

The Classes of Chemical Bond Are a Continuum of Strength Cut by a Temperature

— Only the van der Waals Force Falls below RT , and That Is Why It Breaks at Room Temperature — Cool to **120.27 K** and It Survives — [Paper 278]

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— *From thinking to syncing.* —

Abstract

Ionic, covalent, metallic and hydrogen bonds and the van der Waals force go by separate names. This paper asks what divides them—the answer is that a continuum of strength has been cut by the RT of room temperature. Change the temperature at which one cuts, and the classification changes. No new mathematical theorem and no new law is claimed. First, take the RT of room temperature as the ruler. At 298.15 K, $RT = \mathbf{2.4790}$ kJ/mol (Section 2). Second, divide five bonds by it. Ionic **317.47**, metallic 161.36, covalent **140.38**, hydrogen bond 8.07, van der Waals **0.4034** (Section 2). Third, this is the core of the paper. Only the van der Waals force falls below 1—being weaker than the thermal motion of the room, it breaks at room temperature (Section 3). Fourth, cool it and it survives. At the temperature of liquid nitrogen, 77 K, $RT = 0.6402$ kJ/mol, and the van der Waals force becomes **1.5620** times it (Section 4). Fifth, the boundary temperature is a single number. 1.0 kJ/mol equals RT at $T = \mathbf{120.27}$ K—and the classification changes across it (Section 4). Sixth, the strengths themselves have no break. From 1.0 to 787 is a continuum spanning a factor of **787**, with no jump anywhere (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed—the representative strengths of each bond, the value of RT , and the picture of thermal motion breaking a bond are all standard. No chemistry is built—what is used is one division. The mechanisms of bonding are not discussed—why an ionic bond is strong and a van der Waals force weak is not treated at all. No bond energy is measured—all are cited representative values and vary between sources. The 1.0 kJ/mol for the van der Waals force in particular is a value to show an order of magnitude, and moves by several times between pairs. “Breaking” is not defined rigorously—comparing with RT is a rule of thumb; real dissociation involves activation barriers and configurational entropy. It is used here as a rule of thumb only. No revision of the classification is urged—the custom is useful. What this paper says is only that the boundary is relative to a temperature. The metallic bond is represented by a single value—it in fact varies greatly between metals; one value for iron has been posited. Relation to earlier papers: Paper 275 showed that there is no natural boundary between a semiconductor and an insulator—this paper writes the same figure for chemical bonds. There it was E_g and temperature, here it is bond energy and temperature. Paper 273 counted four different quantities written in the same unit—this paper writes that five names are cutting one continuum. Paper 201 counted “complete” as four different claims—this paper is the converse, a case where there are more names than things. Paper 190 measured rare on a logarithmic scale—this paper writes in the ratio 787. What is added is dividing five bonds by RT into one table, observing that only the van der Waals force falls below 1, computing that at 77 K it becomes 1.5620 and survives, and obtaining the boundary temperature 120.27 K.

1. Notation and Placement

Setting: compare the strength of a bond with the vigour of thermal motion. The measure of thermal motion is RT , with R the gas constant and T the absolute temperature.

The rule of thumb: a bond energy well above RT is not easily broken by thermal motion. Below RT , the thermal motion is the stronger.

Question: what divides the five names?

The answer is that a continuum of strength has been cut by RT . Change the temperature at which one cuts, and the classification changes.

A caution: comparison with RT is a rule of thumb. Real dissociation involves activation barriers and entropy—it is used here as a rule of thumb only.

2. Dividing Five Bonds by RT

Check 2.1: at 298.15 K, $RT = 8.314462618 \times 298.15/1000 = \mathbf{2.4790}$ kJ/mol.

Bond	Representative strength [kJ/mol]	Times RT
Ionic (the NaCl lattice)	787	317.4722
Metallic (iron)	400	161.3582
Covalent (C--C)	348	140.3816
Hydrogen bond (O--H...O)	20	8.0679
van der Waals	1.0	0.4034

Observation 2.2

the upper four run from 8 to 317 times RT , and none of them breaks at room temperature. The last alone falls below 1.

Observation 2.3

the strengths themselves form a continuum spanning a factor of 787, from 1.0 to 787. Between ionic and metallic, and between metallic and covalent, there is no jump—400 and 348 differ by only 1.15.

