University of Southern Queensland

NO WASTE Project: Glass Challenge for Students

- **Ancient to Modern**
- **Every Day and Industrial Uses**
- **Discovery and Quiz Challenge**

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Acknowledgement of Country

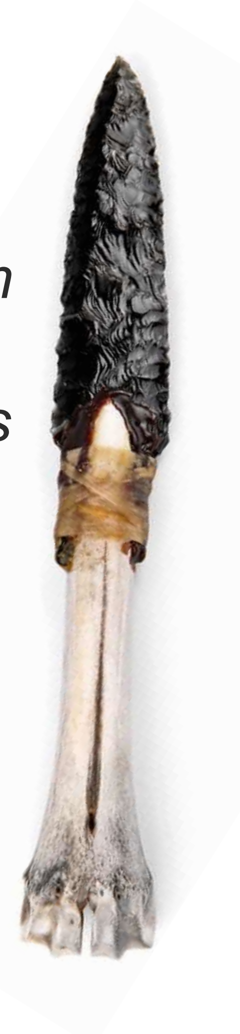
UniSQ would like to acknowledge the traditional owners of the land on which we gather.
We would also like to pay our respect to Elders – past, present and emerging.

(1) What is Glass? What was the first glass used by humans in the Neolithic times?

- **Silicon Dioxide +**
- ***Other oxides that act as a fluxing and physical property modifiers.***
- ***Chilled quickly – i.e., none to little crystallisation, i.e. an amorphous solid.***

Your 1st Task: Discuss and answer

- *Was it naturally occurring or man-made when first used?*
- *What is the difference between (quartz) glass and quartz crystal?*
- *Which rock does obsidian glass have similar chemical composition?*
- *How long do you think it takes to make an obsidian arrowhead from a boulder of the parent rock?*
- *What is an obsidian blade?*
- *What is a fulgurite?*



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(1) cont. Who made the first glass and when?

Your 2nd Task: Discuss and answer

- *How was the first glass discovered and made?*
- *Which of the vessels shown is Greek or Roman?*
- *How much do you think a normal drinking glass would have cost in Roman times (20 AD)?*
- *Why is glass translucent?*
- *Can you be sunburnt by sunshine coming through a glass pane of a window?*
- *Does glass act as a thermal barrier to long wave heat radiation; e.g., from a fireplace, combustion stove or electric radiant heater?*

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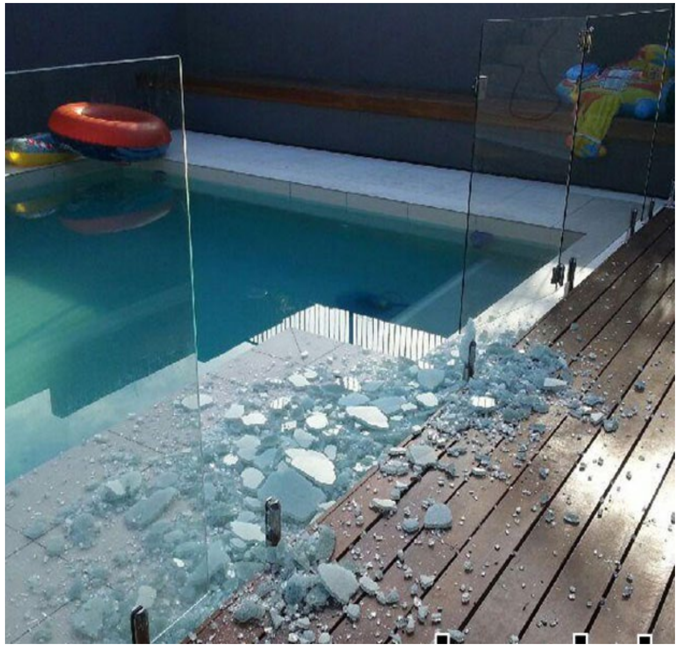
(2) Glass we use in the 21st Century



Your 3rd Task: Discuss & Answer

- *How many of the 8 common glasses in section 2 can you recognise from home?*
- *Can you match the pictures in section 2 to the 8 different types of glass?*
- *Why do car wind screens have laminated glass? Are car windows laminated glass?*
- *How did the swimming pool glass fence crack and shatter?*
- *What oxides make red or pink coloured glass? Can you find their elements in the periodic table?*
- *How does extreme cold effect window glass?*
- *Which of the 8 glass types can be recycled?*

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(2) Making glass from middle ages to 21st Century

What type of glass would you use for structural and roof glass? Why?

