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Exploring the Potential of ZnO-Ag@AgBr/SBA-15 Z-Scheme Heterostructure for Efficient Wastewater Treatment: Synthesis, Characterization, and Real-World Applications

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Table S1. Element composition of Ag@AgBr/SBA-15 and ZnO-Ag@AgBr/SBA-15 samples.

Samples	Si	O	Al	Br	Ag	Zn	Total
Ag@AgBr/SBA-15	32.05	59.19	0.35	1.53	6.88	-	100
10%ZnO-Ag@AgBr/SBA-15	28.62	56.31	0.28	1.32	6.17	7.3	100
20%ZnO-Ag@AgBr/SBA-15	25.48	53.54	0.98	0.19	5.78	14.03	100
30%ZnO-Ag@AgBr/SBA-15	23.53	47.58	0.89	0.14	5.03	22.83	100

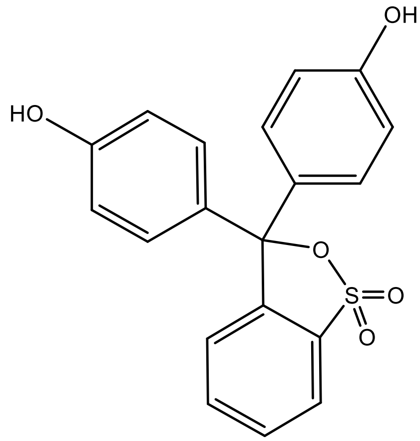
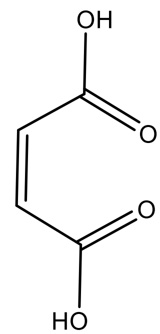
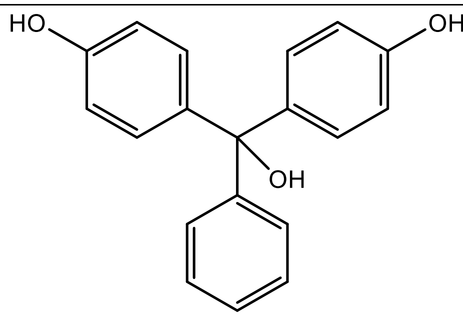
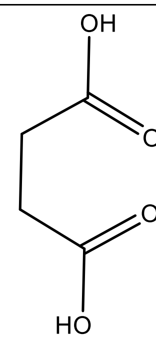
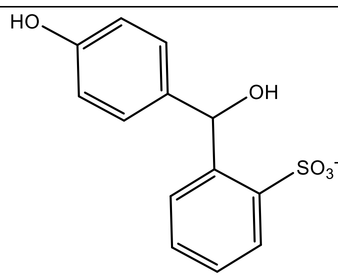
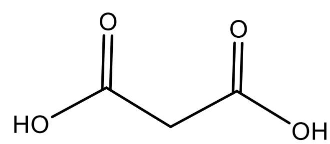
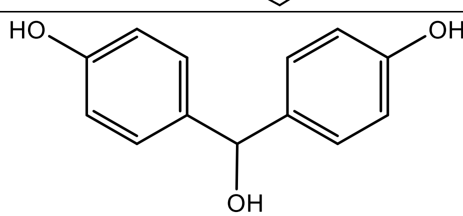
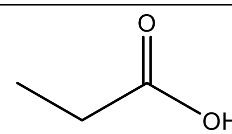
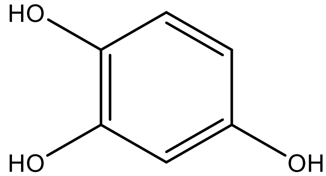
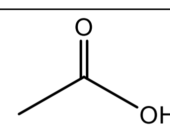
Table S2. Effect of reaction conditions on removal efficiency of phenol red

