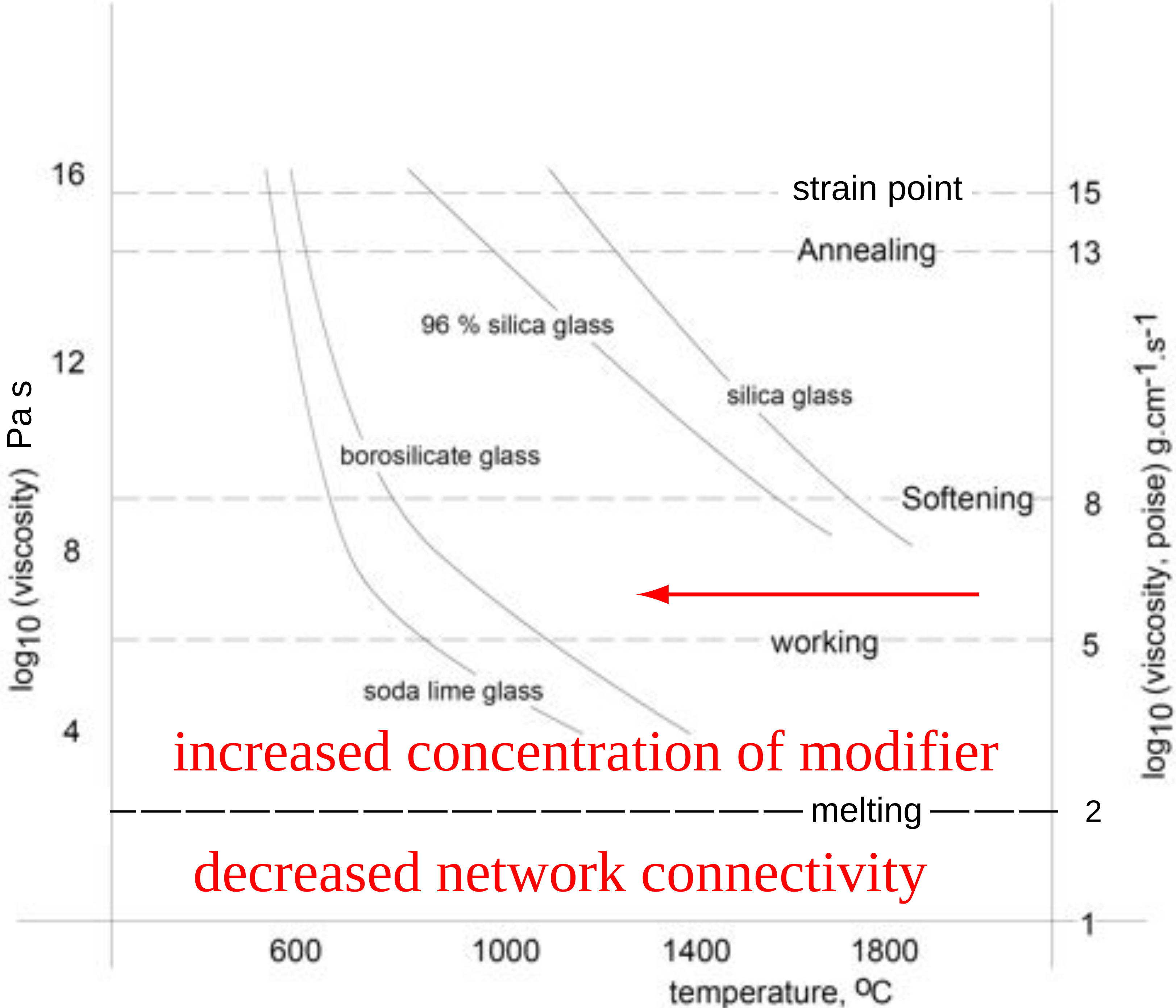
Welcome to 3.091

Lecture 22

November 2, 2009

Engineering Glass Properties; Introduction to Kinetics

Type	Composition, w/o								Properties or uses
	SiO_2	Na_2O	K_2O	CaO	MgO	B_2O_3	Al_2O_3	Other	
Soda-lime	72	14		9	4		1		Window glass
Silica glass (fused quartz)	99.5+								High-temperature applications; low coefficient of expansion
96% silica glass	96.3	<0.2	<0.2			2.9	0.4		Comparable to fused quartz
