

The Glass Transition Temperature Moves with the Speed of Measurement

— Six decades of observation time move T_g by **21.4286 K** — **4.1667 K** per decade — The melting point does not move and T_g does; this is not a property of the substance but the outcome of a rendezvous with the measurement — [Paper 352]

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— *From thinking to syncing.* —

Abstract

The glass transition temperature T_g is written as though it were a material constant. This paper asks whether it is one—the answer is that it is not a constant but a function of the measurement's time scale. No new mathematical theorem and no new law is claimed. First, what is called T_g is where the relaxation time overtakes the observation time (Section 2). Second, this is the core of the paper. Six decades of observation time take T_g from 321.4286 K to 300.0000 K, a fall of **21.4286 K** (Section 3). Third, that is **4.1667 K** per decade, inside the accepted 3–5 K (Section 3). Fourth, the melting point does not move under the same treatment (Section 4). Fifth, so a reported T_g without its measurement conditions is a number without meaning (Section 4). Sixth, the separator is thermodynamic equality against kinetic overtaking (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed—the VFT equation, the rate dependence of the glass transition, and the fragility classification are all standard. We do not build a theory of glasses—the origin of the glass transition (free volume, cooperatively rearranging regions, mode-coupling theory) is not entered. It is named and no more. We make no measurement—no T_g of any particular substance is measured. The numbers are on VFT parameters stated explicitly. Fragility is not the subject—Angell’s strong/fragile classification is named and no more. We do not treat the detail of calorimetry—baseline construction in DSC and the midpoint/onset conventions are not the subject. We build no theory of phase transitions—whether the Ehrenfest classification applies is not entered. Relation to earlier papers: Paper 300 showed whether two things share a root is decidable—by that test, the melting point and the glass transition temperature have distinct roots. Paper 313 showed one word used in four senses—“transition temperature” has the same shape. Paper 351 showed one word “pumping” naming two mechanisms—here one phrase “transition temperature” names two. Paper 333 showed a constant ratio following from cancellation and not from measurement—there too the provenance of something that looked constant was the issue. What is added is giving the rate dependence of T_g as a number from the VFT equation, checking the per-decade shift against the accepted range, setting the contrast with the melting point explicitly, and putting the separator on transition against rendezvous.

1. Notation and the Question

Setting: Write the relaxation time τ by the Vogel–Fulcher–Tammann (VFT) equation.

$$\log_{10} \tau = -14.0 + \frac{B}{T - T_0}, \quad B = 1000 \text{ K}, \quad T_0 = 250 \text{ K}$$

Observation 1.1

T_g is written as “the temperature at which something happens”. One writes that the T_g of polystyrene is 100 degrees Celsius—the same format as a melting point.

Observation 1.2

But the definition of T_g contains a measurement. T_g is where the relaxation time overtakes the observation time—and “observation time” is not a quantity on the substance’s side.

Observation 1.3

The VFT equation diverges as $T \rightarrow T_0$. Because the denominator is $T - T_0$ — $T_0 = 250$ K is called the ideal glass temperature and is not reachable experimentally.

Question: Is T_g a property of the substance?

2. The Definition Contains an Observation Time

Observation 2.1

A glass is a liquid that flows too slowly to look like it is moving. The structure stays liquid and only the motion is slow—how slow counts as “stopped” is decided by how long one waits.

Observation 2.2

So the threshold is a time. By convention $\tau = 100$ s is used to define T_g —the number 100 does not come out of the substance. It comes from how long a laboratory can wait.

Observation 2.3

Cooling rate and observation time are two faces of one thing. Cool faster and less time is available at each temperature—which is why faster cooling raises T_g .

3. 21.4286 K over Six Decades

Calculation 3.1: T_g against observation time (computed in this paper).

Observation time [s]	$\log_{10} t$	T_g [K]	Change from above
10^0	0	321.4286	—
10^1	1	316.6667	−4.7619 K
10^2	2	312.5000	−4.1667 K
10^3	3	308.8235	−3.6765 K
10^4	4	305.5556	−3.2680 K
10^5	5	302.6316	−2.9240 K
10^6	6	300.0000	−2.6316 K

Observation 3.2

This is the core of the paper. Six decades move it by **21.4286 K**—an average of **4.1667 K** per decade, inside the accepted “3 to 5 K per decade”.

Observation 3.3

21.4286 K is not small. In Celsius it is the difference between 48.28 and 26.85 degrees—a span across which the answer to “is it above room temperature” changes.

Observation 3.4

The steps are not equal; they shrink. From **−4.7619** to **−2.6316**—because VFT is not an exponential. An Arrhenius law would give equal steps.

Observation 3.5

It can be checked backwards. Putting the resulting T_g back into VFT gives $\log_{10} \tau = 2.0000000000$ —matching the defined observation time of 10^2 s. The formula closes.

Observation 3.6

Changing B changes the size of the shift. A smaller B gives a smaller shift per decade——so the strength of the rate dependence is itself material-specific. That is the content of fragility.

4. The Melting Point Does Not Move

Observation 4.1

The same treatment at the melting point gives nothing. Warm ice six decades more slowly and 273.15 K is still 273.15 K——the melting point is where two free energies are equal, and it contains no waiting time.

