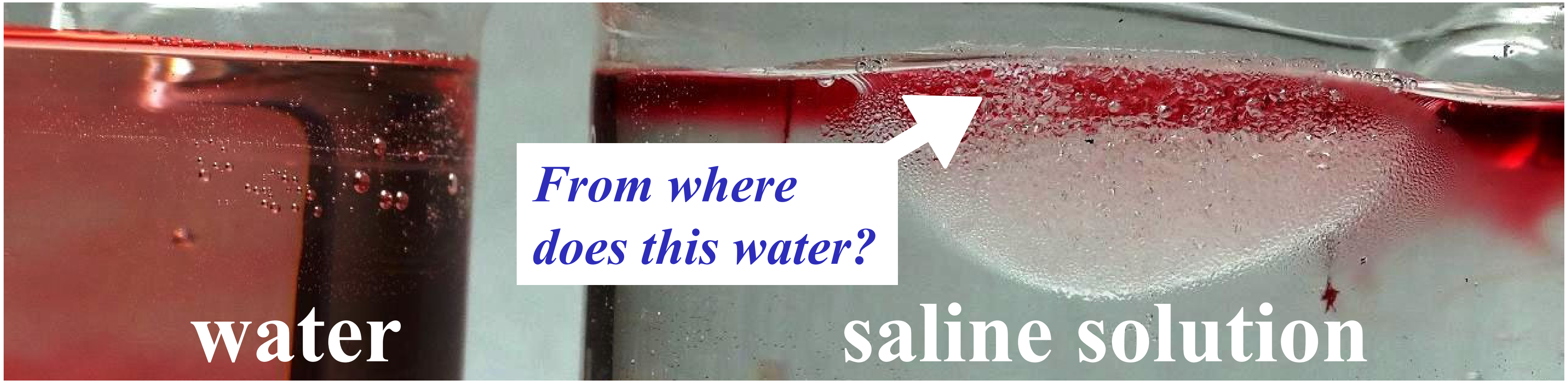
G. Pinto, P. Lahuerta, *Educació Química*, 21, 54-62 (2015)


water
saline solution
Time of melting ice in saturated aqueous salt solution (min)
0
20
40
60
80
100
120
140
0
10
20
30
Time of melting ice in water (min)

Other questions:

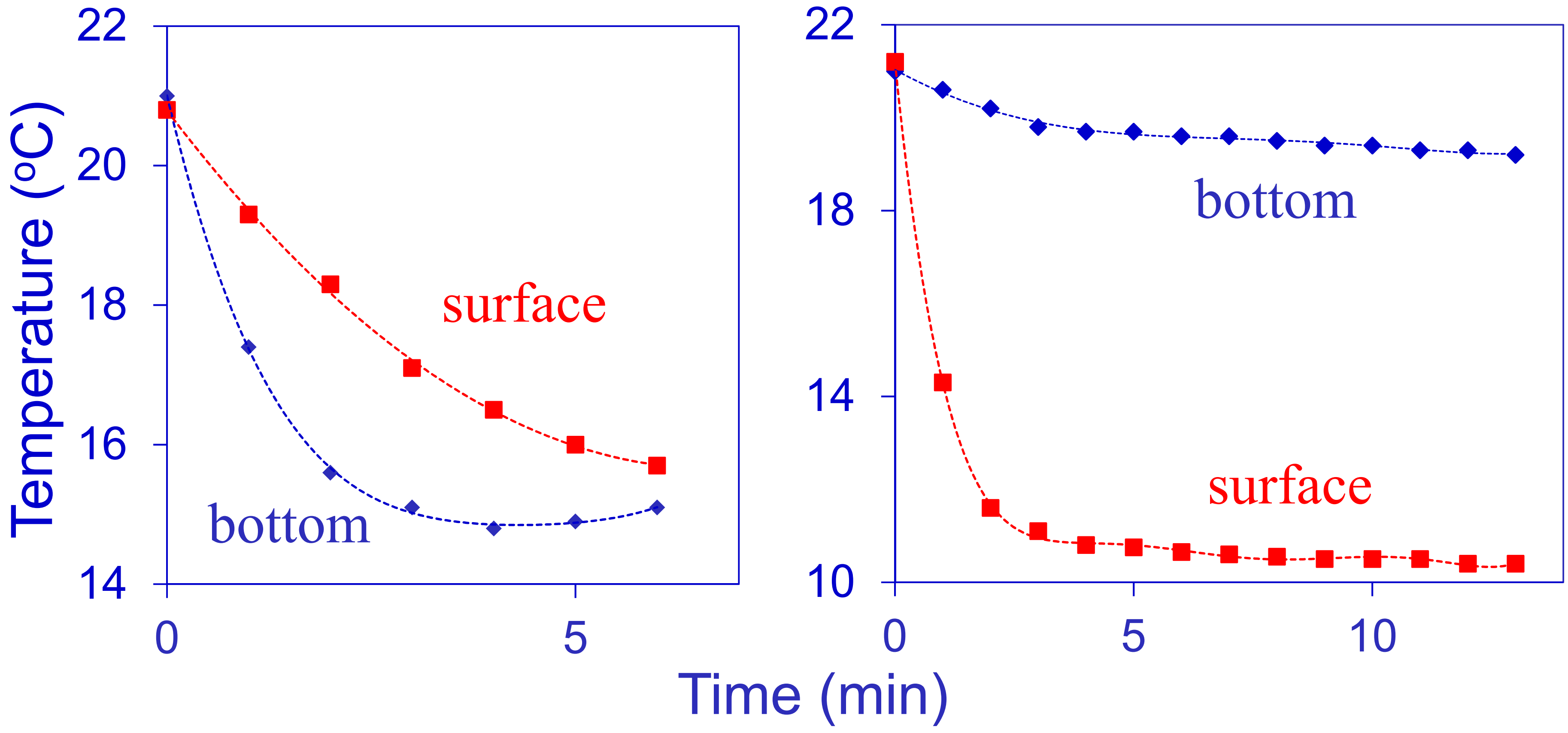
Why moves one of the ice cubes?