Your 4th Task: Matching Industrial Glass description to pictures

- *Read/discuss section 6 and see if you can match the different types of industrial glass to the pictures. (Ask questions as needed.)*
- *Which of these can currently be recycled?*
- *What is the UniSQ NO WASTE Research and Development Project about?*

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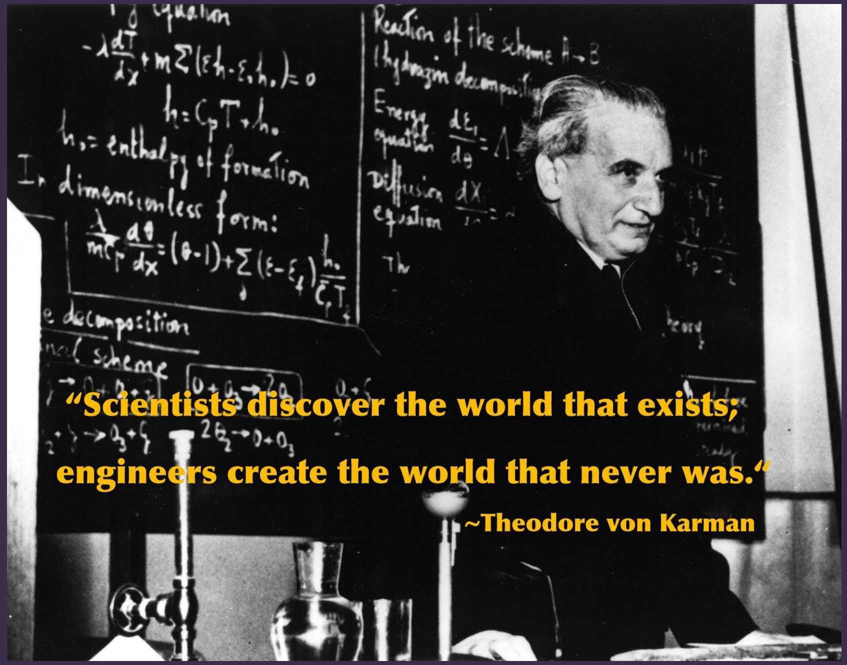

(1)Intro to History of Glass

(2)From ancient blades and scalpels, to drink containers and to works of art for the ancient rich, to common household use! ***[(Online Periodic Table Link)]***

What is Glass

Glass is generally based on Silicon Dioxide/Silica (SiO_2) from quartz based pure sand, with different fluxing agents or additives that change the nature of the product. Glass is a quenched liquid formed into an amorphous solid that has minimal crystalline structure as shown for the most used soda glass in figure 1(a).

Modern soda-lime glass is the most common form of glass produced. It is composed of ~70% silica (SiO_2), 15% soda (sodium oxide from sodium carbonate), and 9% lime (calcium oxide from calcium carbonate), with much smaller amounts of various other compounds. Softening temperature is generally ~700°C, working temperature of ~150°C, and able to withstand ~50-60°C differential thermal shock before shattering.

(a) (b) (c) (d)

Figure 1: (a) *typical glass amorphous solid liquid structure compared to quartz crystal;* ***(b)*** *Obsidian glass used for arrow heads;* ***(c)*** *A fulgurite ("frozen lightning) Quartz glass found on a beach;* ***(d)*** *Ancient Greek Glass Amphora circa 150 BC (left) and 4th Century Roman Glass Cage Cup AD(right)*

First glass use and production:

Discussion 1: The oldest form of glass used by Neolithic humans is natural volcanic obsidian or 70% silica glass, with varying constituents mainly of Magnesium Oxide and Magnetite (Black Iron Oxide Fe_3O_4). This volcanic glass is similar to granite in composition, but has chilled too quick for quartz crystals to form. Obsidian can produce cutting edges many times finer than even the best steel scalpels. At 30 angstroms – an angstrom is equal to one hundred millionth of a centimetre – an obsidian scalpel can rival diamond in the fineness of its edge; and has been used as weapons, scrapers, and for knives for craniectomy brain surgery since pre-historic times. ***Question: How long to make a obsidian arrow head?*** Silica glass is also formed by severe lightning strikes on sandy beaches or mountain ridges with sand patches, and produces what is known as fulgurites (petrified lightning), see fig. 1(c).

