***Enhancing Hydrogen Peroxide Activation in Heterogeneous Fenton Reaction by Codoping Hydrochar with Iron and Copper: Characterization, and Process Optimization***

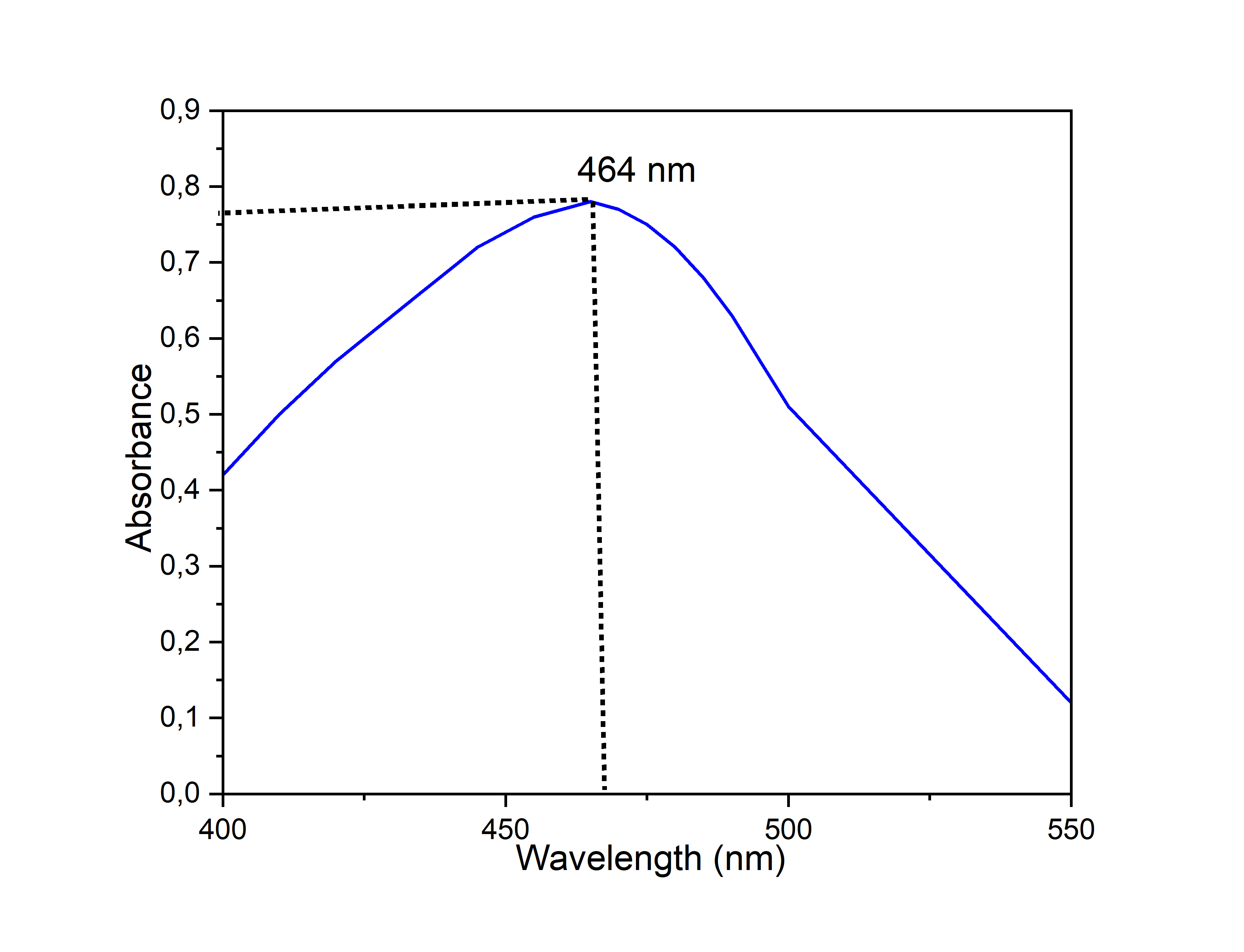
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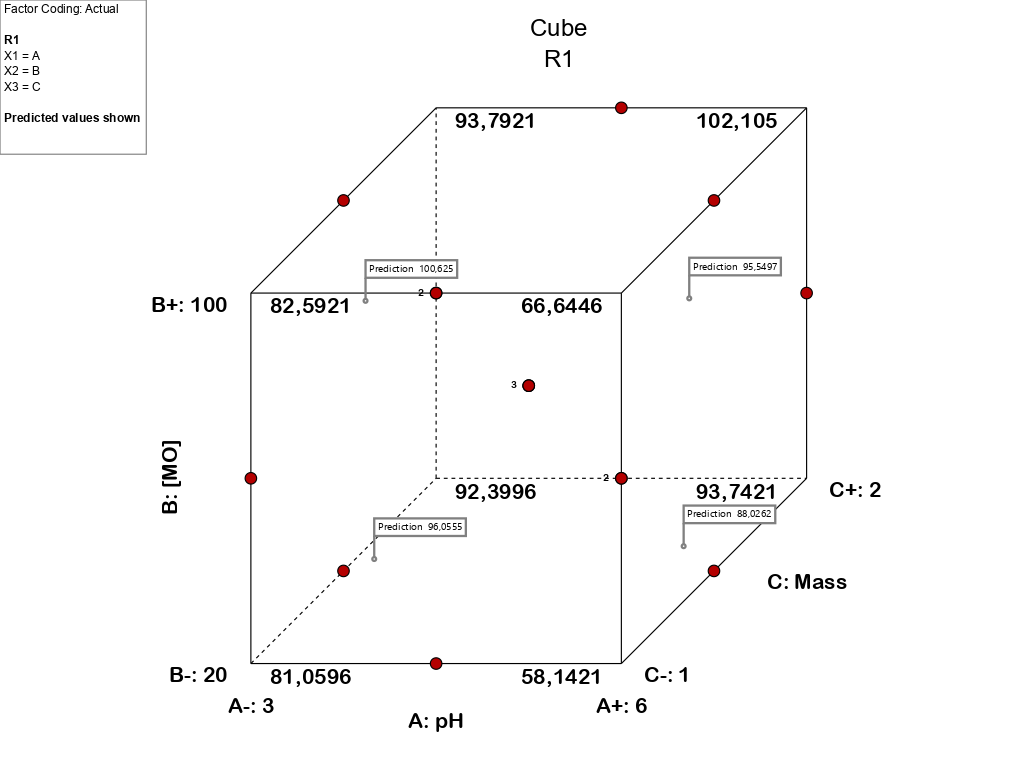
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**Fig 1S. (a) spectrum of methyl orange MO, (b) calibration curve of methyl orange at 464nm wavelength.**

