



CORNING

## The Science Behind Glass

Ron Stewart, PhD  
Corning Development Associate  
Science & Technology

# Overview

- What is glass?
- Unique features of glass
  - Chemical durability
  - Thermal behavior
  - Electrical



# Practical Definition for Commercial Glass

**glass** (gläs)

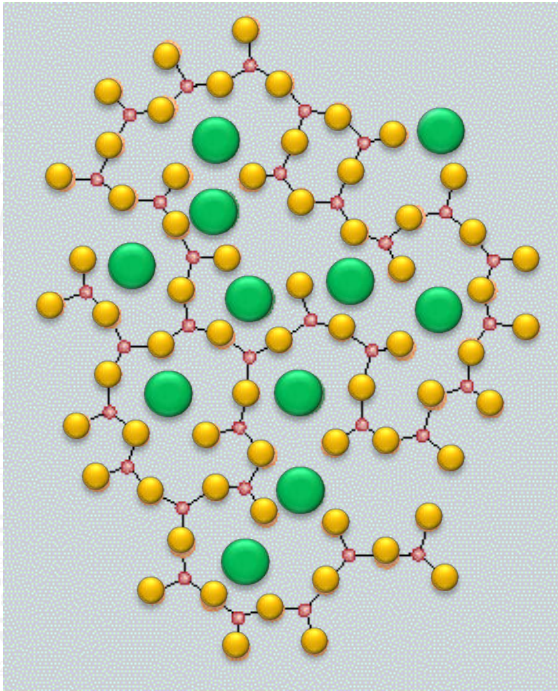
*n.*

- 1. Inorganic transparent material*
- 2. Hard, brittle, mechanical solid with modest strength (70MPa) in bulk form at room temp.*
- 3. Chemically durable, dielectric*



# Many types of silicate glasses...

## The commercial glass chemist's periodic table



**5 B**      **8 O**  
**13 Al**   **14 Si**

**Glass formers**  
(make a stable glass network)

hydrogen 1 H 1.0079	helium 2 He 4.0026																														
lithium 3 Li 6.941	beryllium 4 Be 9.0122	boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180																								
sodium 11 Na 22.990	magnesium 12 Mg 24.305	aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948																								
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.88	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.63	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80														
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc 98	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.6	iodine 53 I 126.905	xenon 54 Xe 131.29														
caesium 55 Cs 132.91	barium 56 Ba 137.33	lanthanum 57 La 138.905	cerium 58 Ce 140.12	praseodymium 59 Pr 140.908	neodymium 60 Nd 144.24	promethium 61 Pm 145	europium 62 Eu 151.964	gadolinium 63 Gd 157.25	terbium 64 Tb 158.925	dysprosium 65 Dy 162.5	holmium 66 Ho 164.930	erbium 67 Er 167.259	thulium 68 Tm 168.930	ytterbium 69 Yb 173.054	lutetium 70 Lu 174.967	hafnium 71 Hf 178.49	tantalum 72 Ta 180.948	tungsten 73 W 183.84	rhenium 74 Re 186.207	osmium 75 Os 190.23	iridium 76 Ir 192.22	platinum 77 Pt 195.08	gold 78 Au 196.97	mercury 79 Hg 200.59	thallium 80 Tl 204.38	lead 81 Pb 207.2	bismuth 82 Bi 208.98	polonium 83 Po [209]	astatine 84 At [210]	radon 85 Rn [222]	
francium 87 Fr [223]	radium 88 Ra [226]	actinium 89 Ac [227]	thorium 90 Th 232.038	protactinium 91 Pa 231.036	uranium 92 U 238.029	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]	lawrencium 103 Lr [260]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [277]	meitnerium 109 Mt [268]	unnilium 110 Uun [271]	ununium 111 Uuu [272]	unbinium 112 Uub [277]	untrium 113 Uut [284]	unquadrium 114 Uuq [289]	unpentium 115 Uup [288]	unhexium 116 Uuh [289]	unseptium 117 Uus [294]	unoctium 118 Uuo [294]