Why water droplets are produced on the outer wall of the vessel?



Do we observe the same if sugar instead of salt is used?

New experiments…



water **saline solution**

Possible further inquiries:

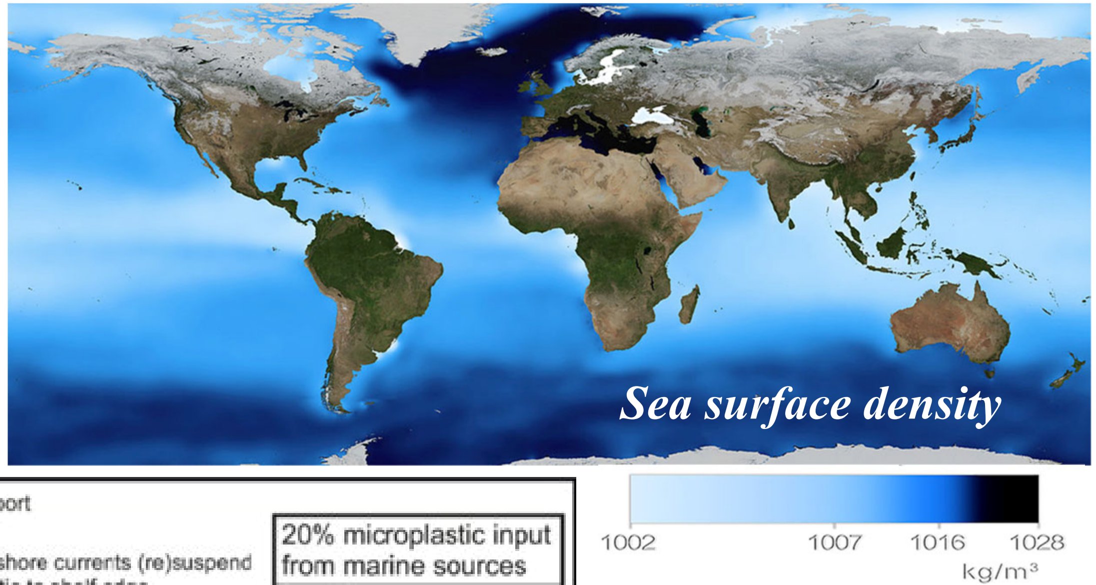
- Is it possible to get a transparent ice cube in the freezer at home?

