Teachers' Card

Glass Raw Materials

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General Introduction

In this toolkit there are presented different raw materials used to produce glass. Glasses with different colours will be used in this lab activity, where the students will try to find which element of the Periodic Table is used to give colour or luminescence to glass (Figure 1).
These activities aim to help the students explore the properties and wide variety of glass applications and learn about the glass composition.
This toolkit is very comprehensive, and the activities can be carried out by participants from 5 to 18 years old. The deepening of the concepts inherent to the experiment must be done according to the age of the participants.

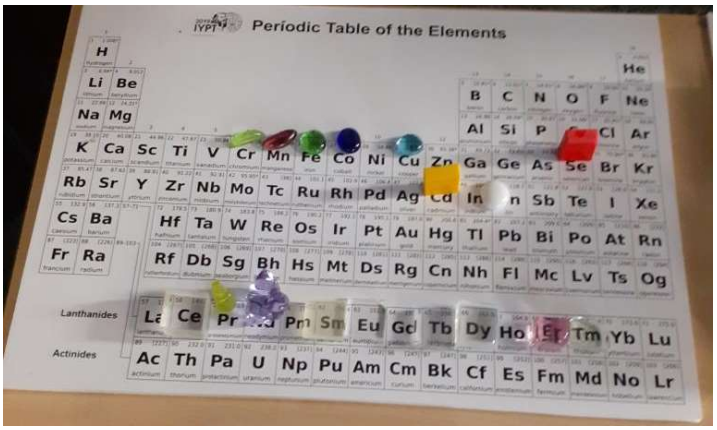

Figure 1 . Coloured and luminescent glasses placed in the periodic table on the correspondent used element.

Key words: *Glass composition, colourants, luminescence*

Extended background information

Glass materials are very attractive for the development of eco-friendly, engineer safe and fully recyclable smart-materials. Glasses can be a solution for a more sustainable future as a fully recyclable material that can partially substitute plastics in different applications. Industrially, the most common glass composition is the soda-lime silicate used in packaging, containers and windows float glass. Nevertheless, borosilicate glasses are frequently used in Pyrex kitchen utensils, laboratory glassware and optical applications since they have better thermal shock properties and can withstand higher temperatures without deforming.
This toolkit refers to the advantages of the usage of glass materials. For students, this toolkit can help comprehend some glass compositions and which elements of the periodic table can be used to obtain coloured or luminescent glasses.

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Key Competence European Framework

Literacy competence
S1. Ability to understand and interpret concepts, feelings, facts or opinions in oral and written form.
S2. Ability to express concepts, feelings, facts or opinion in written and oral form.
S3. Ability to interpret the world and relate to others.
Mathematical competence and competence in science, technology and engineering
S1. Ability to use constructed thinking in order to solve a problem in every situation.
S4. Readiness to address new problems from new areas.
S6. Ability to extract qualitative information from quantitative data
S8. Ability to design experimental and observational studies and analyse data resulting from them.
Personal, social and learning to learn competence
S1. Ability to pursue and persist in different kinds of learning.
Citizen competence
S1. Ability to effective interaction with other people
S3. Ability to work effectively and collaborate with other team members
Entrepreneurship competence
S1. Awareness of local, national, European culture heritage and their place in the world
Cultural awareness and expression competence
S2. Creativity/innovation

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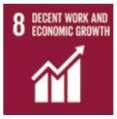
United Nations' Sustainable Development Goals

The Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including those related to poverty, inequality, climate change, environmental degradation, peace and justice.

Please indicate which goal/s can be linked to this activity

	 Enable access to basic services		 Equal access to global expertise
	 Safe medical devices		 Sustainable urbanization
	 Access to education	✓	 Responsible consumption and production
	 Less hardship, more opportunities		 Strengthen resilience, reduce disaster impact
	 Safe and affordable water		 Reduce marine pollution
✓	 Energy – the golden thread	✓	 Sustainable use of terrestrial ecosystems
	 Safety of workers and economic growth		 Promote peaceful and inclusive societies
✓	 Resilient infrastructure and sustainable industrialization	✓	 Better access to technology and innovation

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Contents – Theoretical principles

Glass definition is a topic that has been discussed over time. J. E. Shelby defined glass as "an amorphous solid completely lacking in long range, periodic atomic structure, and exhibiting a region of glass transformation behaviour". The glass transformation range, or glass transition range, describes a thermodynamic region of the material where it occurs the phase transformation from a liquid to a glass structure and vice-versa, presenting a strong volume change (Figure 2).