**Figure 2S: Geometrical location of the experimental points of the BBD design for k=3 factors.**

**Table 1S: experimental matrix of the BBD design.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Variables | | | Response 1 |  |
| Run | **A:pH** | **B:[MO]**  **(mg/l)** | **C:Mass**  **(g/l)** | **Degradation (%)** | |
| **Experimental** | **predicted** |
| 1 | 3 | 100 | 1,5 | 97,43 | 98,25 |
| 2 | 6 | 100 | 1,5 | 96,64 | 94,43 |
| 3 | 4,5 | 60 | 1,5 | 93,78 | 93,79 |
| 4 | 3 | 60 | 1 | 88,47 | 85,17 |
| 5 | 4,5 | 60 | 1,5 | 90,51 | 93,79 |
| 6 | 6 | 20 | 1,5 | 88,28 | 87,46 |
| 7 | 3 | 60 | 2 | 97,64 | 97,91 |
| 8 | 4,5 | 60 | 1,5 | 97,08 | 93,79 |
| 9 | 3 | 20 | 1,5 | 96,04 | 98,25 |
| 10 | 4,5 | 100 | 1 | 69,99 | 72,47 |
| 11 | 6 | 60 | 2 | 99,44 | 102,74 |
| 12 | 4,5 | 20 | 1 | 64,76 | 65,85 |
| 13 | 6 | 60 | 1 | 66,01 | 65,74 |
| 14 | 4,5 | 100 | 2 | 95,28 | 94,19 |
| 15 | 4,5 | 20 | 2 | 96,33 | 93,85 |