Discussion 2: Glass manufacturing is thought to have started 4000 years ago, due to the natron trade. Natron is the hydrated sodium carbonate with the formula $Na_2(CO_3)10(H_2O)$ rock mineral used and much sought after originally for mummification in Egypt. It is possible that Phoenician (Syrian) merchants who traded this natural desert saltpan rock, used them to make fires on beach sides, and the combination of the sodium salt and quartz in the sand produced beads of glass. This gradually changed after decades of observation into the first glass making using plant potash as a flux and finely crushed quartz sand, heated to 750°C. By 1500 BC glass making in Palestine and Egypt occurred for glass vessels. It was not until 1st century BC that Syrians invented glass blowing. Later the Romans spread this technique to Galicia (part of Portugal), Germany and France. ***Question – a glass cup in Roman times cost?***

Why does glass appear translucent?

Discussion 3: Visible light photons (packages of electro-magnetic energy) do not have sufficient energy to excite the closely bound electrons in oxide glasses (e.g. SiO_4). Therefore they just pass through the glass matrix as being transparent. However ultra-violet some UVA light, and all UVB/C is absorbed by the glass, and is opaque and heats the glass. ***Question: Can you get a suntan/sunburn or make vitamin D with light that has come through the common window pane?*** At the other end of the spectrum, near-infra-red created at near room temperature matter is blocked, however longer wave infra-red (e.g. radiant and wood combustion stove heaters) is transmitted through glass losing room heat rapidly. Normal window glass has only a 4% reflected loss of visible light at each gas-solid interface surface.

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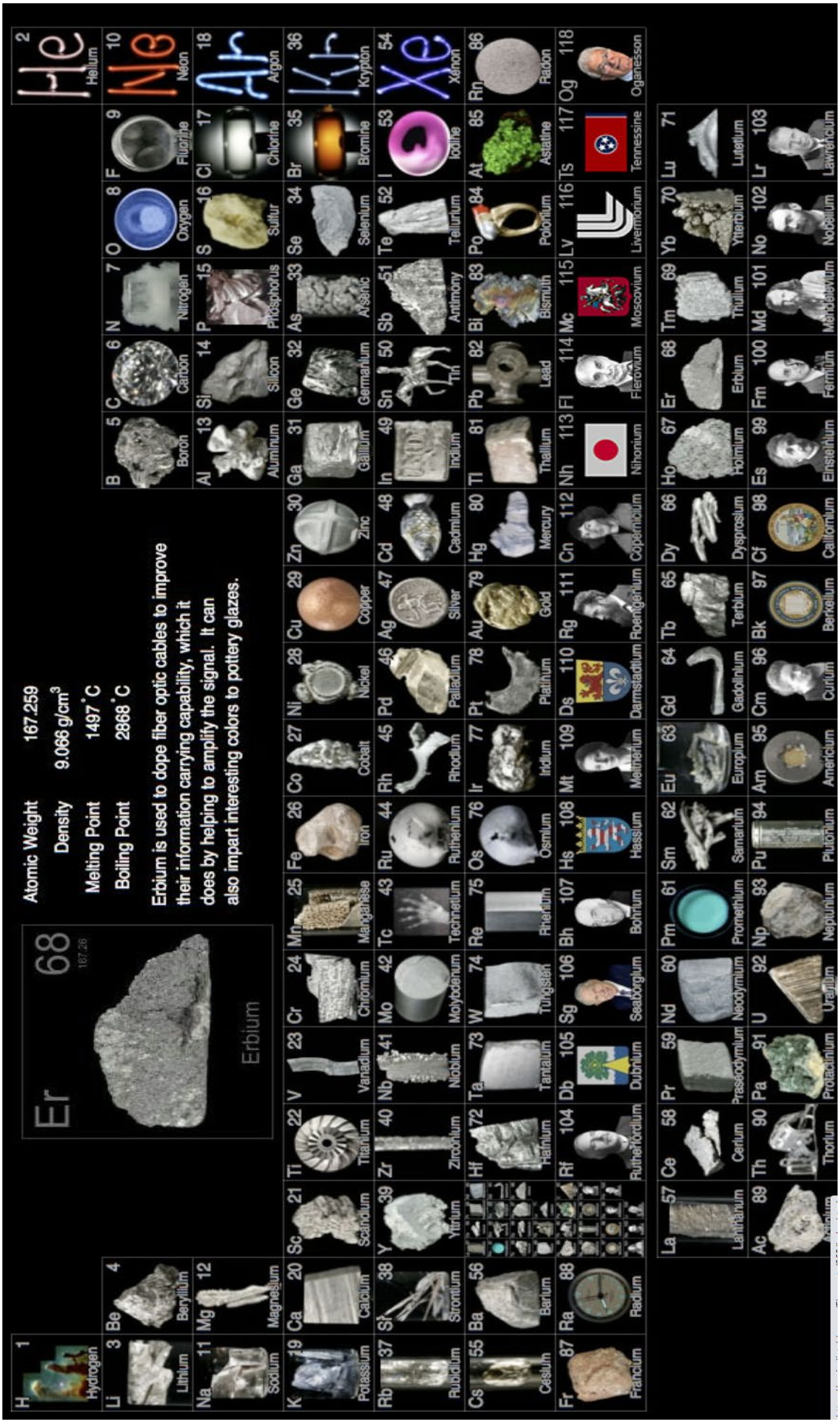