Influence factors	Reaction conditions	Factors of changes	Removal (%)
Effect of initial phenol red concentration	$V_{phenol\ red}$ =100 mL, $m_{catalyst}$ = 400 mg/L, pH = 5	[Phenol red] =10 mg/L	99.4
		[Phenol red] =15 mg/L	98.9
		[Phenol red] =20 mg/L	98.8
		[Phenol red] =25 mg/L	91.5
Effect of initial pH	$V_{phenol\ red}$ =100 mL, $m_{catalyst}$ = 400 mg/L, [Phenol red] = 20 mg/L	pH=3	99.2
		pH=5	98.8
		pH=7	92.5
		pH=9	72.4
Effect of amount of photocatalysts	$V_{phenol\ red}$ =100 mL, [Phenol red] = 20 mg/L, pH = 5	$m_{catalyst}$ = 200 mg/L	87.6
		$m_{catalyst}$ = 300 mg/L	92.8
		$m_{catalyst}$ = 400 mg/L	98.8
		$m_{catalyst}$ = 500 mg/L	99.4
Effects of different types of natural surface waters	$V_{phenol\ red}$ =100 mL, [Phenol red] = 20 mg/L, pH = 5, $m_{catalyst}$ = 400 mg/L	Hong river	94.7
		To Lich river	31.1
		Hoan Kiem lake	69.6
		West lake	89.8
Reaction radical trap experiments	$V_{phenol\ red}$ =100 mL, [Phenol red] = 20 mg/L, pH = 5, $m_{catalyst}$ = 400 mg/L	No Scavenger	98.8
		TBA ($^{\bullet}OH$)	65.2
		AO (h^+)	51.1
		BQ ($^{\bullet}O_2^-$)	24.4
		$K_2Cr_2O_7$ (e^-)	98.2

Table S3. Comparative results of Phenol red pollutants removal by various heterogeneous materials

Samples	Reaction conditions	Removal efficiency (%)	Reaction time (min)	Ref.
20%ZnO-Ag@AgBr/SBA-15	Lamp: Solar light irradiation. [Catalyst] = 400 mg/L [Phenol red] = 20 mg/L T = 25 ^oC pH = 5	98,6	120	This word
TiO_2	Lamp: Solar light irradiation. [Catalyst] = 600 mg/L [Phenol red] = 13.3 mg/L T = 25 ^oC pH = 4.4	87.3	100	[1]
Nb(2.0)/TiO_2	Lamp: UV, 400 W [Catalyst] = 100 mg/L [Phenol red] = 20 mg/L	94	160	[2]
CuO/ZnO/TiO_2	Lamp: UV light, 6 W [Catalyst] = 100 mg/L [Phenol red] = 10 mg/L T = 30 ^oC pH = 6	100	180	[3]
TiO_2	Lamp: 15 W [Catalyst] = 500 mg/L [Phenol red] = 10.3 mg/L pH = 4.5	92	240	[4]
ZnO	Lamp: UV light irradiation [Catalyst] = 500 mg/L [Phenol red]= 0.38 mg/L pH = 6.5 T = 25 °C	97	60	[5]
Goethite (α-FeOOH)	Lamp: UV (Philips HPW 125) [Catalyst] = 1000 mg/L [Phenol red]= 10^{-5} mol/L = 3.54 mg/L pH = 3 T = 25 ^oC	41.25	240	[6]

Table S4. Results of LC-MS analysis decomposition of Phenol red on photocatalyst 20%ZnO-Ag@AgBr/SBA-15

m/z	**Probable structure**		**Probable structure**
355.28		**116.16**	
290.24		**118.06**	
279.03		**104.05**	
216.35		**74.04**	
126.81		**60.04**	