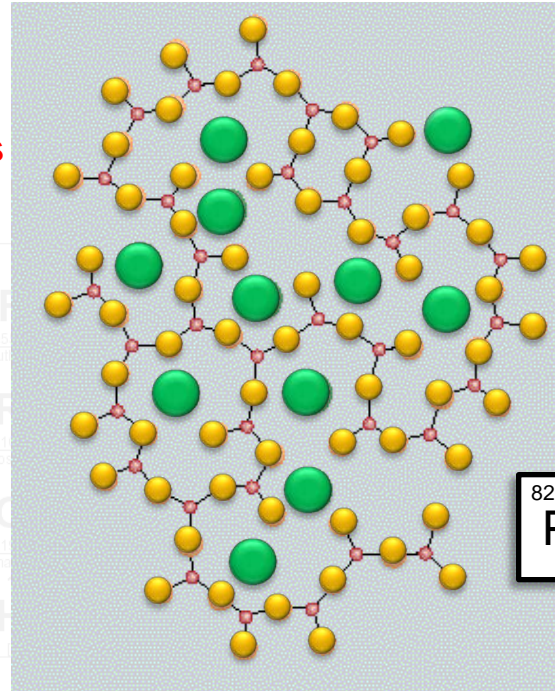


# Many types of silicate glasses...

## The commercial glass chemist's periodic table

hydrogen 1 H	
3 Li	4 Be
11 Na	12 Mg
19 K	20 Ca
37 Rb	38 Sr
55 Cs	56 Ba
87 Fr	88 Ra

**Network Modifiers**  
(promote melting – fluxes  
Impart durability - stabilizers)



scandium 21	titanium 22	vanadium 23	chromium 24	manganese 25	iron 26
Sc	Ti	V	Cr	Mn	Fe
44.956	47.867	50.942	51.996	54.938	55.845
yttrium 39	zirconium 40	niobium 41	molybdenum 42	technetium 43	ruthenium 44
Y	Zr	Nb	Mo	Tc	Ru
88.906	91.224	92.906	95.94	[98]	101.07
lutetium 71	hafnium 72	tantalum 73	tungsten 74	rhenium 75	osmium 76
Lu	Hf	Ta	W	Re	Os
174.967	178.49	180.95	183.84	186.21	190.23
lawrencium 103	rutherfordium 104	dubnium 105	seaborgium 106	bohrium 107	hassium 108
Lr	Rf	Db	Sg	Bh	Hs
[260]	[261]	[262]	[263]	[264]	[265]

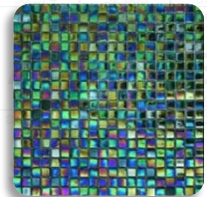
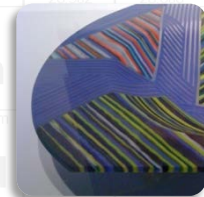
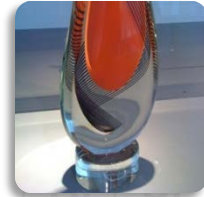
# Many types of silicate glasses...

## The commercial glass chemist's periodic table

### Colors and contaminants

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cesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *																		thallium 81 Tl 204.38	lead 82 Pb 207.2	
francium 87 Fr [223]	radium 88 Ra [226]	89-102 **	lutetium 71 Lu 174.97	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [283]	meitnerium 109 Mt [268]	ununnium 110 Uun [271]	ununium 111 Uuu [272]	ununium 112 Uub [277]							bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]