ILLUSTRATED PERIODIC TABLE – REFERENCE MATERIAL

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(2) Glass use in 21st Century

How many do you have at home?

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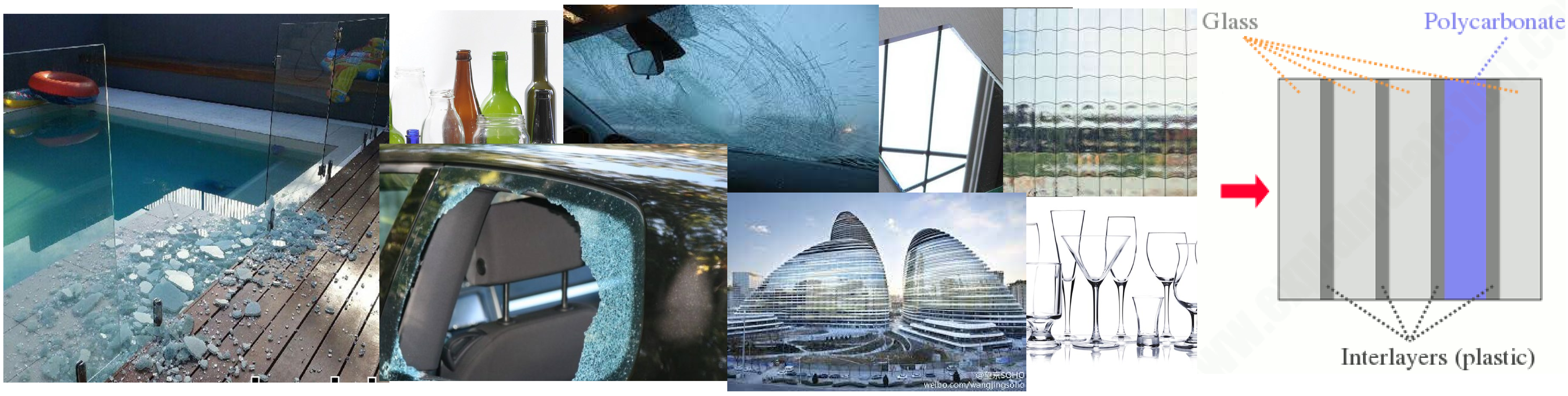
Glass is not always simple!