Borosilicate	80.5	3.8	0.5			12.9	2.2		Resistant to heat and to chemicals
Light flint optical	54	1	8					37PbO	High index of refraction
Surface-strengthened glass	55	16	2	2		2	19	$4TiO_2$	Cookware
Glass-ceramic	56				15		20	$9TiO_2$	Radomes



increased concentration of modifier

decreased network connectivity

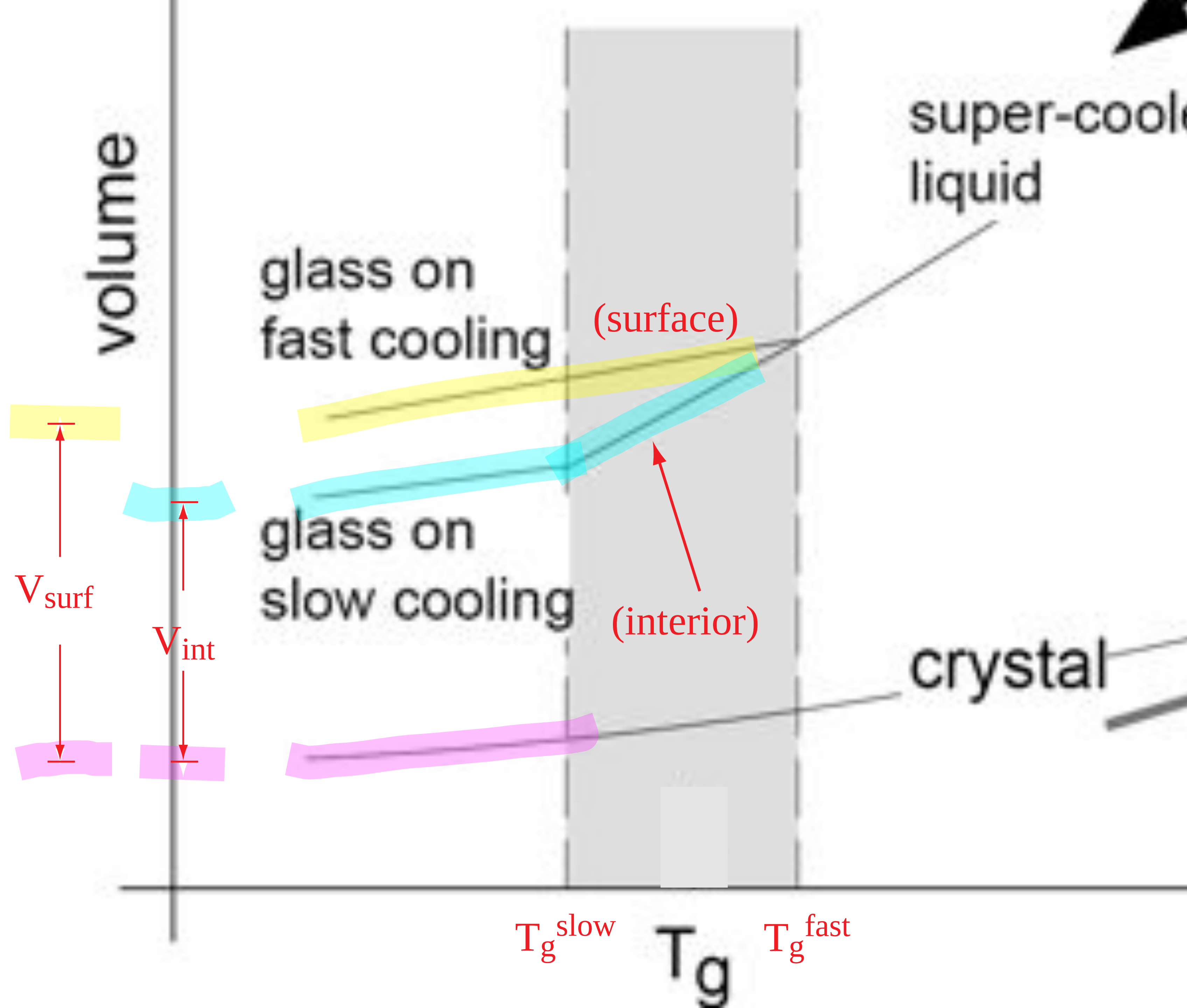
working point: ($\eta \approx 10^5$ poise) temperature above which it is possible to *form* the glass, *i.e.*, press, draw, shape