3. The Core: Only the van der Waals Force Falls below 1

Observation 3.1

the number 0.4034 means that the thermal motion is some 2.5 times the stronger. So at room temperature what is held by van der Waals forces is continually breaking and re-forming.

Check 3.2: see where the line at 1 is crossed.

Bond	Times RT	Against 1
Ionic	317.4722	above
Metallic	161.3582	above
Covalent	140.3816	above
Hydrogen bond	8.0679	above
van der Waals	0.4034	below

Observation 3.3

the line at 1 is crossed in one place only. And that one place coincides exactly with the customary boundary between “a chemical bond” and “an intermolecular force”—the line of the classification has been drawn at the position of room-temperature RT .

Observation 3.4

the separator—what has to be changed for the classification to change. The temperature. Not one bond energy has been moved.

4. Cool It and It Survives

Check 4.1: lower the temperature and recompute RT .

Temperature	RT [kJ/mol]	van der Waals (1.0) is RT times
298.15 K (room)	2.4790	0.4034 (it breaks)
120.27 K	1.0000	1.0000 (the boundary)
77 K (liquid nitrogen)	0.6402	1.5620 (it survives)

Observation 4.2

across 120.27 K the van der Waals force moves from the side weaker than thermal motion to the side stronger. The temperature is $T = 1000/R = 120.27$ K—a simple number, the bond energy divided by the gas constant.

Observation 4.3

at 77 K it becomes 1.5620. Inside liquid nitrogen, what is held by van der Waals forces stays held—one and the same force is a “bond” or a “fluctuation” according to the temperature.

Observation 4.4

Paper 275 wrote that the boundary between a semiconductor and an insulator moves with temperature. This paper is the same figure—there it was E_g and kT , here bond energy and RT , and in both the classification is made by the same operation of dividing an energy by a temperature.

5. The Strengths Themselves Have No Break

Check 5.1: set out the five values by the ratio between neighbours.

Neighbours	Ratio	A jump?
Ionic 787 over metallic 400	1.97	not a jump
Metallic 400 over covalent 348	1.15	not a jump
Covalent 348 over hydrogen bond 20	17.4	large but continuous
Hydrogen bond 20 over van der Waals 1.0	20.0	large but continuous
Whole span, 787 over 1.0	787	—

Observation 5.2

the metallic and covalent bonds differ by only **1.15**. And still they carry separate names—what separates the names is not the strength (it is the mechanism).

Observation 5.3

meanwhile the hydrogen bond and the van der Waals force differ by **20**, and both are sometimes called “intermolecular forces”. The ordering of strengths and the ordering of names do not agree.

Observation 5.4

a point to state honestly—the five names are divided by mechanism, not by strength. What this paper says is that only the higher division, between “a chemical bond” and “an intermolecular force”, is cut by room-temperature RT .

6. Roll Call and Closing

1. Room-temperature RT (Check 2.1): **2.4790 kJ/mol**.
2. Five divided by RT (Check 2.1): from **317.47** down to **0.4034**.
3. The line at 1 is crossed once (Check 3.2): by the van der Waals force alone.
4. It coincides with the custom (Observation 3.3): the line sits at RT .
5. The boundary is **120.27 K** (Check 4.1): $T = 1000/R$.
6. **1.5620** at **77 K** (Check 4.1): it moves to the surviving side.
7. Metallic and covalent differ by **1.15** (Check 5.1): and carry separate names.
8. A continuum spanning **787** (Check 5.1): with no jump.
9. Names divide by mechanism (Observation 5.4): not by strength.

Closing: the strengths of bonds form a continuum spanning a factor of **787**, from 1.0 to **787 kJ/mol**. The metallic and covalent bonds differ by only **1.15** and carry separate names, while the hydrogen bond and the van der Waals force differ by **20** and are both called intermolecular forces—the ordering of strengths and the ordering of names do not agree. In one place only does a name coincide with the strength. Divide the five by the room-temperature $RT = 2.4790$ kJ/mol and the van der Waals force alone falls below 1 (at **0.4034**)—and that is exactly the customary

boundary between “a chemical bond” and “an intermolecular force”. But that boundary is a line drawn by a temperature and not something the matter carries—cool to **120.27 K** and the line is crossed, and at **77 K** it stands at **1.5620** and survives. One thing separates them—writing down at which temperature's RT one divided. Write it down, and names divided by mechanism separate from names divided by temperature. Do not write it down, and one reads a line drawn at room temperature as a line drawn by nature.

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