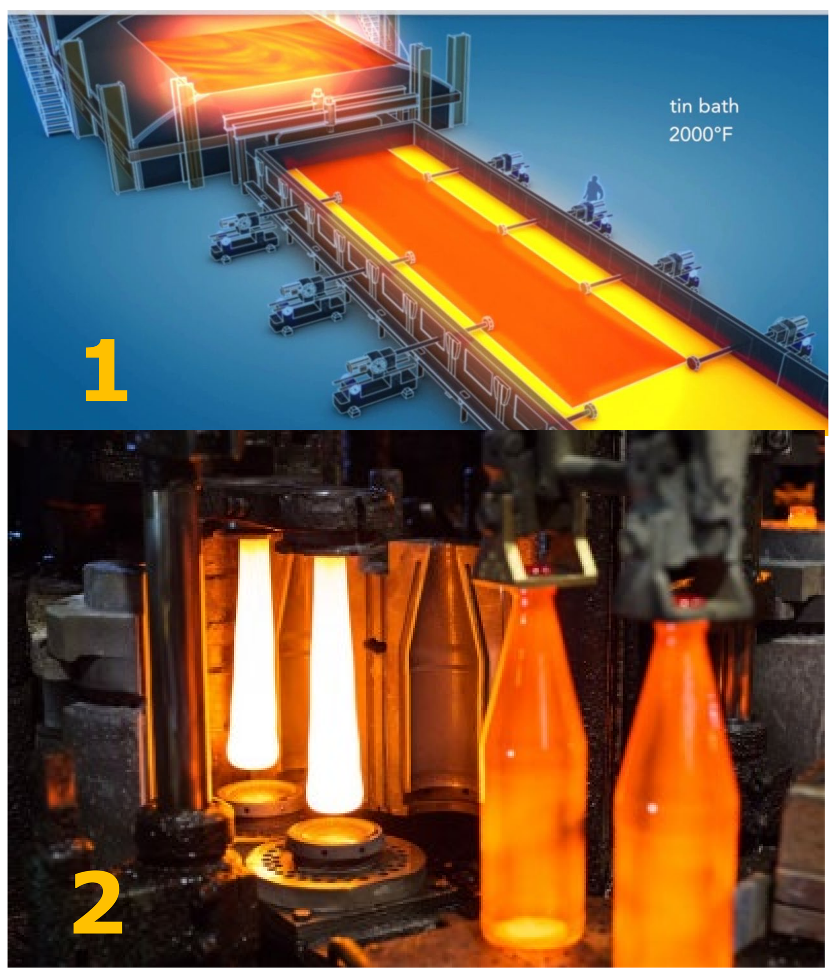
- ❑ **(a) Soda Lime Glass normal glass**
- ❑ **(b)Toughened/Tempered Glass**: Glass doors and panels; swimming pool glass fence, general domestic glassware, bottles and glass jars
- ❑ **(c)Annealed Glass**: Table-tops, cabinet doors, domestic sliding windows,.
- ❑ **(d)Laminated Glass** (Poly vinyl butadiene PVB interlayer): car windscreens, structural glass, skyscraper glazing;
- ❑ **(e)Low E (or Emissivity) Glass**: Energy Efficient Glass (transparent metal sputter heat /cold coating): High rise building / architectural extra large windows
- ❑ **(f)Bullet Proof Glass** (multi-laminated PVB glass + Polycarbonate insert): Special protection / Train driver windshields (withstand 20kg dead weight impact at 120 to 300 km/h)
- ❑ **(g)Wired Glass** (wire mesh inset glass casting): fire safety glass.
- ❑ **(h) Mirror Glass** (silver/copper coated sealed backing).



Quiz: 1) Match the different glass types to the glasses listed above. How many of these glass types can you find at home? *(1,0,1,0,0,0,0.5,0)*