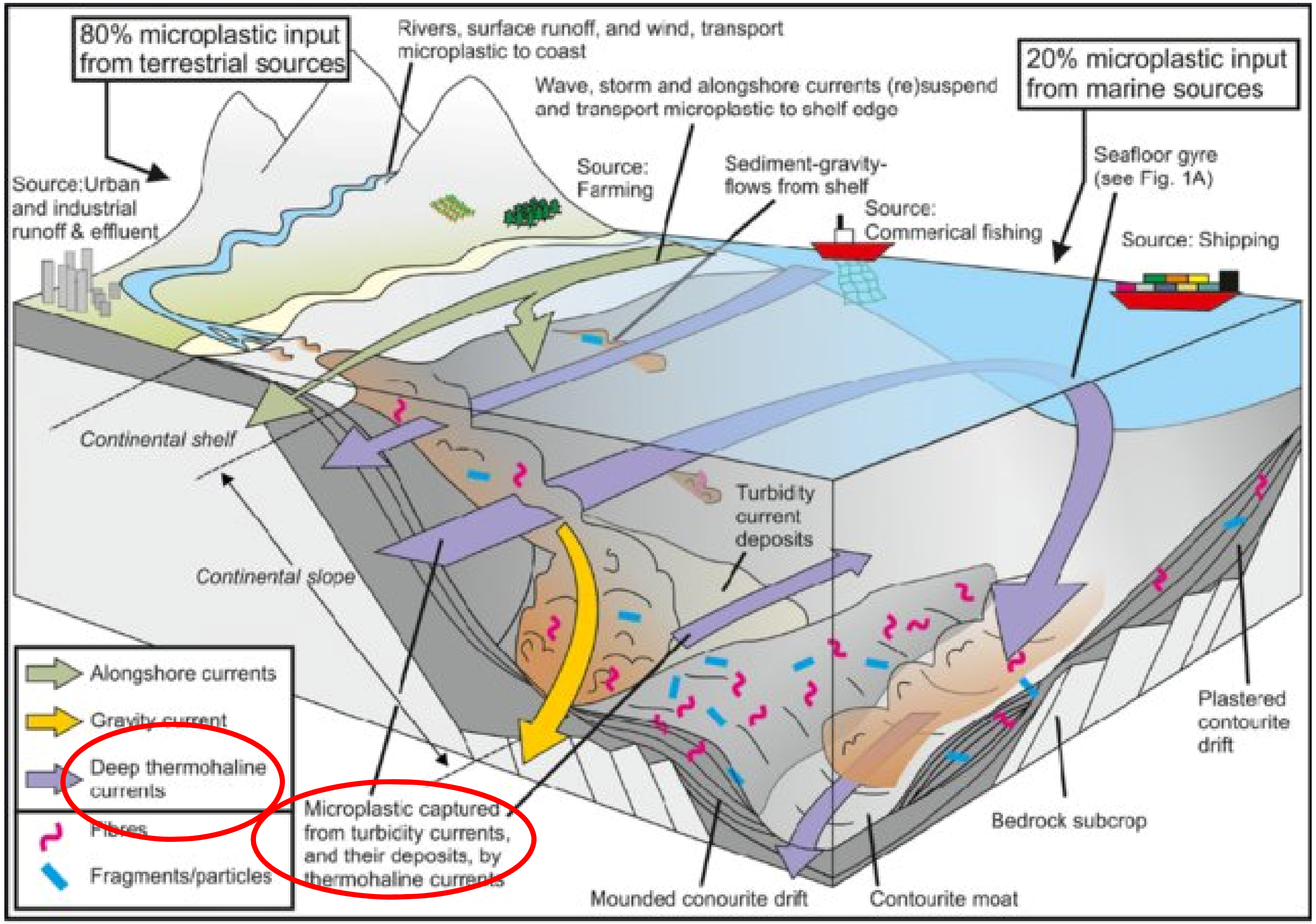
- What happens if we add an ice cube on cooking oil?

- Why?