23 V 24 Cr 25 Mn 26 Fe 27 Co 28 Ni



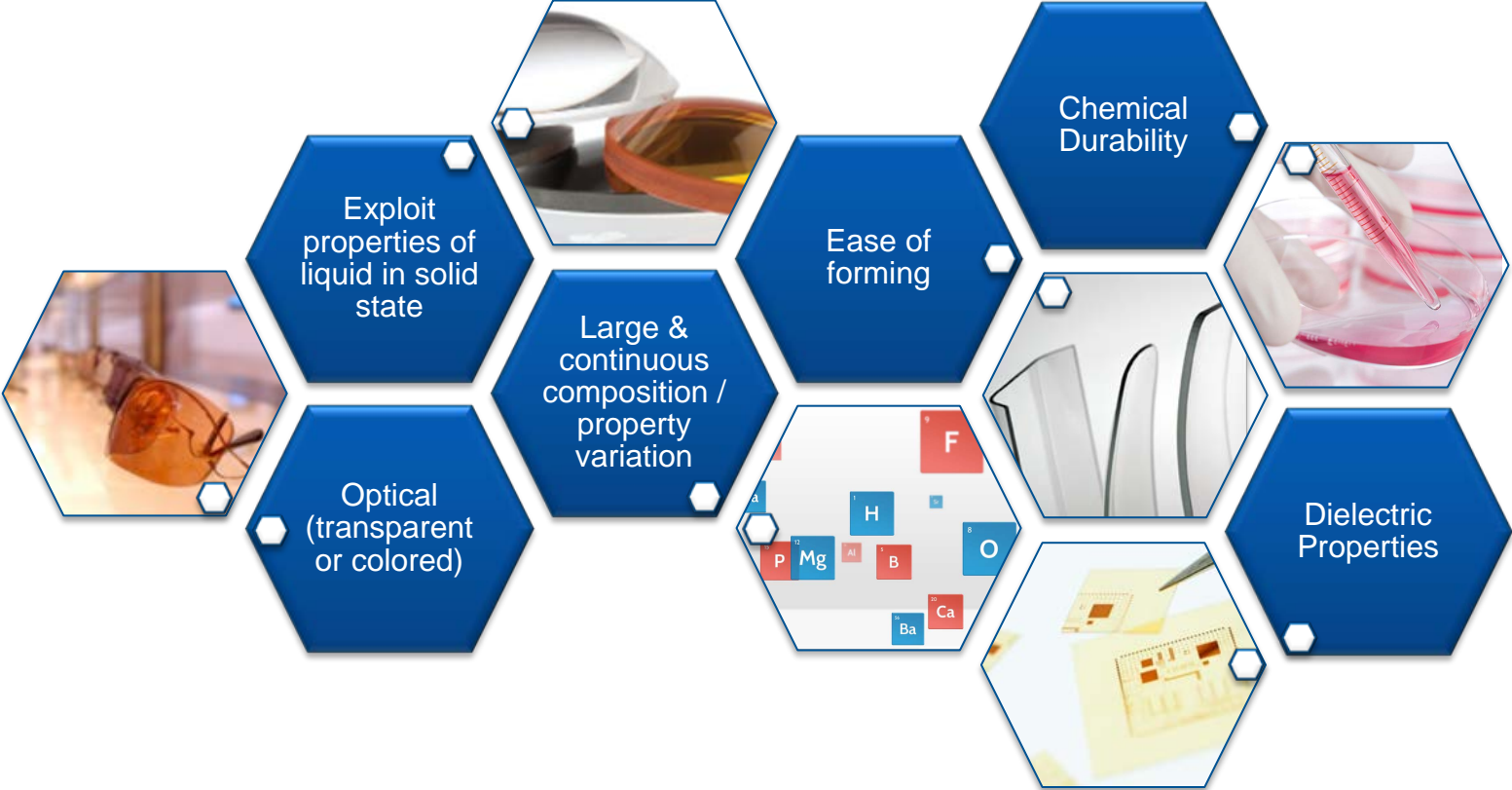
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## The commercial glass chemist's periodic table

**Finishing Agents  
(remove small bubbles)**

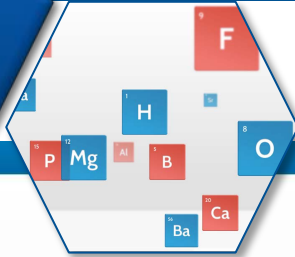
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# Uniqueness of Glass





Large & continuous composition / property variation



- Glass is a good solvent
- Tailor-made properties (CTE)

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**Fact 07**

Although silicon and oxygen are the predominant constituents of glass, silica is also a gracious collaborator with its friends on the periodic table. A survey of glass research reveals more than 50 other elements that have been used as additives to silica glass in order to create glasses with unique physical, thermal, or optical properties for a wide variety of technical and artistic applications.

