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Comments on An Article by Francesco Minisci and Francesca Fontana.

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Abstract: Evidence is summarized to show that the latest aspects of Gif chemistry do not involve Fenton-type radical chemistry.

The preceding article by Minisci and Fontana provides a welcome opportunity to comment on the difference between Fenton chemistry and Gif chemistry[1]. The former mechanism involves Fe^{II} and H_2O_2 (or *tert.*-butyl hydroperoxide) and produces hydroxyl radicals and thence, in the presence of saturated hydrocarbons, carbon radicals. Gif chemistry utilizes the couple Fe^{II} + superoxide or Fe^{III} + H_2O_2 (or *tert.*-butyl hydroperoxide) to give Fe^{III}–OOH and thence a high valent iron species which we regard as an Fe^{V} oxenoid.

Professor Minisci has published many important articles on the coupling of carbon radicals with protonated heterocycles like pyridine and quinoline[2]. Indeed we have frequently cited this work since such coupling is a clear indication of carbon radicals in a mechanism[3]. Carbon radicals are not present in the great majority of the Gif chemistry based on superoxide or H_2O_2. Minisci and Fontana[2] suggest that carbon radicals are involved in the Gif chemistry involving *tert.*-butyl hydroperoxide (TBHP).

In Gif chemistry two intermediates can be detected, A and B. We have shown in thorough experimentation[1] that B is a hydroperoxide (or a hydroperoxide complexed to Fe^{III}) and that A can be intercepted by many other reagents than oxygen. It is **not** a carbon radical because it fails many tests for radicals, including the pyridine test[4]. In the context presented it is an iron-carbon bond (Fe^{V} and Fe^{III}).

When Fe^{III}–TBHP experiments are run at 60°C in the absence of a trap[5], coupling to pyridine is readily detected (Table 1). Under argon the reaction at 60°C is about 30% efficient (with respect to TBHP). At 0°C or room temperature coupling to pyridine is less and cyclooctene and cyclooctyl-*tert.*-butyl mixed peroxide are formed with an overall efficiency of 15-20%. We consider that the cyclooctene arises from an Fe^{V}–carbon bonded species by β-elimination to give Fe^{III} and that the mixed peroxide is an Fe^{V} ligand coupling product. At the higher temperatures the iron-carbon bond decomposes to give carbon radicals.

Table 1. The effects of temperature on the Fe^{III}–TBHP oxidation reaction of cyclooctane (**1**) under an atmosphere of argon.[a]

Temp. (°C)	**Reaction** time (d)	**Product** (mmol)			
		2	**3**	**4**	**5**
80	3	0.510	1.800	0.570	tr.
60	5	0.527	1.803	0.481	0.315
40	10	0.564	1.319	0.416	0.436
RT	14	0.453	0.482	0.196	0.692
0	20	0.410	0.210	0.092	0.801

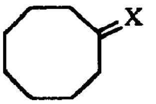
a) employing $Fe(NO_3)_3{\bullet}9H_2O$ (1 mmol), cyclooctane (50 mmol) and TBHP (10 mmol). tr. = traces, RT = room temperature.

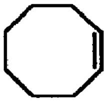
In contrast the presence of chloride ion[6] (Table 2) leads to formation of cyclooctyl chloride with up to 80% efficiency. In the presence of sufficient chloride ion a quantitative yield of chloride is seen with no formation of pyridine coupled products (Table 3).

Table 2. The effects of LiCl on the Fe^{III}–TBHP chlorination reaction of cyclooctane (**1**).[a]

LiCl (mmol)	**Product** (mmol)				**Efficiency** of TBHP (%)
	6	**7**	**8**	Σ	
0	0.54	0.30	1.26	2.20	44.0
1	0.63	0.30	1.40	2.33	46.6
5	0.49	0.11	2.13	2.73	54.6
10	0.40	0.13	3.08	3.61	72.2
15	0.17	0.09	3.92	4.18	83.6

a) The reactions were carried out using $FeCl_3{\bullet}6H_2O$ (0.5 mmol) and TBHP (5 mmol) at 60°C.