softening point: ($\eta \approx 10^8$ poise) temperature above which glass *flows under its own weight*

annealing point: ($\eta \approx 10^{13}$ poise) temperature above which *residual stresses can be relieved within 15 min*

strain point: ($\eta \approx 10^{15}$ poise) temperature below which glass can be *rapidly cooled* without introducing internal stresses capable of fracture

1 Pa s = 10 poise; $\eta_{water} \approx 10^{-2}$ poise



volume
super-cool
liquid
glass on
fast cooling
(surface)
glass on
slow cooling
(interior)
crystal
V surf
V int
Tg slow
Tg
Tg fast

why do we study kinetics?

✏ productivity &
resource utilization
☞ competitiveness

✏ energy & the environment

✏ societal:
science in service of humanity

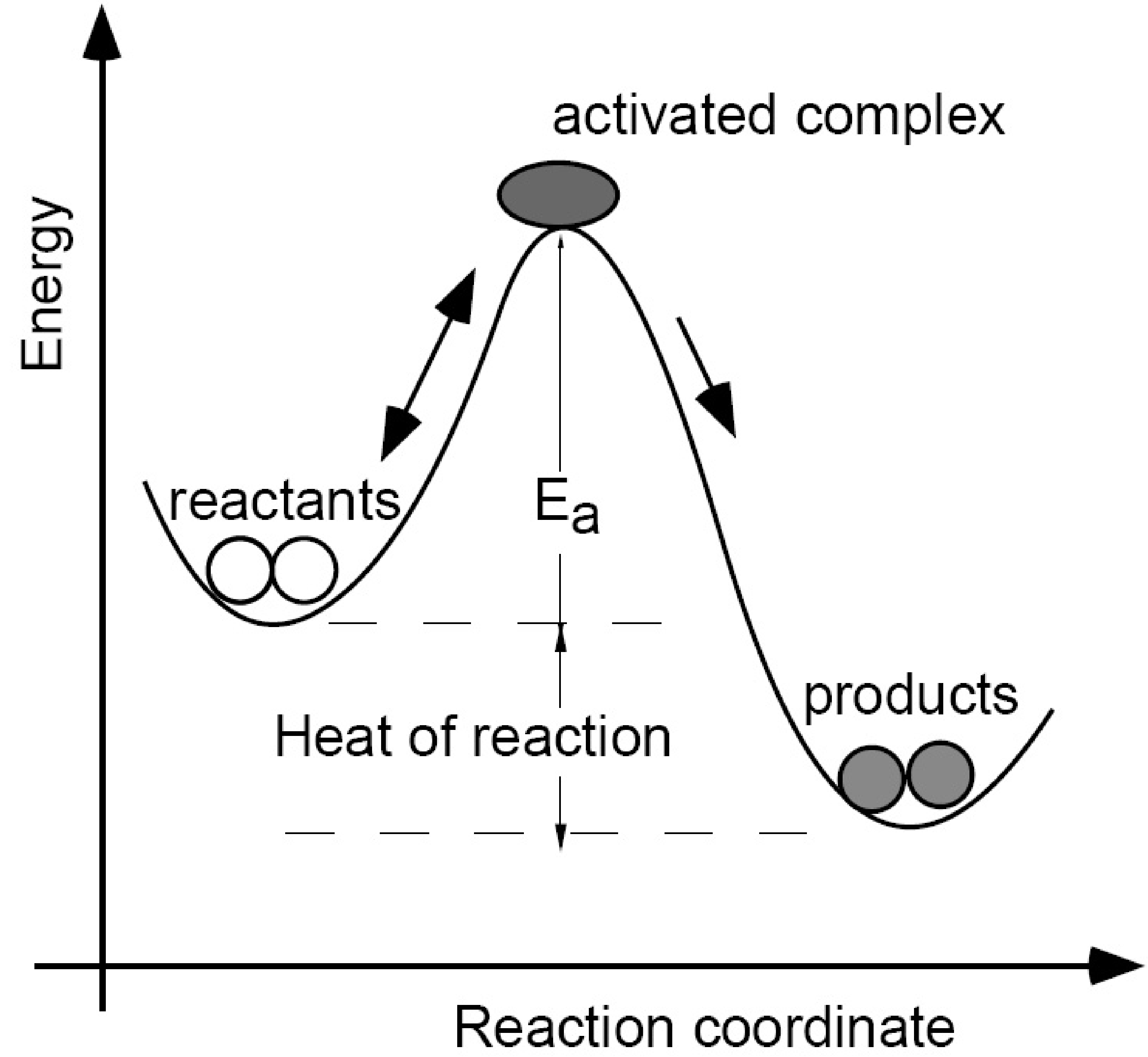
on the topic of airbags

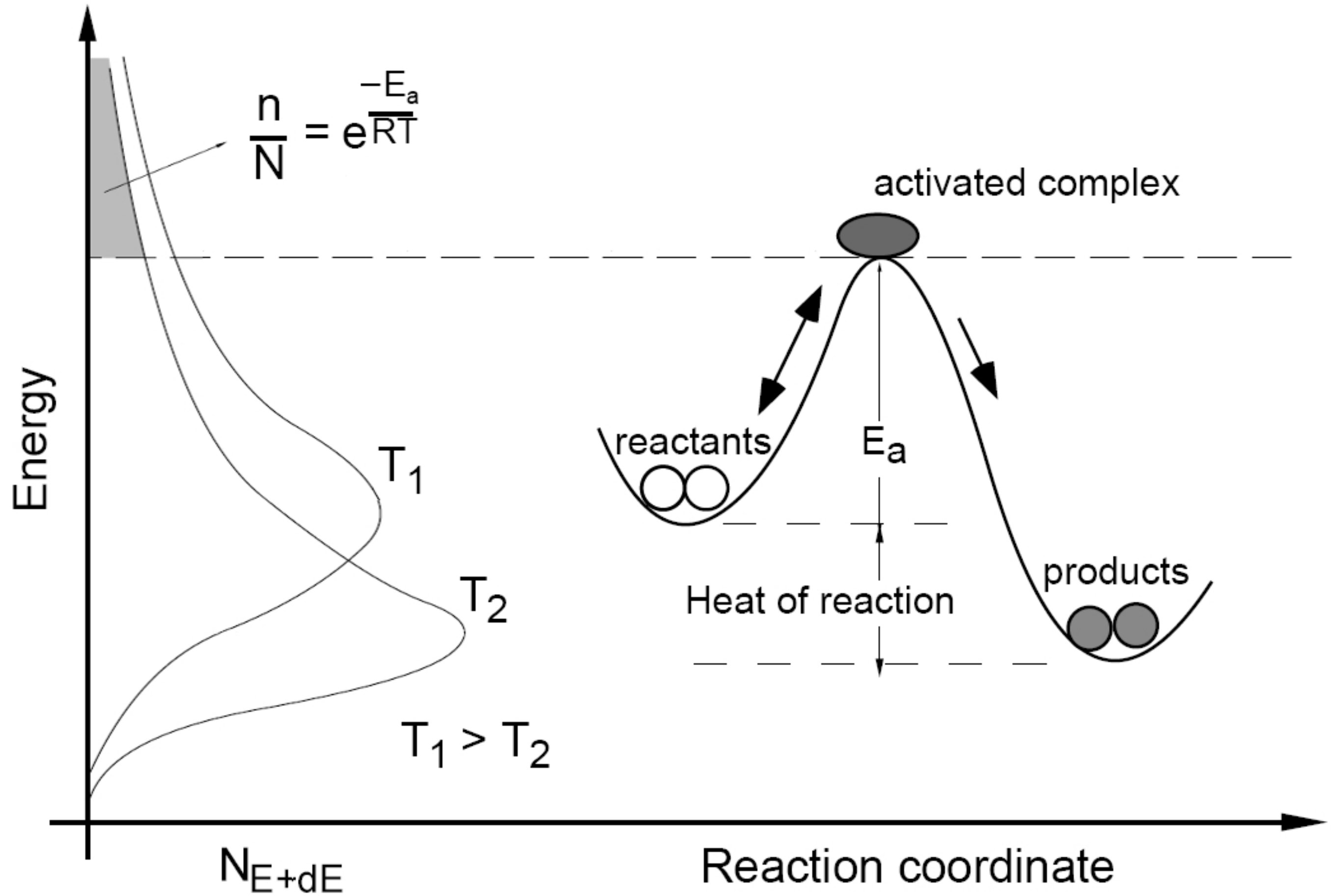
$$NaN_3 \xrightarrow{300°C} 3/2\ N_2 + Na$$