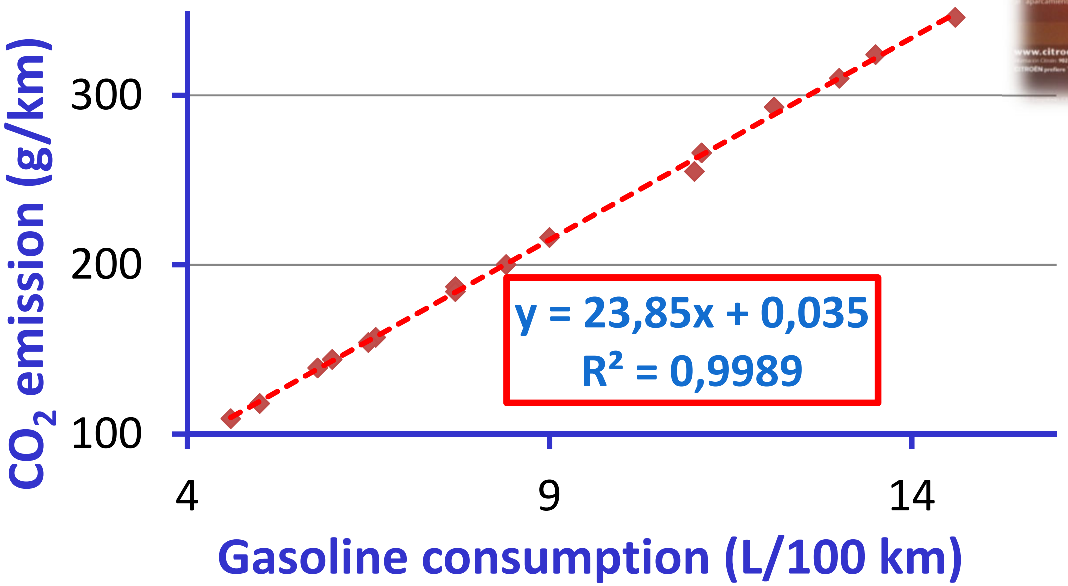
What good is all this?

An important application:
understanding of the thermohaline circulation





Case 2: Relationship between vehicle fuel consumption and CO_2 emissions



Gasoline: $C_8H_{18} + 12.5\ O_2 \rightarrow 8\ CO_2 + 9\ H_2O$

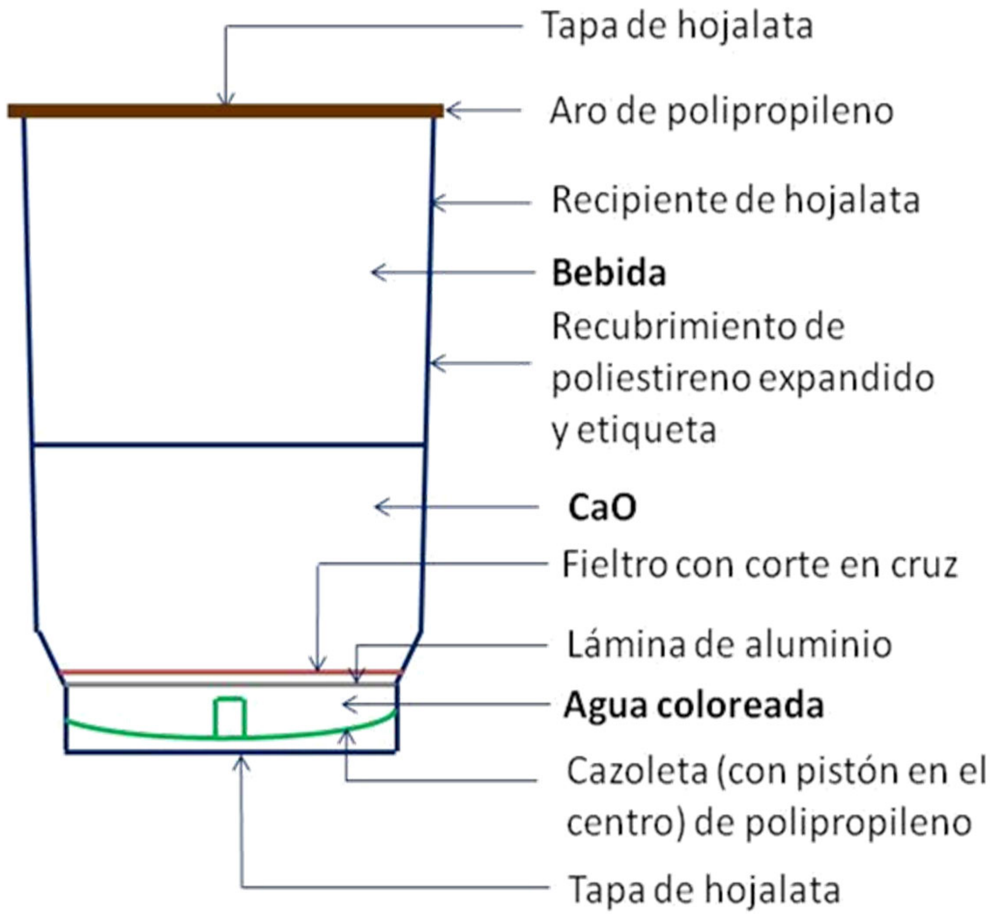
$$CO_2 \text{ emission} = \frac{\text{Octane consumption (L/100 km)}}{100 \text{ km}} \cdot 0.75 \frac{\text{kg}}{\text{L}} \cdot \frac{1 \text{ kmol octane}}{114.22 \text{ kg}} \cdot \frac{8 \text{ kmol } CO_2}{\text{kmol octane}} \cdot$$