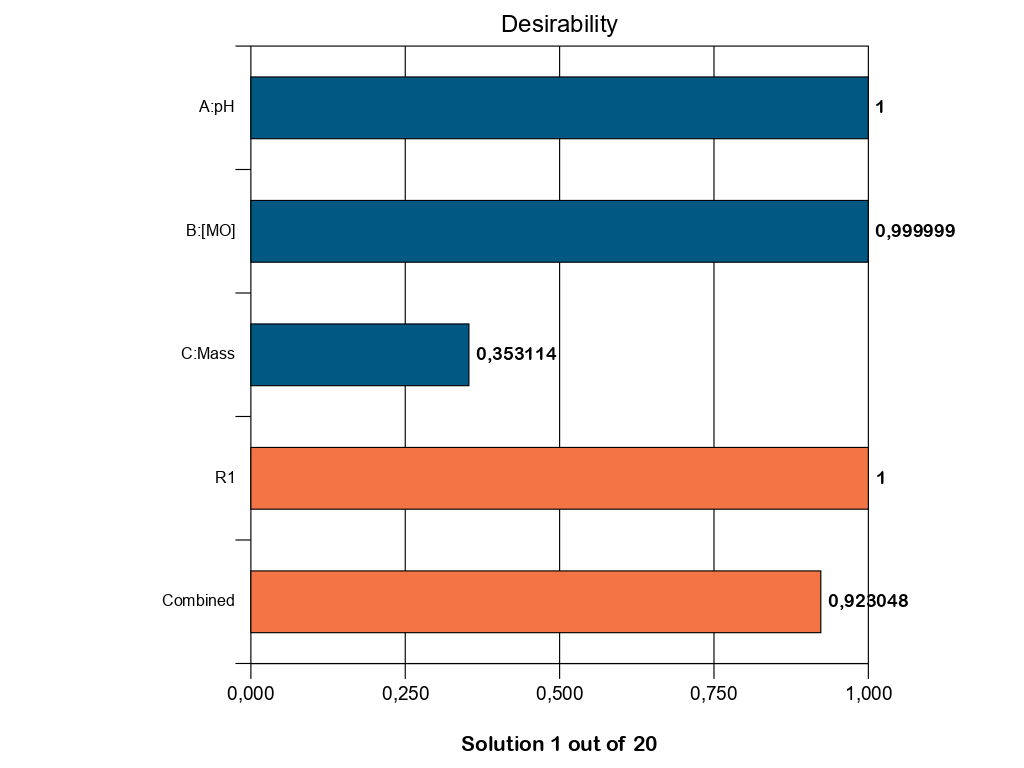
**Table 2S: ANOVA analysis for the quadratic Degradation (%) model**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Source | Sum of Squares | df | Mean Square | F-value | p-value |  |
| Model | 1965,58 | 9 | 218,40 | 31,98 | 0,0007 | significant |
| A-pH | 106,65 | 1 | 106,65 | 15,62 | 0,0108 |  |
| B-[MO] | 48,96 | 1 | 48,96 | 7,17 | 0,0440 |  |
| C-Mass | 1095,12 | 1 | 1095,12 | 160,35 | < 0.0001 |  |
| AB | 12,15 | 1 | 12,15 | 1,78 | 0,2399 |  |
| AC | 147,14 | 1 | 147,14 | 21,54 | 0,0056 |  |
| BC | 0,0049 | 1 | 0,0049 | 0,0007 | 0,9797 |  |
| A² | 52,05 | 1 | 52,05 | 7,62 | 0,0398 |  |
| B² | 61,48 | 1 | 61,48 | 9,00 | 0,0301 |  |
| C² | 429,71 | 1 | 429,71 | 62,92 | 0,0005 |  |
| Residual | 34,15 | 5 | 6,83 |  |  |  |
| Lack of Fit | 27,16 | 3 | 9,05 | 2,59 | 0,2906 | not significant |
| Pure Error | 6,99 | 2 | 3,49 |  |  |  |
| Cor Total | 1999,73 | 14 |  |  |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Std. Dev. | 2,61 |  | R² | 0,9829 |
| Mean | 89,00 |  | **Adjusted R²** | 0,9522 |
| C.V. % | 2,94 |  | **Predicted R²** | 0,7748 |
|  |  |  | **Adeq Precision** | 16,9454 |

**Table 4: Optimization constraints using the desirability function**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Name** | **Goal** | **Lower Limit** | **Upper Limit** | **Importance** | **Graphe** |
| **A : pH** | maximize | 3 | 6 | 3 |  |
| **B : [MO]** | maximize | 20 | 100 | 4 |  |
| **C : Mass** | minimize | 1 | 2 | 1 |  |
| **R1** | maximize | 64,76 | 99,44 | 5 |  |



**Figure 3S : Optimization desirability function**