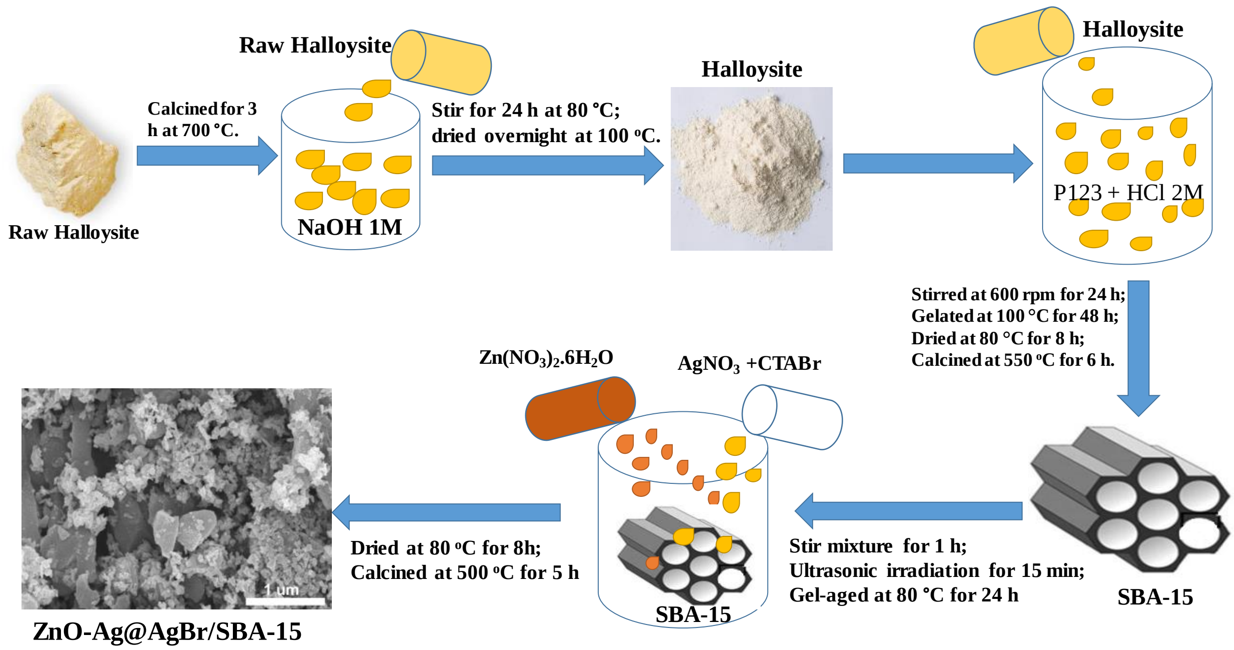


Figure 1S. Schematic synthesis of ZnO-Ag@AgBr/SBA-15 materials from natural halloysite

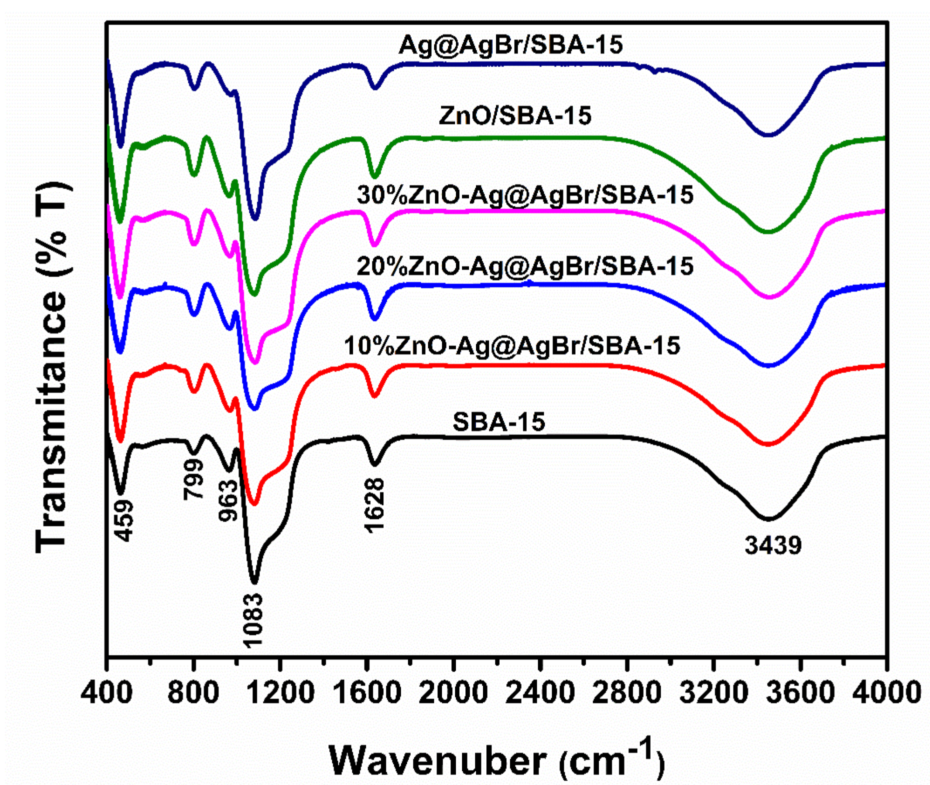


Figure S2. FT-IR spectra of Ag@AgBr/SBA-15, ZnO/SBA-15 and ZnO-Ag@AgBr/SBA-15 samples