1 X = H_2 **2**
3 X = *o*-pyridyl, H
4 X = *p*-pyridyl, H
5 X = $OOC(CH_3)_3$, H
6 X = O
7 X = OH, H
8 X = Cl, H

Table 3. The effects of LiCl on the Fe^{III}–TBHP chlorination reaction of cyclooctane (**1**).[a]

LiCl (mmol)	**Product** (mmol) **8**	**3**	**4**	**5**
20	9.94	—	—	—
15	10.02	—	—	—
10	6.87	0.22	0.09	tr.
5	4.11	0.26	0.10	0.10
3	2.67	0.34	0.13	0.42

a) The reactions were carried out using $Fe(NO_3)_3 \cdot 9H_2O$ (1 mmol) cyclooctane (1) and TBHP (10 mmol). tr. = traces.

As has been already reported[7] a number of other anions including azide and thiocyanate ions also react efficiently with saturated hydrocarbons. At 60°C the half-life for radical formation is about 2,500 minutes. In contrast the half-lives for the formation of chloride, azide and thiocyanate are respectively 110, 300 and almost 1 minute. The thiocyanate reaction is very fast (a few minutes half-life) even at 0°C where pyridine coupling shows little radical formation. Also the chloride reaction, although slow at room temperature, proceeds with the same efficiency at 60°C.

If radical reactions were involved then diphenylmethane should be more reactive than cyclooctane. In fact, at room temperature cyclooctane is more than 20 times more reactive than diphenylmethane per **carbon-hydrogen bond**[7].

Finally[8], we have studied in detail the relative reactivity of intermediate A and of genuine carbon radicals (generated from Barton esters using the powerful xenon MM™ lamp[9]) towards Tempo and towards chloride, azide and thiocyanate ions. As expected Tempo captures genuine carbon radicals with great efficiency[4]. It is however a poor trap for A. When carbon radicals are generated in the presence of chloride, azide and thiocyanate ions a saturated hydrocarbon and an Fe^{III} salt (i.e. under Gif conditions) but without the oxidant, no coupling is seen to the anions. If oxidant is added as well as Tempo the radicals generated are captured by Tempo and the normal Gif chemistry with the anions is seen. Thus radical chemistry and Gif chemistry are independent of each other.

The comments of Minisci and Fontana[2] are, of course, relevant to the Fenton chemistry that they have summarized. Gif chemistry is, again, a different chapter in the reactivity of saturated hydrocarbons.

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References

1. For reviews see: Walling, C. *Acc. Chem. Res.* **1975**, *8*, 125 (Fenton chemistry); Barton, D.H.R.; Doller, D. *Ibid.* **1992**, *25*, 504 (Gif chemistry).
2. Minisci, F.; Fontana, F., preceding article and references there cited especially: Minisci, F. *Acc. Chem. Res.* **1975**, *8*, 165.
3. Barton, D.H.R.; Bovin, J.; Motherwell, W.B.; Ozbalik, N.; Schwartzentruber, K.M.; Jankowski, K. *Nouveau J. Chim.* **1986**, *10*, 387; Barton, D.H.R.; Halley, F.; Ozbalik, N.; Schmitt, M.; Young, E.; Balavoine, G. *J. Am. Chem. Soc.* **1989**, *111*, 7144.
4. Barton, D.H.R.; Bévière, S.D.; Csuhai, E.; Doller, D.; Liu, W.-G. *Ibid.* **1992**, *114*, 2147.
5. Barton, D.H.R.; Chavasiri, W. *Tetrahedron*, **1993**, in press.
6. *Idem, Ibid.*, **1993**, in press.
7. Barton, D.H.R.; Bévière, S.D.; Chavasiri, W.; Doller, D.; Hu, B. *Tetrahedron Lett.* **1993**, *34*, 1871; Barton, D.H.R.; Bévière, S.D. *Ibid.* **1993**, *34*, 5689; Barton, D.H.R.; Bévière, S.D.; Chavasiri, W. *Tetrahedron*, **1993**, in press.
8. Barton, D.H.R.; Chavasiri, W.; Hill, D.R.; Hu, B. *New J. Chem.*, **1993** in press.
9. Barton, D.H.R.; Jaszberenyi, J. Cs.; Tang, D. *Tetrahedron Lett.* **1993**, *34*, 3381.

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