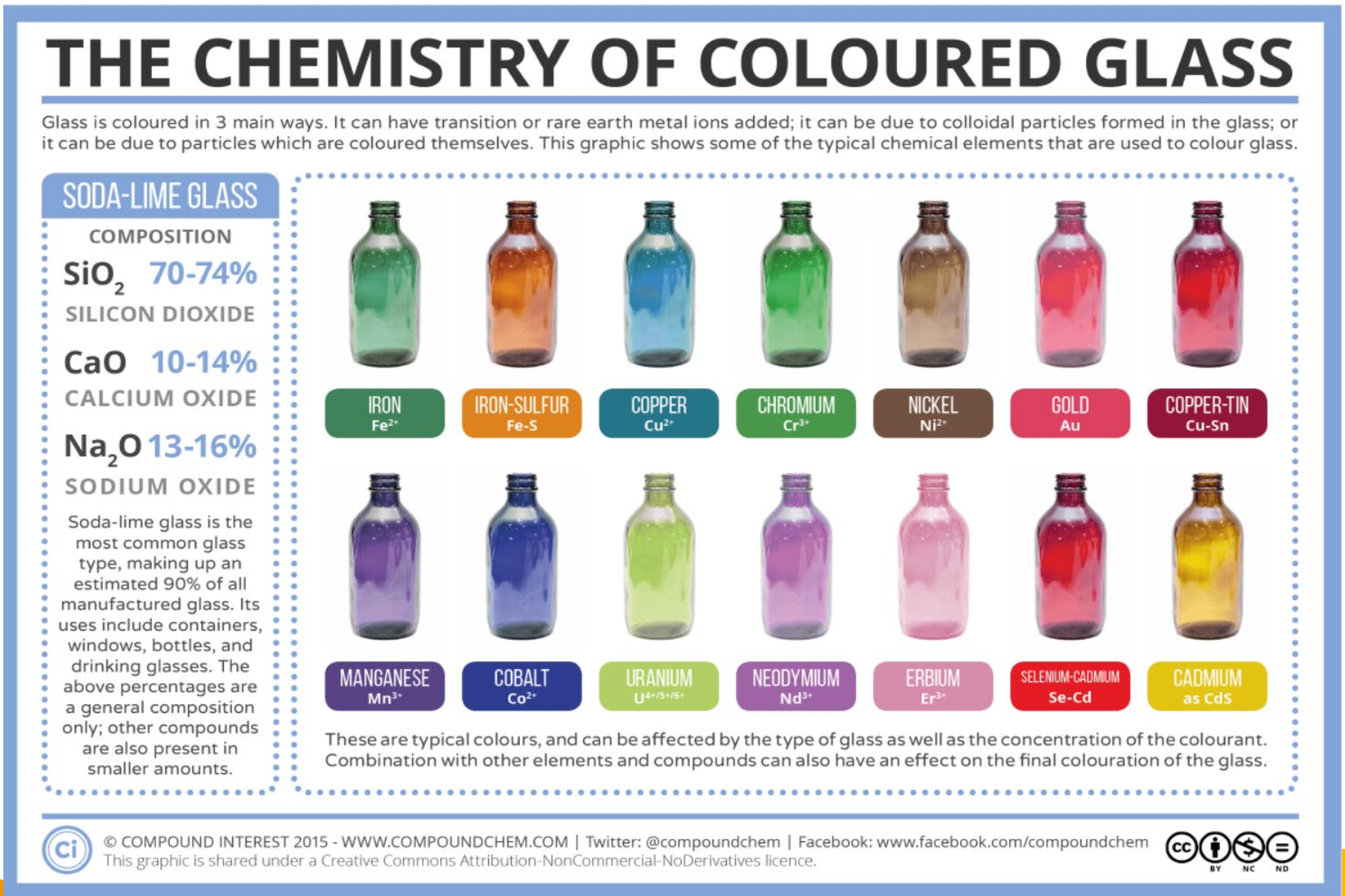
Which glass types can be recycled back into new glass? ❑ (a), ❑ (b), ❑ (c), ❑ (d), ❑ (d), ❑ (f), ❑ (f), ❑ (g), ❑ (h)

Are there other uses for glass that cannot be recycled back into making new glass?



Producing glass product:

For centuries, flat glass was produced by blowing a large bubble of molten glass at the end of a metal tube and beating the heated result flat. The blown cylinder process continued to be developed until the mid 19th century; hence many early Australian homes have ripples in window glass. Modern Glass Making In the early 20th century, techniques were developed to draw molten glass into sheets and mechanically polish them on both sides. This process met the demand for modern building and automotive glass, but was replaced in 1959 when Pilkington Brothers introduced the Float Glass process (i.e. item 1 to right) using a molten tin bath, which now accounts for ninety percent of the world's flat glass (invented by Sir Alastair Pilkington in 1952). Glass blow/casting is used for domestic bottles and glassware (i.e. item 2 to the right).



Oxides for colour!