$$\cdot \frac{44.01 \text{ kg}}{\text{kmol } CO_2} \cdot 10^3 \frac{\text{g } CO_2}{\text{kg}} = 23.1 \text{ (g } CO_2 \text{ / L} \cdot \text{km) x Octane consumption (L in 100 km)}$$

M. T. Oliver-Hoyo, G. Pinto, *J. Chem. Ed.*, 218-220 (2008)

Case 3: About self-heating beverage containers

There are commercial products that claim to heat their contents based on the dissolution process of a salt or on a chemical reaction.



M. T. Oliver-Hoyo, G. Pinto, J. A. Llorens, *J. Chem. Ed.*, 86, 1277-1280 (2009)
G. Pinto, M.T. Oliver-Hoyo, J. A. Llorens, *J. Chem. Ed.*, 86, 1280A-1280B (2009)
M. Prolongo, G. Pinto. *Educació Química*, 7, 4-14 (2010)

a. **Describe** the container and the chemical reaction.

$CaO\ (s) + H_2O\ (l) \rightarrow Ca(OH)_2\ (s)$

b. **Calculate** excess / limiting reactants and the mass of product that can be formed.

CaO: 1.07 mol (limiting)

Excess of **0.21 mol water (3.78 g)**; thus, it could be **79.29 g $Ca(OH)_2$**

c. **Search** (different sources) the values of $\Delta_f H^o$ and present them in a table.

	$\Delta_f H^o$, at 298 K and 1.00 atm, kJ/mol		
Substance	*Source 1*	*Source 2*	*Source 3*
$CaO(s)$	-635.09	-635	-635.09
$H_2O(l)$	-285.83	-286	-285.8
$Ca(OH)_2(s)$	-985.14	-987	-986.09

d. **Calculate** the heat (kJ/mol) evolved.

$\Delta H^o = -985.14 + 635.09 + 285.83 =$ **-64.22 kJ/mol**

e. **Prepare a table** with end temperatures and compare them.

1,07 mol · 64.22 kJ/mol = 68.72 kJ ≡ $16.42 \cdot 10^3$cal

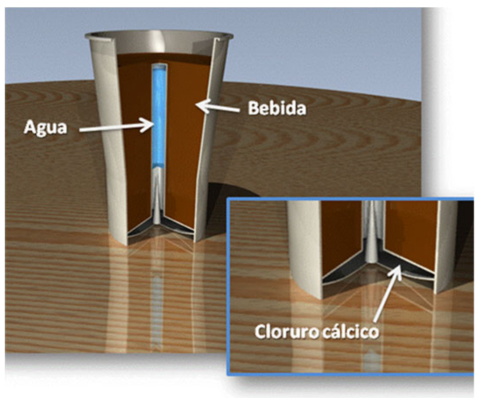
$Q = m \cdot C \cdot \Delta T \Rightarrow \Delta T = 67.2$ ºC