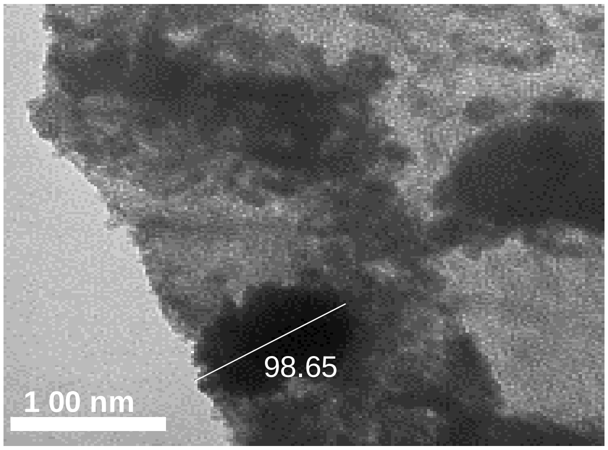


Figure S3. TEM image of 30%ZnO-Ag@AgBr/SBA-15 sample

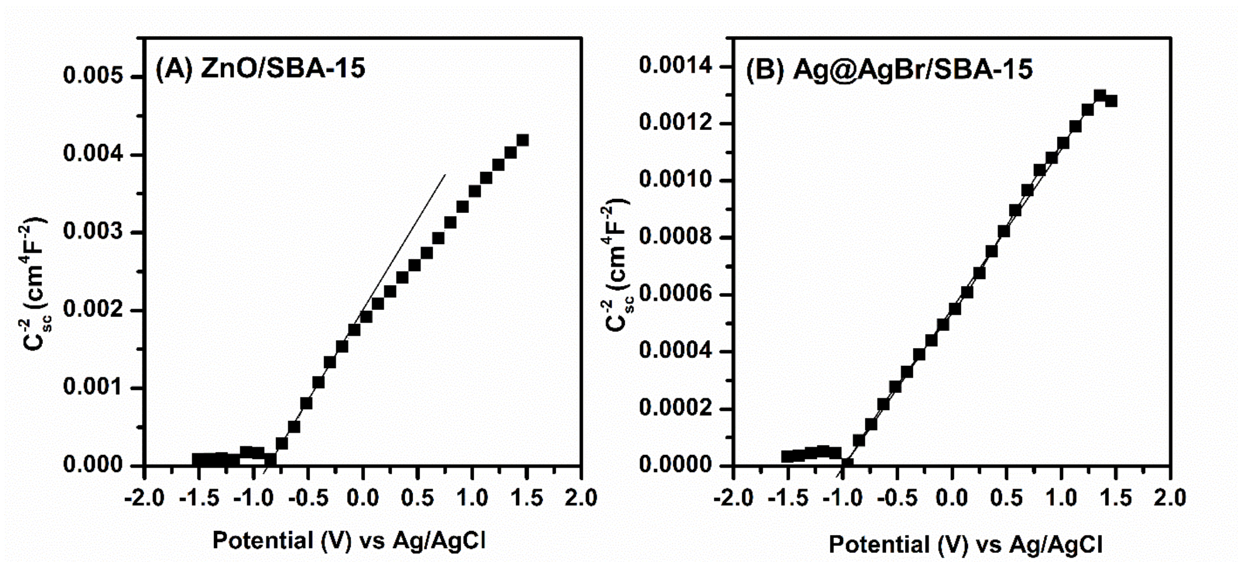


Figure S4. Mott Schotky plot of ZnO/SBA-15 (A) and Ag@AgBr/SBA-15 (B) samples

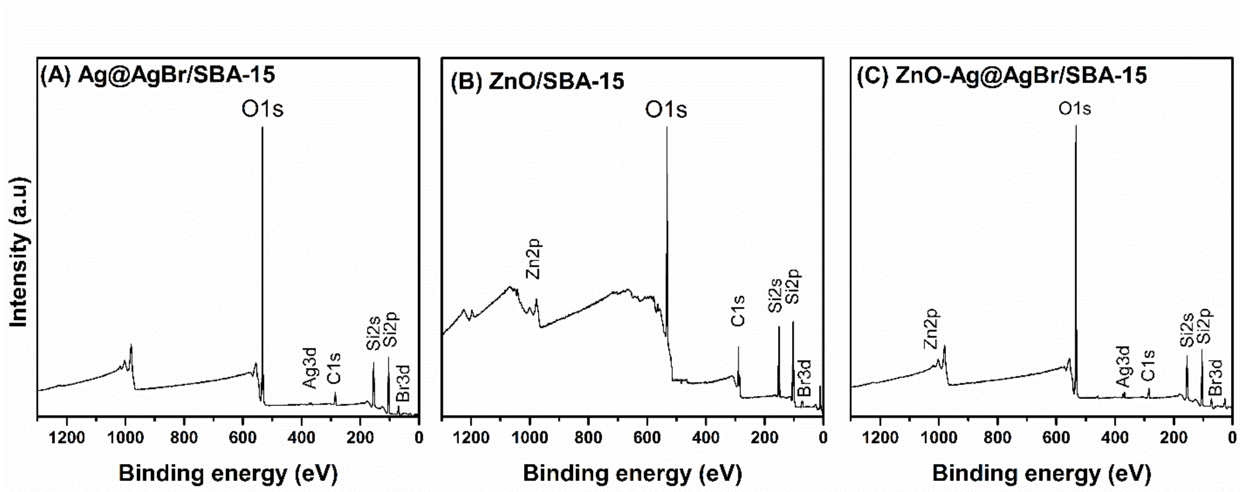


Figure S5. Survey XPS spectra of (A) Ag@AgBr/SBA-15, (B) ZnO/SBA-15 and (C) 20%ZnO-Ag@AgBr/SBA-15 samples

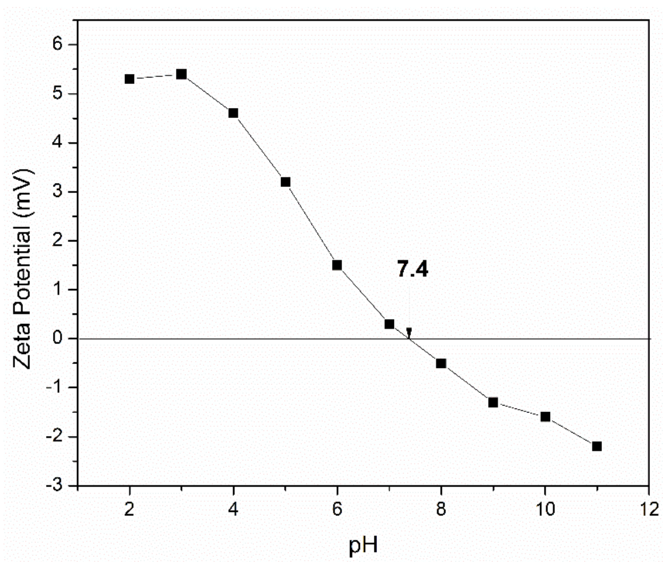


Figure S6. Zeta-potential as a function of pH in 20%ZnO-Ag@AgBr/SBA-15

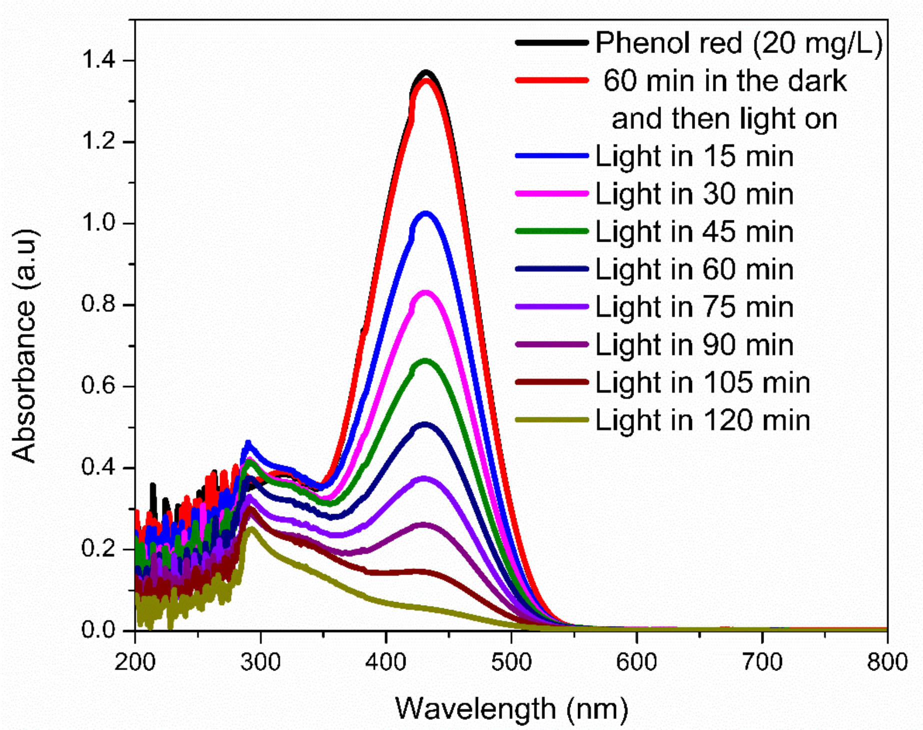


Figure S7. UV-Vis spectra the degradation of phenol red using 20%ZnO-Ag@AgBr/SBA-15 sample

