Contact Angles in Three-phase (Oil/Water/Gas) Systems and the Bartell-Osterhof Equation

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ABSTRACT

Three-phase oil/water/gas systems in porous media show rather complex behaviour. Indeed, considering the wettability of the solid surface within the porous medium, they are actually four-phase systems! Wettability in such systems is usually considered as the wetting of one of the liquid phase, such as oil or water, and this appears to conform reasonably well to experimental observation; that is, we may characterize the wetting of the solid surface by the oil water contact angle, cos θ_{ow}. But this does not *a priori* indicate to us what are the wetting behaviours of the other fluid pairs (gas/oil and gas /water) are; that is, what do we expect that cos θ_{go} and cos θ_{ow} are?

Some years ago the Author came up with an elegant equation which beautifully (and thermodynamically) constrained the behaviour of the three contact angles *viz* cos θ_{ow} (defining the wettability) as well as cos θ_{go} and cos θ_{ow}. Unfortunately, he soon after discovered that he had been pipped to the post by two researchers called Bartell and Osterhof in the journal *Industrial & Engineering Chemistry* in 1927! This paper is not well known and its importance in three-phase flow in porous media had certainly not been grasped. As a consolation prize for *not* discovering the Bartell-Osterhof equation, the Author and his collaborators have discovered an astonishing range of results using this result. These range from why does oil spread on most leaves but water does not – see below?

The answer to this is the same as why certain oil/water/gas wetting orders are observed in porous media, why three phases flow as they do through rocks and what happens to the wetting order as the gas and oil approach miscibility. They are all well explained by the Bartell-Osterhof equation and the Author's only satisfaction is that he is sure that neither Bartell nor Osterhof were aware of any of the wonderful consequences of their equation!