Observation 4.2

Here the criterion of Paper 300 does the work. Both are written as “the temperature at which something changes”——but one is fixed by a thermodynamic equality and the other by a kinetic overtaking. Distinct roots.

Observation 4.3

So reporting T_g requires reporting conditions. Writing “ T_g is 320 K” does not say whether it is the 10^0 s value or the 10^6 s one——and on the numbers of this paper those two differ by 21.4286 K.

Observation 4.4

The melting point has no such need. One may report it without a cooling rate because writing one would not change the answer——whether the condition may be omitted is what separates the character of the two temperatures.

Observation 4.5

To be stated honestly——supercooling and superheating do affect melting. But those are departures from equilibrium, and the equilibrium value itself does not move—— T_g has no counterpart to an “equilibrium value that does not move”.

5. The Separator: A Transition, or a Rendezvous?

Observation 5.1

The separator——whether the temperature is fixed by a thermodynamic equality or by one time scale overtaking another.

	What fixes it	Moves with conditions	Latent heat
Melting point	equality of free energies	no	yes
Glass transition	relaxation overtaking observation	yes (4.1667 K/decade)	no

Observation 5.2

The rightmost column is an independent check. That the glass transition has no latent heat has long been known——the classification of this paper agrees with that independently known fact.

Observation 5.3

The separator can be moved. Setting $T_0 = 0$ turns VFT into Arrhenius, and the rate dependence remains——what the move removes is only the shrinking of the steps, not the rate dependence itself.

Observation 5.4

It can be moved so as to abolish T_g . Let $B \rightarrow 0$ and the relaxation time stops depending on temperature, so T_g cannot be defined——a check that the formula is doing work.

Observation 5.5

To be stated honestly——4.1667 K and 21.4286 K are values on a model with $B = 1000$ K and $T_0 = 250$ K stated explicitly. Another substance gives other numbers——what does not move is only the direction: a longer observation time lowers T_g .

Observation 5.6

One last thing——some of the numbers written down as “properties of a substance” are outcomes of a rendezvous between substance and measurement. T_g is the clearest example——when a quantity wears the face of a constant, it is worth looking for a time inside its definition.

6. The Census and the Close

1. An observation time is in the definition (Observation 1.2): not on the substance’s side.
2. The convention is $\tau = 100$ s (Observation 2.2): how long a laboratory can wait.
3. 321.4286 K at 10^0 s (Calculation 3.1): a fast measurement.
4. 300.0000 K at 10^6 s (Calculation 3.1): a slow one.
5. 21.4286 K over six decades (Observation 3.2): a span across room temperature.
6. 4.1667 K per decade (Observation 3.2): inside the accepted 3–5 K.
7. Steps shrink from -4.7619 to -2.6316 (Observation 3.4): Arrhenius would be equal.
8. Back-substitution gives $\log_{10} \tau = 2.0000000000$ (Observation 3.5): the formula closes.
9. The melting point does not move (Observation 4.1): no waiting time in it.
10. The glass transition has no latent heat (Observation 5.2): an independent check.

Closing: The glass transition temperature T_g is reported in the same format as a melting point——write “the T_g of polystyrene is 100 degrees Celsius” and it wears the face of a material constant. But the definition of T_g contains an observation time——a glass is a liquid that flows too slowly to look like it is moving, and how slow counts as “stopped” is decided by how long one waits. The conventional $\tau = 100$ s does not come out of the substance; it comes from how long a laboratory can wait. So the number moves with the speed of measurement——on the VFT equation, stretching the observation time six decades from 10^0 s to 10^6 s takes T_g from 321.4286 K to 300.0000 K, a fall of 21.4286 K. That is 4.1667 K per decade, inside the accepted “3 to 5 K per decade”. In Celsius it is the difference between 48.28 and 26.85 degrees — a span across which the answer to “is it above room temperature” changes. The

same treatment at the melting point gives nothing—warm ice six decades more slowly and 273.15 K is still 273.15 K, because the melting point is where two free energies are equal and contains no waiting time. By the criterion of Paper 300 the two have distinct roots: one is fixed by a thermodynamic equality, the other by a kinetic overtaking. The practical consequence shows in how one reports—writing “ T_g is 320 K” does not say whether it is the 10^0 s value or the 10^6 s one, and on the numbers of this paper those two differ by 21.4286 K. One may report a melting point without a cooling rate because writing one would not change the answer; whether the condition may be omitted is what separates the character of the two temperatures. One thing separates them—whether the temperature is fixed by a thermodynamic equality or by one time scale overtaking another. There is an independent check—that the glass transition has no latent heat has long been known, and the classification here agrees with that independently known fact. To be said honestly—4.1667 K and 21.4286 K are values on a model with $B = 1000$ K and $T_0 = 250$ K, and another substance gives other numbers. What does not move is only the direction: a longer observation time lowers T_g . One last thing—some of the numbers written down as “properties of a substance” are outcomes of a rendezvous between substance and measurement. T_g is the clearest example, and when a quantity wears the face of a constant it is worth looking for a time inside its definition.

References

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