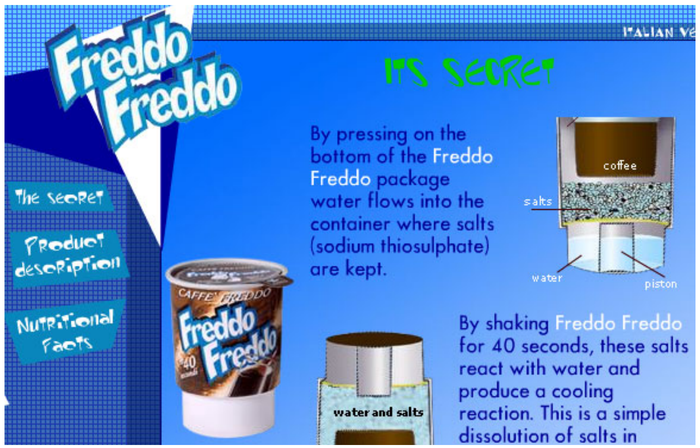
Procedure	End temperature (ºC)
Experimental	62.8
According to manufacturer	62.5
Calculated (theoretical)	89.7

g. Identify and discuss the **assumptions** made.

h. Comment on **advantages/disadvantages** and suggest **ways to improve** these cans.

i. Comment on any interesting aspect of this activity (possibility to cool beverages, instructions, additional information…).





Case 4: Termochemistry and condensing boilers

There is a known "*Plan Renove*" for domestic boilers in Spain, that is part of the "*Action Plan for Energy Saving and Efficiency*" developed for promoting the use of "condensing boilers".

a. Through suitable sources, **collect in a table a typical composition of natural gas** expressed as % vol. and mole fraction.

Substance	Formula	Composition	
		% Vol	Molar faction
Methane	CH_4	87.0-96.0	0.870-0.960
Ethane	C_2H_6	1.5-5.1	0.015-0.051
Propane	C_3H_8	0.1-1.5	0.001-0.015
Isobutane	C_4H_{10}	0.01-0.3	0.0001-0.003
Butane	C_4H_{10}	0.01-0.3	0.0001-0.003
Isopentane	C_5H_{12}	Traza-0.14	Traza-0.0014
Pentane	C_5H_{12}	Traza-0.14	Traza-0.0014
Nitrogen	N_2	0.7-5.6	0.007-0.056
Carbon dioxide	CO_2	0.1-1.0	0.001-0.010
Oxygen	O_2	0.01-0.1	0.0001-0.001
Hydrogen	H_2	Trace-0.02	Trace-0.0002

- Confusion substance / element / hydrocarbon.
- Sum of % ≠ 100 %

G. Pinto, *Educació Química*, 14, 29-38 (2013).

b. **Create a table with the composition of a ‘model’ natural gas**, considering only the two major hydrocarbons.

Substance	**Composition**	
	Molar fraction	**% Wt.**
Methane	0.850	75.1
Ethane	0.150	24.9

- Examples: 86.75 and 13.25.
- Some students copy wrong data from peers, changing only one hundredth.

c. Consulting **adequate sources**, provide a table where data with $\Delta_f H^o$ (kJ/mol) for gases of previous section and for CO_2(g), H_2O(g) y H_2O(l).

	$\Delta_f H^o$ (kJ/mol)		
Substance	*Source 1* (298,15 K y 1 bar)	*Source 2* (298 K y 1 atm)	*Source 3* (298 K y 1 bar)
CH_4(g)	-74.6	-74.9	-74.9
C_2H_6(g)	-84.0	-84.7	-83.7
CO_2(g)	-393.51 ± 0.13	-394	-393.509
H_2O(g)	-241.826 ± 0.040	-242	-241.818
H_2O(l)	-285.830 ± 0.040	-286	-285.830

- Sometimes wrong value or sign.

d. **Calculate ΔH^o_{comb}** (kJ/mol) of natural gas, at 25ºC, assuming that the **water is obtained as gas.**

$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$ $\Delta H^o = -803$ kJ/mol

$C_2H_6(g) + 7/2\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(g)$ $\Delta H^o = -1429$ kJ/mol