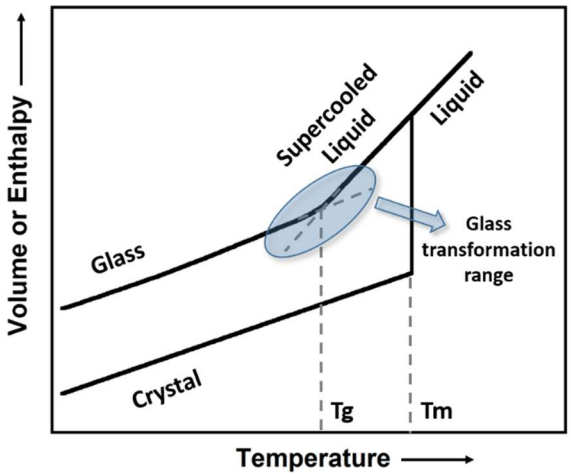

Figure 2. Volume-temperature diagram for the formation of crystal and glass structures indicating the glass transition temperature (Tg) and the crystal melting temperature (Tm).

The melt-quenching method, which consists in fusion followed by cooling of inorganic raw materials at high temperatures, is the most common technique to produce inorganic glasses. The used raw materials can be divided in:

a) *Glass former or network former* - The primary glass formers are SiO_2, B_2O_3, PbO and P_2O_5, which all readily form single component glasses. Silica is the principal glass former but is fused at very high temperatures (ca. 1700 ºC), making it a very expensive process.
b) *Flux or modifier network* - To decrease the fusion temperature fluxes are added to the glass composition, ex. Na_2O, K_2O, Li_2O. But those oxides besides decreasing the fusion temperatures also cause partial net ruptures that decrease the glass stability.
c) *Stabilizer* – Stabilises certain glass properties and act with an intermediate character between the network former and the modifier, ex.: CaO, Al_2O_3, ZnO.
d) *Secondary components* – have specific functions, such as colourants, (Fe, Co, Cu, Au), decolourants (As_2O_3), opacifiers (F-) or fining agents for bubbles removing.

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The following colourants give rise to different colours:

Table 1. Various colourants in different oxidation states and respective colours

Colourant	Oxidation state	Colour
Copper	Cu^{2+}	Blue
Chromium	Cr^{3+}	Green
	Cr^{6+}	Yellow
Manganese	Mn^{2+}	Yellow
	Mn^{3+}	Violet
Iron	Fe^{2+}	Light Blue
	Fe^{3+}	Yellow to Brown
	Fe^{2+} + Fe^{3+}	Green
Cobalt	Co^{2+}	Blue(CoO_4), Pink (CoO_6)
	Co^{3+}	Green

Another type of colourants commonly used are aggregates of colloidal nature, where one or more components have dimensions between 1 nm and 1 µm. This group includes cadmium sulfoselenide that originates from yellow to red colours, copper and gold nanoparticles that provide red ruby glasses and silver nanoparticles usually used on yellow glasses.

Rare earths includes the elements of the *f* block of the periodic table: the lanthanides and the actinides. These elements are among those that were first described for the synthesis of luminescent glass. Different lanthanides give rise to different luminescent colours under UV light: red-orange and blue (europium, Eu^{3+} and Eu^{2+}, respectively), green (terbium, Tb_4O_7), yellow (dysprosium, Dy_2O_3), orange (samarium, Sm_2O_3), blue (cerium, CeO_2) and violet (thulium, Tm_2O_3).

This toolkit present different examples of natural raw materials as sand, shells and salicornia ashes that can be used as a silica, calcium and sodium sources, respectively. It also presents different coloured and luminescent glasses synthesised using various elements.

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Activity

In this toolkit, there are two activities to explore the glass raw materials. These activities aim to introduce the students to the definition of glass and explore its composition, properties and wide variety of applications.
This toolkit is very comprehensive, and the activities can be carried out by participants from 5 to 18 years old. The deepening of the concepts inherent to the experiment must be done according to the age of the participants.

The lab activity just involves one experimental phase, there will be one Module

Module 1 – Glass Raw Materials

Learning Pathway

Step 1- Time & Activity: 10 minutes: Teachers do a short introduction with a prepared PowerPoint presentation.

Step 2 – Time& Activity: i.e. 10 minutes: Depending on the number of students in the class, if necessary, students can be divided into groups (the number of students in each group is at the discretion of the teacher). Follow the procedure presented on the student's card for activity #1.

Step 3 – Time& Activity: i.e. 15 minutes: Depending on the number of students in the class, if necessary, students can be divided into groups (the number of students in each group is at the discretion of the teacher). Follow the procedure presented on the student's card for activity #2.

Step 4 – Time& Activity: 10 minutes: Discuss the results and the obtained knowledge.

Evaluation

A PowerPoint Quiz to check the comprehension of the contents

Appendix1 – Quiz- What is glass?

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Description of Student's Cards

This activity focuses on understanding what is glass and discovering the different raw materials used to produce glass. It is also focused on the various colourants used to obtain different colours or luminescence in glass.

List of Students Cards associated to this toolkit:

Student's Card 1 – Glass Raw Materials

Sources

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