Mixed originally with the silicon dioxide clean sand:

- Iron added as Iron Oxide II (Fe_2O_3)=> **Deep green;**
- Iron Oxide II (Fe_2O_3) and elemental sulphur (S)=> **deep green-brown glass**
- Chromium Oxide (CrO_2)=> **drab army green**
- Mixtures of Chromium Oxide(CrO_2), Arsenic (As) and Tin Oxide (SnO_2) => **emerald-green glass**

Added to molten glass:

- Copper Oxide (CuO & CuO_2) or Cobalt Oxide microparticles added to molten glass => **blue glass**
- Nickel (Ni) micro-particles added to molten glass => **dark chocolate brown glass**
- Gold (Au) microparticles added to molten glass => **rose red coloured glass**
- Adding copper-tin alloy microparticles to molten glass => **ruby red glass**
- Manganese Oxide (Mn_3O_4) microparticles added to molten glass => **purple glass**
- (Uranium) Oxide Diuranate (e.g. $Na_2U_2O_7{\cdot}6H_2O$)added to molten glass => **pale green glass**
- Oxides of neodymium (NdO2) and cerium (CeO2) => **violet glass**
- Oxides of Erbium (Er_2O_3) => **pink coloured glass**
- Mixing Elemental Selenium microparticles, Cadmium Sulphide (CdS), arsenic trioxide (As_2O_3)=> **various deep shades of red**
- Cadmium Sulphide (CdS) => **yellow glass**

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(3) Industrial Glass Puzzle | *From Rockets to the Mundane.*

New Applications for Glass

Instruction: Match the illustrations to the types of industrial Glass.

Industry has produce some new glass types. These include:

- ❑ (a) **Quartz Glass**: (SiO_2) Operating Temperature 1,100°C; nominally 70 times as strong as normal glass, and thermal shock ΔT ~1000°C. Used for high-temp equipment & specialised lighting.
- ❑ (b) **PYROCERAM** ($2MgO\text{-}2Al_2O_3\text{-}5SiO_2$) Operating temperature 700 °C, nominally 7 times as strong as normal glass, and thermal shock ΔT ~up to 850°C. Used in high-temp rocket nose cones.
- ❑ (c) **Borosilicate glass** (70–80wt% SiO_2, 7–13wt% B_2O_3 4–8wt% Na_2O or K_2O, and 2–8wt% Al_2O_3) Operating temperature 230°C; nominally 5 times as strong as quartz glass, high chemical resistance, and thermal shock ΔT ~up to 170°C. Used in laboratory glassware. This glass has Mohs hardness of 7.2 (i.e topaz will scratch it, quartz will not.)
- ❑ (d) **Vitrelle Glass**: Safe operating temperature 175°C. Thermal shock resistance is same as normal glass. Annealed inner layer, and crystalline high compressive chip-free outer skin. Often used as a chip resistant replacement for porcelain applications.; non-porous compared to soda lime glass.