accelerometer ☞ electric current

$$10\ Na + 2\ KNO_3 \longrightarrow 5\ Na_2O + K_2O + N_2$$

$$5\ Na_2O + K_2O + n\ SiO_2 \longrightarrow \text{alkaline silicate glass}$$


activated complex
Energy
reactants
E$_a$
Heat of reaction
products
Reaction coordinate



$\frac{n}{N} = e^{\frac{-E_a}{RT}}$
activated complex
Energy
reactants
E_a
T_1
T_2
products
Heat of reaction
$T_1 > T_2$
N_{E+dE}
Reaction coordinate

Radiocarbon Dating

Willard F. Libby: Nobel Prize 1960

* in the upper atmosphere, radioactive carbon is produced naturally by cosmic rays which generate neutrons:

$${}_{7}N^{14} + {}_{0}n^{1} \Rightarrow {}_{6}C^{14} + {}_{1}p^{1}$$

* ${}_{6}C^{14}$ enters the carbon cycle, $\therefore$ ratio of ${}_{6}C^{14}/{}_{6}C^{12}$ constant in all organisms (as is ${}_{6}C^{13}/{}_{6}C^{12}$)

* upon death, conc. of ${}_{6}C^{14}$ falls via ${}_{6}C^{14} \Rightarrow {}_{7}N^{14} + {}_{-1}\beta^{0-}$

* measure ${}_{6}C^{14}/{}_{6}C^{12}$ to determine age ($t_{½} = 5730$ y)

Half-lives and applications of some radioactive isotopes

Radioactive Isotope	Half-Life	Typical Uses
Hydrogen-3 (tritium)	12.32 yr	Biochemical tracer
Carbon-11	20.33 min	PET scans (biomedical imaging)
Carbon-14	5.70×10^3 yr	Dating of artifacts
Sodium-24	14.951 hr	Cardiovascular system tracer
Phosphorus-32	14.26 days	Biochemical tracer
Potassium-40	1.248×10^9 yr	Dating of rocks
Iron-59	44.495 days	Red blood cell lifetime tracer
Cobalt-60	5.2712 yr	Radiation therapy for cancer
Technetium-99*m**	6.006 h	Biomedical imaging
Iodine-131	8.0207 days	Thyroid studies tracer
Radium-226	1.600×10^3 yr	Radiation therapy for cancer
Uranium-238	4.468×10^9 yr	Dating of rocks and Earth's crust
Americium-241	432.2 yr	Smoke detectors

*Denotes *metastable*, where an excited nucleus decays to the ground state of the same isotope.

