



November 20, 2023

We have measured advancing contact angles for your fire-fighting solution (Inferno X Sample :080923B) at two different concentrations (0.25% and 2.0% of as received sample, each prepared in water) against the surfaces of the Spruce and Red Cedar wood samples that you submitted. Pure water was also tested as a control/comparison.

Ten 2.0 microliter drops of each of each of three test liquids (water, 0.25% and 2.0%) were placed on the surface of each wood sample and measured for contact angle 1.0 second after droplet placement. 1.0 second was determined to be enough time for each drop to spread to a consistent advancing contact angle without significant volume loss due to the liquid soaking into the sample - which does happen if given sufficient time.

We wanted to study surface wetting differences in this work. We could perhaps have another controlled study to look at penetration rate differences if you are interested in that. However, in this work, at least 98% of each drop placed was still above the surface when each spreading/advancing contact angle was measured.

The following contact angles were determined, each 1.0 second after drop placement:

Advancing Contact Angles for Liquids on Spruce Sample			
Drop #	Water Contact Angle (degrees)	0.25% Inferno X Contact Angle (degrees)	2.00% Inferno X Contact Angle (degrees)
1	81.6	44.7	22.7
2	81.5	44.2	23.0
3	82.1	44.1	22.7
4	82.1	44.5	22.4
5	81.6	44.8	22.4
6	81.6	44.3	22.8
7	81.8	44.7	22.4
8	81.9	44.5	22.3
9	82.2	44.2	22.4
10	81.9	44.9	22.9
Average	81.8	44.5	22.6
Std. Dev.	0.2	0.3	0.2

Advancing Contact Angles for Liquids on Red Cedar Sample			
Drop #	Water Contact Angle (degrees)	0.25% Inferno X Contact Angle (degrees)	2.00% Inferno X Contact Angle (degrees)
1	68.4	32.6	12.9
2	68.4	32.6	13.1
3	68.6	32.5	13.5
4	67.8	32.5	13.1
5	68.1	32.9	12.9
6	68.3	33.2	13.5
7	68.4	33.1	13.1
8	68.0	32.6	13.1
9	68.0	33.0	13.6
10	68.1	32.5	13.5
Average	68.2	32.8	13.2
Std. Dev.	0.2	0.3	0.3

As you can see, there is a significant difference between the two types of wood in terms of contact angle, even with pure water. Pure Water on the Spruce sample averaged 81.8°, but pure water of the Red Cedar sample averaged 68.2°. Red Cedar is just inherently more wettable than the Spruce. This led us to a small side study.

If you look up surface energy values for woods by type on the internet you will not find very many specifics. All I could consistently find was a board statement that various woods vary in surface energy from 30 mJ/m² to 50 mJ/m². Having the water contact angle of both of these woods, we decided to add contact angle testing with diiodomethane. This allowed us to use the water contact angle values and the diiodomethane contact angles, along with Fowkes theory (as discussed in mathematical detail in the enclosed technical note #401) to calculate the surface energies of the two wood samples. The following diiodomethane contact angles were determined.

Drop #	Diiodomethane Contact Angles on Spruce (degrees)	Diiodomethane Contact Angles on Red Cedar (degrees)
1	56.2	51.9
2	56.3	52.7
3	56.2	51.9
4	56.2	52.6
5	56.5	52.6
6	56.8	52.6
7	56.6	52.4
8	56.5	52.2
9	56.4	51.9
10	56.2	52.4
Average	56.4	52.3
Std. Dev.	0.2	0.3

Combining these data with the water contact angle data on the samples, as given above, and the Fowkes theory leads to the following surface energy values for the two wood samples.

Wood Type	Overall Surface Energy (mJ/m ²)	Polar Component (mJ/m ²)	Dispersive Component (mJ/m ²)	Surface Polarity (%)
Spruce	34.37	3.73	30.65	10.84
Red Cedar	41.96	8.98	32.98	21.40

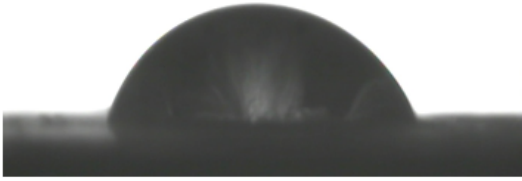
This surface energy work was just an aside. However, it does confirm that surface energy varies by wood type, and that the surface energies of both wood samples in this study are found to be in the literature expected range of 30 mJ/m² to 50 mJ/m².

In any regard, Inferno X, both at 0.25% and 2.00% decreases the contact angle on each wood sample relative to pure water contact angles – more so of course at 2.00% than at 0.25% . The inherent nature of the wood itself still does play a role in the contact angle result even with the Inferno X solutions. The table below again summarizes the results.

Wood Type	Average Water Contact Angle (degrees)	Average 0.25% Inferno X Contact Angle (degrees)	Average 2.00% Inferno X Contact Angle (degrees)
Spruce	81.8	44.5	22.6
Red Cedar	68.2	32.8	13.2

However, clearly the Inferno X greatly promotes wetting of both types of wood, relative to pure water. Some example pictures of various contact angles are also shown below as a visual.

Water on Spruce Drop #1 = 81.6°



Water on Red Cedar Drop #1 = 68.4°



0.25% Inferno X on Spruce Drop #1 = 44.7°



0.25% Inferno X on Red Cedar Drop #1 = 32.6°



2.00% Inferno X on Spruce Drop #1 = 22.7°



2.00% Inferno X on Red Cedar Drop #1 = 12.9°



Best Regards,

A handwritten signature in black ink, consisting of a cursive 'C' followed by 'Rulison'.

Christopher Rulison, Ph.D.
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