$0{,}85\cdot(-803\ kJ/mol) + 0{,}15\cdot(-1429\ kJ/mol) =$ **-897 kJ/mol**

- *$CH_4(g) + C_2H_6(g) + 11/2\ O_2(g) \rightarrow 3\ CO_2(g) + 5\ H_2O(g)$* $\Delta H^o = -2229{,}1$ kJ/mol
- *$CH_4(g)$ + **$4\ O_2(g)$** $\rightarrow CO_2(g) + 2\ H_2O(g)$* $\Delta H^o = -803$ kJ/mol (*goes well*) ***[sic.]***
- Some students compared with values of ΔH^o_{comb} from *Handbook*.

e. **Repeat calculation** by assuming that the **water is obtained as liquid.**

$0{,}85\cdot(-891\ kJ/mol) + 0{,}15\cdot(-1561\ kJ/mol) =$ **-992 kJ/mol**

- A group: "*It is due to condensation of water, i.e.: $H_2 + ½\ O_2 \rightarrow H_2O$*" *[sic.]*

f. Determine the **quantity of natural gas that should be used, in a condensing boiler**, per each mole of natural gas that should be used in the other boiler, in order to obtain the same energy. Discuss **economic and social implications.**

$$\frac{897\ kJ / mol\ gas\ conventional\ boiler}{992\ kJ / mol\ gas\ conden.\ boiler} =$$

$$= 0.904\ mol\ gas\ condens.\ boiler / mol\ gas\ conventional\ boiler$$

- Values by students: **0.90 - 0.91** mol gas condens. boiler / mol gas conventional boiler.
- Comments on the greenhouse effect.
- *"It reduces the consumption of natural gas (non-renewable energy source)".*
- *"Impacts not only the user, but in the country: facilitates the use of gas for future generations".*

g. Discuss if the condensate water in the condensing boiler is **acid or alkaline.**

$$CO_2(g) + H_2O(ac) \leftrightarrows HCO_3^-(ac) + H^+(ac)$$

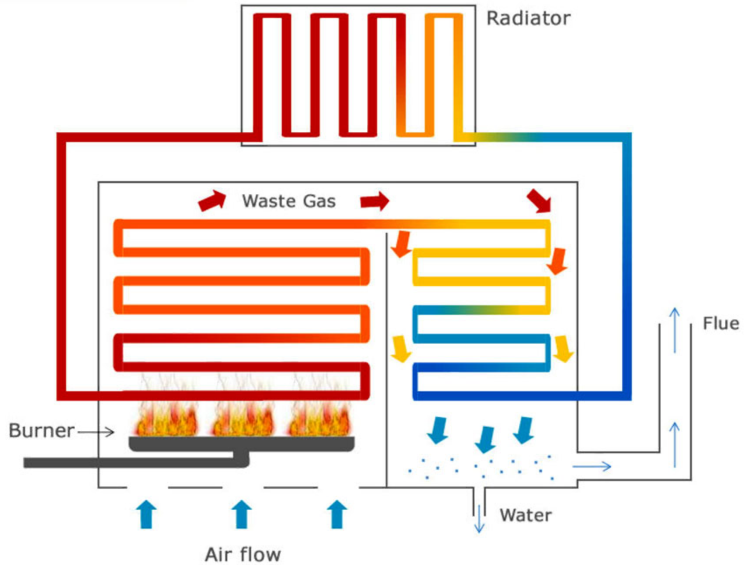
- pH between 3 and 5 (technical problems in drainage).
- *"It isn't too acidic, because carbonic acid is weak" [sic.].*

h. Itemize the assumptions made in your calculations.

- A ‘model’ composition and normal conditions were assumed.
- Combustion gases go out at 150-180 ºC (conventional) and ~55 ºC (condensing).

1. Discuss any aspect of interest (additional data, sustainability, environment, need to subsidise it, obtaining natural gas ...).

A condenser boiler



- Fuel Savings / CO_2 emission reduction.
- Operation of boilers (combustion, heat exchanger, drainage, smokestack ...).
- Quantity of condensed water.
- *Fracking* (hydraulic fracturing).