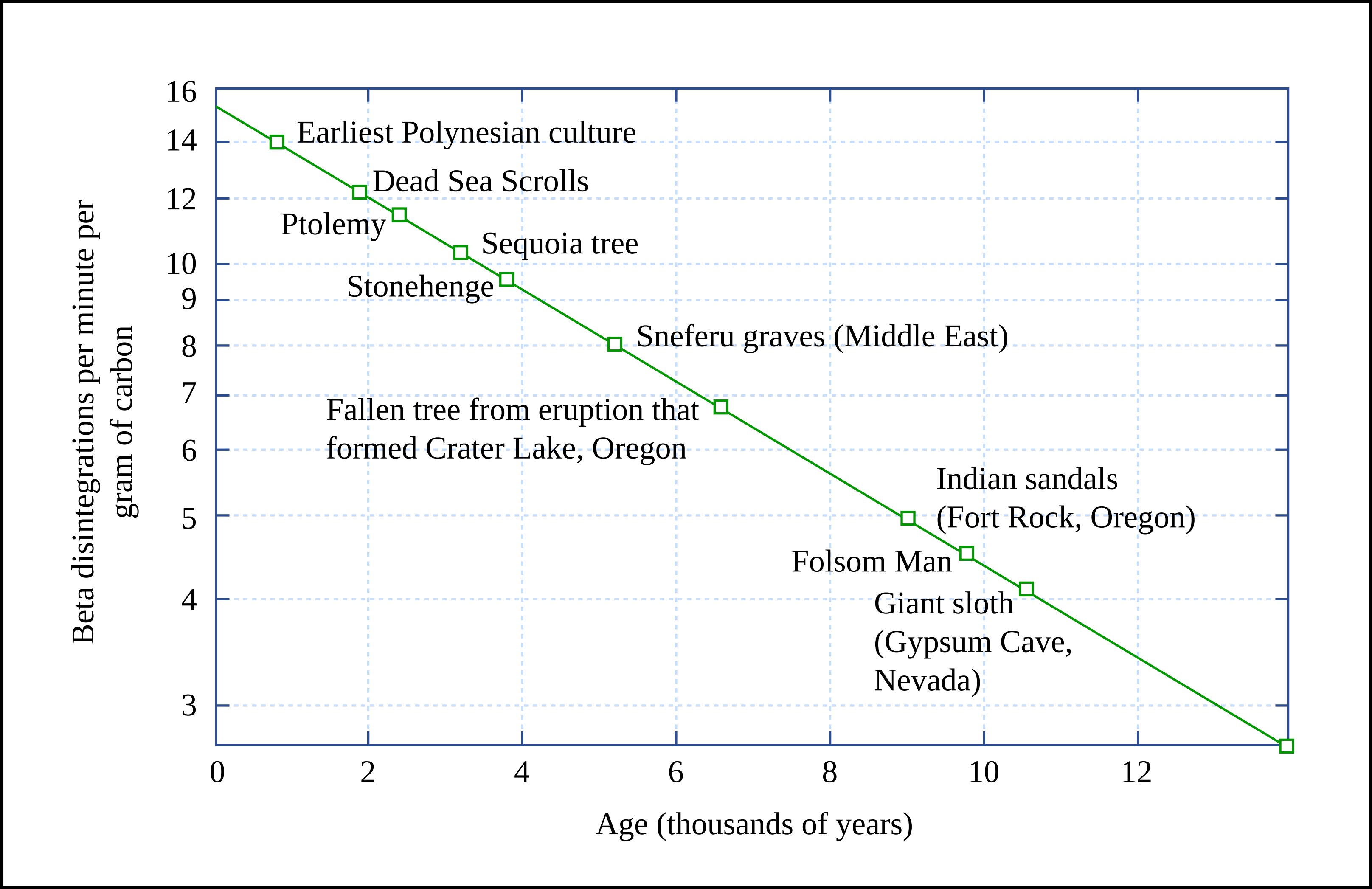
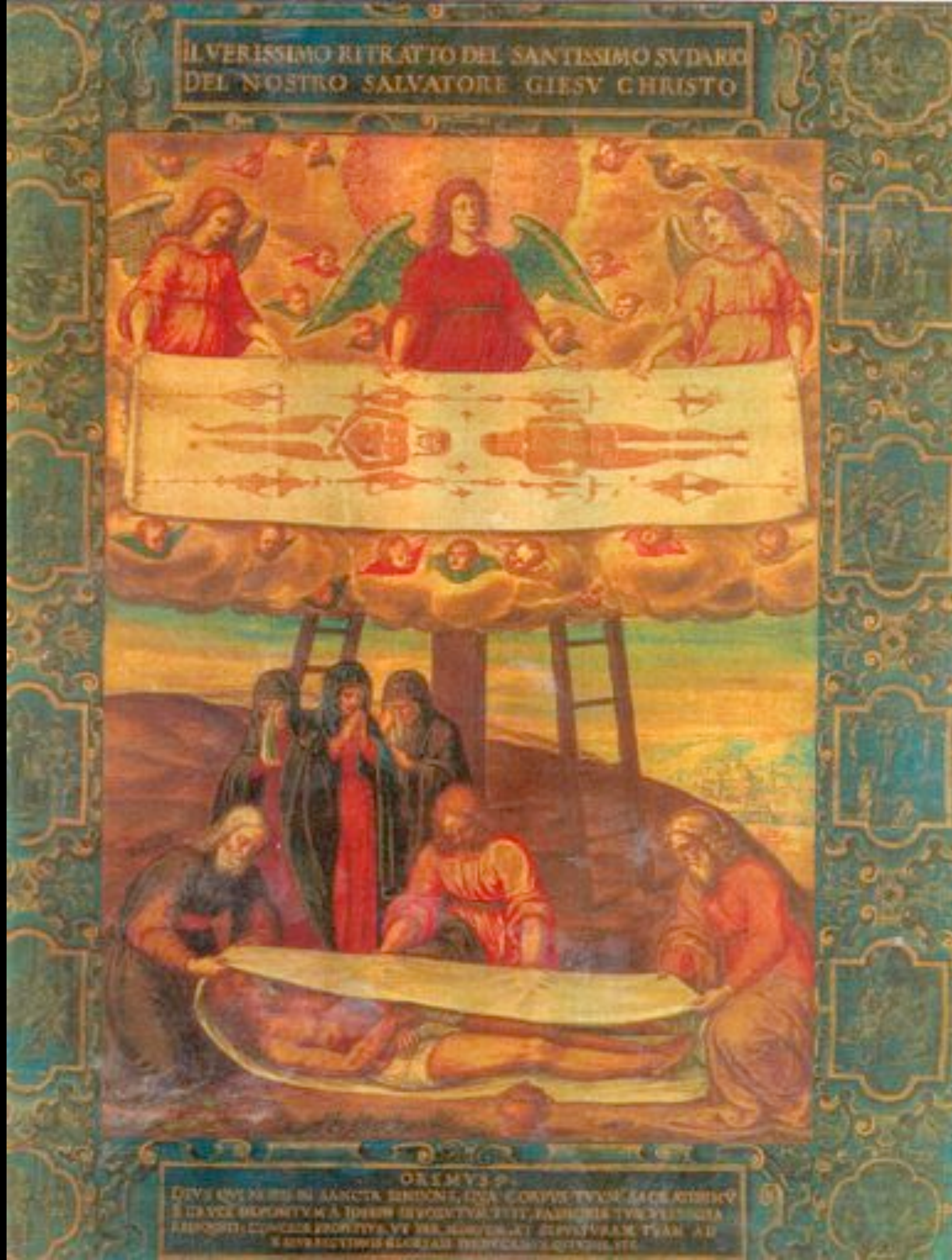


Image by MIT OpenCourseWare. Adapted from Fig. 14.13 in Averill, Bruce, and Patricia Eldredge. *Chemistry: Principles, Patterns, and Applications*. San Francisco, CA: Pearson/Benjamin Cummings, 2007. ISBN: 080538039.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OREMVS

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c.f. 1354

3 labs in 3 countries: 1260-1390

Geoffroi de Charny

But wait! There was a fire in 1532 at Chambéry

fire →
water + smoke
bacteria, mold
paraffin →
expert error?