Supplemental

Considering the reaction kinetics denoted in Eq. (6), in accordance with the experimental procedure, the hydroxyl radical reaction rate *S*rad is expressed as

where *V* and *m*rad are solution volume and radical scavenging amount, respectively. The radical scavenging amount *m*rad is a normalized concentration defined as radical concentration (exactly DMO–hydroxyl radical adduct concentration) divided by its reference concentration (molref measured by ESR. The initial condition in Eq. (S1) is *m*rad= 1 at *t* = 0, of its own accord, in a batch reaction system that satisfies Eq. (5). As the measurement is conducted at very low concentration, Eq. (S1) is rewritten as

Note that Δ*t* is approximately a constant value that a measurement is taken place 5 min after mixing all of the ingredients. The unit of *S*radmight be . If ESR measurement could give an absolute concentration of the radicals, the numerator should be mol instead of “1”.

Using the radical concentration *C*rad or , then Eq. (S2) is approximated as

Those units of *C*radaccordingly are or simply (−) with Eq. *m*rad. Fig. 5 is drawn based on Eq. (S2′) in the vertical axis. Note that the horizontal axis might be denoted as CNT concentration that is assumingly proportional to the number of reaction sites per unit amount of carbon atoms.

Meanwhile, the equilibrium condition of the reaction system is determined using chemical reaction equations of Eqs. (5) and (6) as

where *K*1and *K*2 are equilibrium constants of Eqs. (5) and (6), respectively. In Eqs. (S3) and (S4), the individual concentrations of components are considered such that the activity should be 1 under the ultra-diluted concentration system. As Fig. 5 suggests that the following expression shows slope *k* of plots:

As *k* is always negative, the following relation is assumed:

Then, Eq. (S5) is rewritten as the following differential equation:

As one can assume *dC*Dn = *C*Dn in the ultra-diluted condition and use a relationship

*V*Δ*t* = const

Eq. (S7) is solved as

(S8)

where *q* and *r* are arbitrary constants. Although *S*rad is 1 at *C*Dn = 0, Eq. (S8) cannot have a point (*C*Dn, *S*rad) = (0,1) because the first term of Eq. (S8) includes the *log* function. To solve this discrepancy, a small finite number *s* is added in the following manner:

(S9)

Eq. (S9) is numerically solved using the “Solver” function in Microsoft Excel to determine *q*, *r*, and *s*. The result is shown as a solid line in Fig. 5.

As a summary,

1. *k* = 0; *S*radbecomes constant, which means no radical scavenge reaction occurs.
2. *k* = constant; *S*rad= *αC*Dn, which means a straight line.
3. *k* = Eq. (S5); there exists an equilibrium point.

While (i) through (iii) are derived kinetically, it is necessary to take into account the equilibrium assumed by Eqs. (S3) and (S4), which satisfies both of the equations simultaneously. To carry this out, the absolute number for *C*Dn should be measured, but it is not possible at this moment.