- *“At first it is more expensive, but energy is better utilized.”*
- *“The data show that it is very convenient, economically and ecologically, to use condensing boilers and given the high price, a subsidy is usually necessary.”*

Summative analysis of the homework (GOAL problem-solving protocol was recommended).

- ♦ Gather information about the problem.
- ♦ Organize the information.
- ♦ Analyze the problem.
- ♦ Learn from your effort.

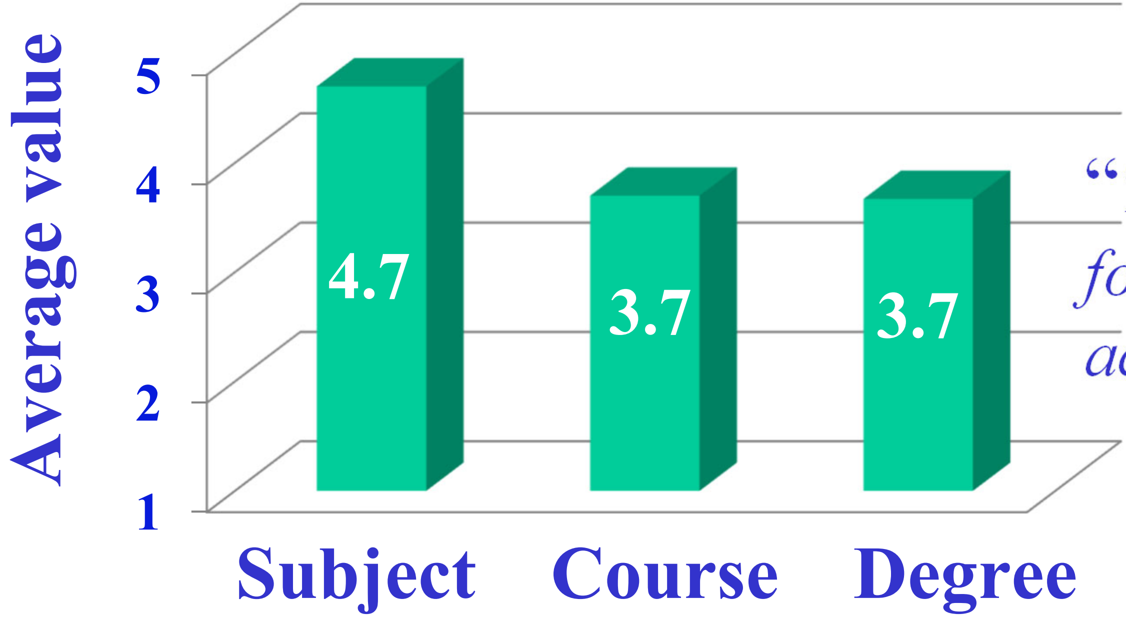
See: http://www.phyast.pitt.edu/~akl2/Phys0174/info/tips/problem_solving.html
Prof. Adam Leibovich, University of Pittsburgh

- *"We liked the activity for learning to use the strategy GOAL, being a good problem-solving method that will be useful in other subjects".*
- *"It has not been easy, but the effort was worth learning and we remembered basic concepts".*
- *"It was a different homework to what we are used to, entertaining and helpful to understand certain topics studied in the classroom".*
- *"It has helped us deepen concepts…".*
- *"Theoretical data are not equal to the experimental".*

Case 5: Critical analysis of pseudoscientific deceptive information

The `secret´: this kind of glass is made with SiO_2…

Students' point of view



"The subject is important for my future professional activities"

- *This kind of exercises helps us* ***understand better the world around us.***
- *Makes chemistry* ***a tangible experience*** *so that it is not only solving problems on a piece of paper.*
- *It shows chemistry* ***is not only formulas*** *and* ***is valuable for something****.*
- *Chemistry is very boring, any tool to make it* ***more interesting*** *is worth the try.*
- *My chemistry teacher said that* ***"chemistry is everything"****, and this helped me to see why.*
- *It serves to relate concepts of chemistry with products we can easily find.*

Teacher evaluation by students

You can see his passion for the subject: he uses practical examples.

He proposed tasks for things that are not on the syllabus, such as condensing boilers ...

for your attention

More information: gabriel.pinto@upm.es