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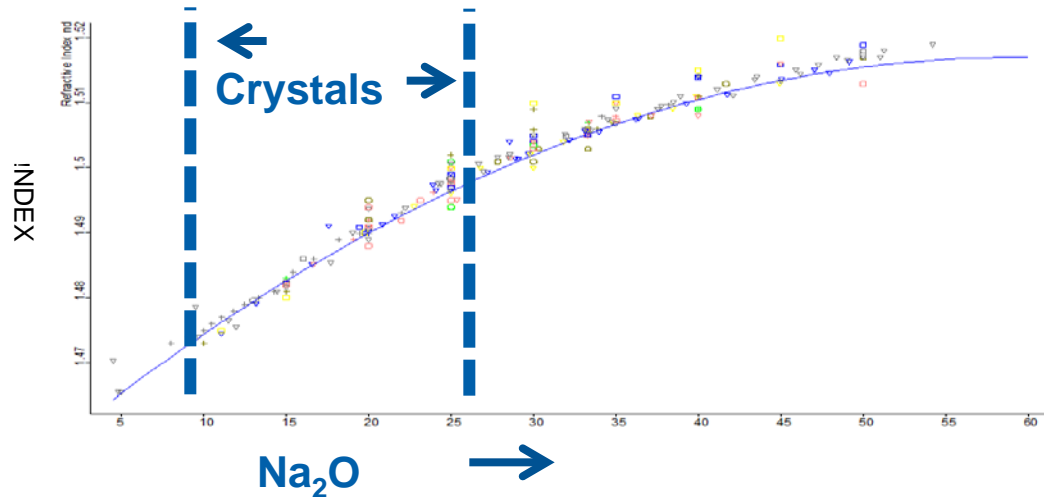
Exploit  
properties of  
liquid in solid  
state



- Phase separation
- Crystallization
- Glass-Ceramics



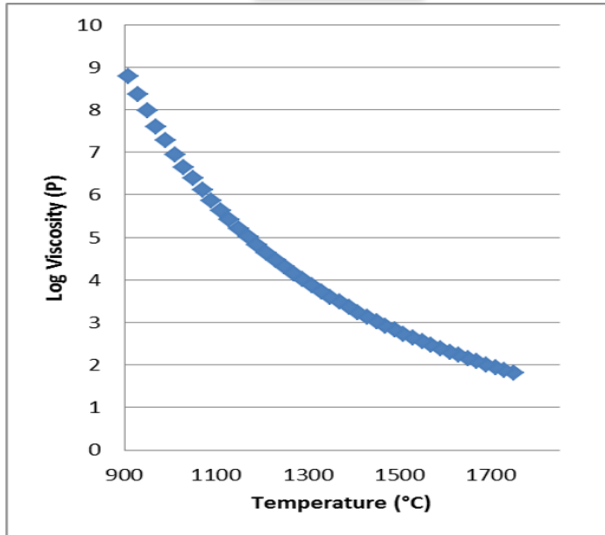
- Continuous property variation in glass
- Tailor made index



Ease of forming



- Viscosity varies smoothly and continuously with temperature

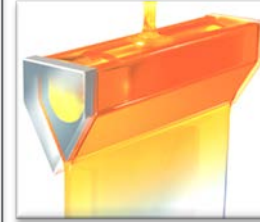


#### Rods, fibers, canes



- Tube making
- Fiber draw

#### Sheets



- Fusion draw
- Float process
- Rolling or stamping

#### Forms



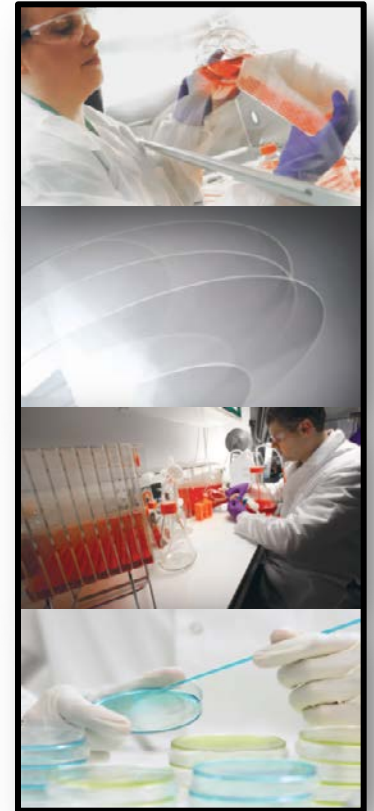
- Glass blowing, lamp-working
- Ribbon machine
- Bottle machine

## Chemical Durability



### Chemical durability depends on composition

- Acids & mild bases
- Water, atmosphere ( $\text{CO}_2$ )
- Commercial glasses resistant to solvents



## Dielectric Properties



- Can have low dielectric constant
- Low loss tangents





# Summary

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- Commercial Glasses: mainly silicate based, but much compositional variety
- Glass is a good inorganic solvent
  - Can have many elements / oxides plus SiO<sub>2</sub> (silica)
- Glass has continuous variation of properties with composition
  - Can tailor properties like CTE, Index, Density, Electrical
  - Smooth viscosity change with temperature allows many types of forming processes for technical products and artwork
- Glasses can be chemically & mechanically durable

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