□ 1

SURF BOARD

□ 2

HALOGEN LAMP

□ 3

CORELLE DINNER PLATES

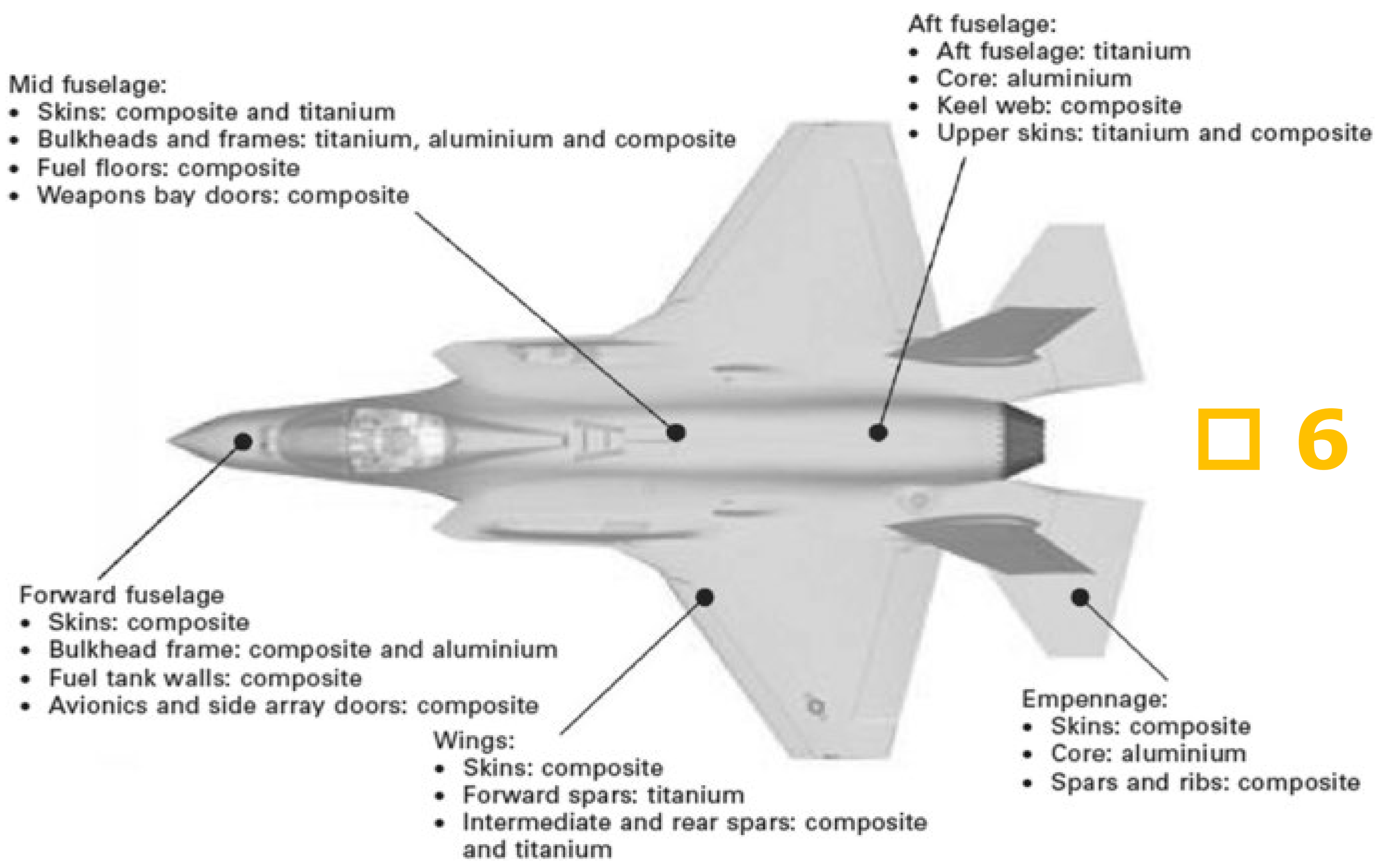
□ 4

LAB BEAKER

□ 5

CORNING WARE

☑ Which of these can be recycled and how?



□ 6

Industrial Glass Fibre:

Discussion 1: (e) **Glass fibre** is formed from a molten liquid state, forced through a platinum head with tiny holes. It has been used as fibre reinforcement for epoxy resins (fibreglass construction). Tensile Strength ~2800 MPa, 5% elongation to break and modulus of elasticity of ~72.4 GPa. Glass fabrics retain 50% of room temperature tensile strength at 370°C, 25% at 480°C. Safe working temperature of 250°C.

Discussion 2: (f) E Glass (55wt% SiO_2, CaO 19wt%, Al_2O_3 15wt%, Br_2O_3 7.5%, MgO 2.5wt%, Fluorides 1%wt, TiO 0.8%, balance of Na_2O, K_2O with traces of Iron oxide) Safe working temperature of 400°C. Alkali resistant glass fibre used in high strength fibreglass construction or reinforced polymers used in the electrical, power industry and wind-turbine blades; 3,400 MPa, 4.7% elongation to break and modulus of elasticity of ~72.0 GPa.

Discussion 3: (g) S Glass (65wt% SiO_2, CaO 0.3wt%, Al_2O_3 55wt%, MgO 10wt%, Safe working temperature of 540°C. Fluorides 1%wt, balance of Na_2O, K_2O with traces of Iron oxide) used for higher tensile applications in aerospace; 4,600 MPa, 5.2% elongation to break and modulus of elasticity of ~89 GPa.

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