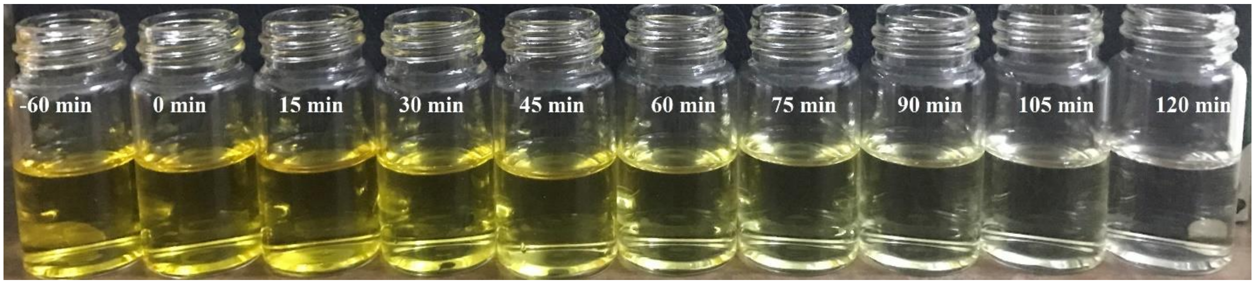


Figure S8. Images of phenol red samples in water treated on photocatalyst 20%ZnO-Ag@AgBr/SBA-15 at different times.

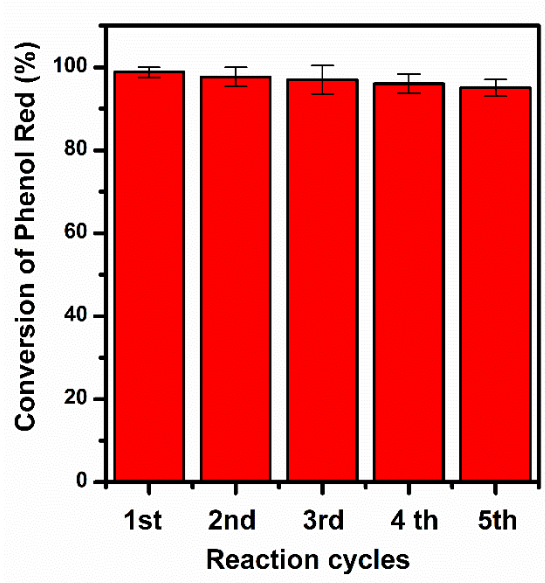


Figure S9. Stability of 20%ZnO-Ag@AgBr/SBA-15 sample at different cycles of reaction

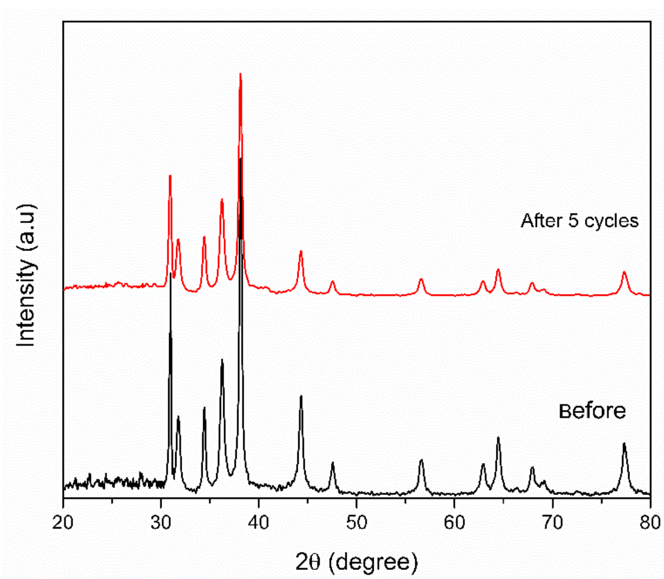


Figure S10. XRS spextra of 20%ZnO-Ag@AgBr/SBA-15 before and after 5 cycles reactions.

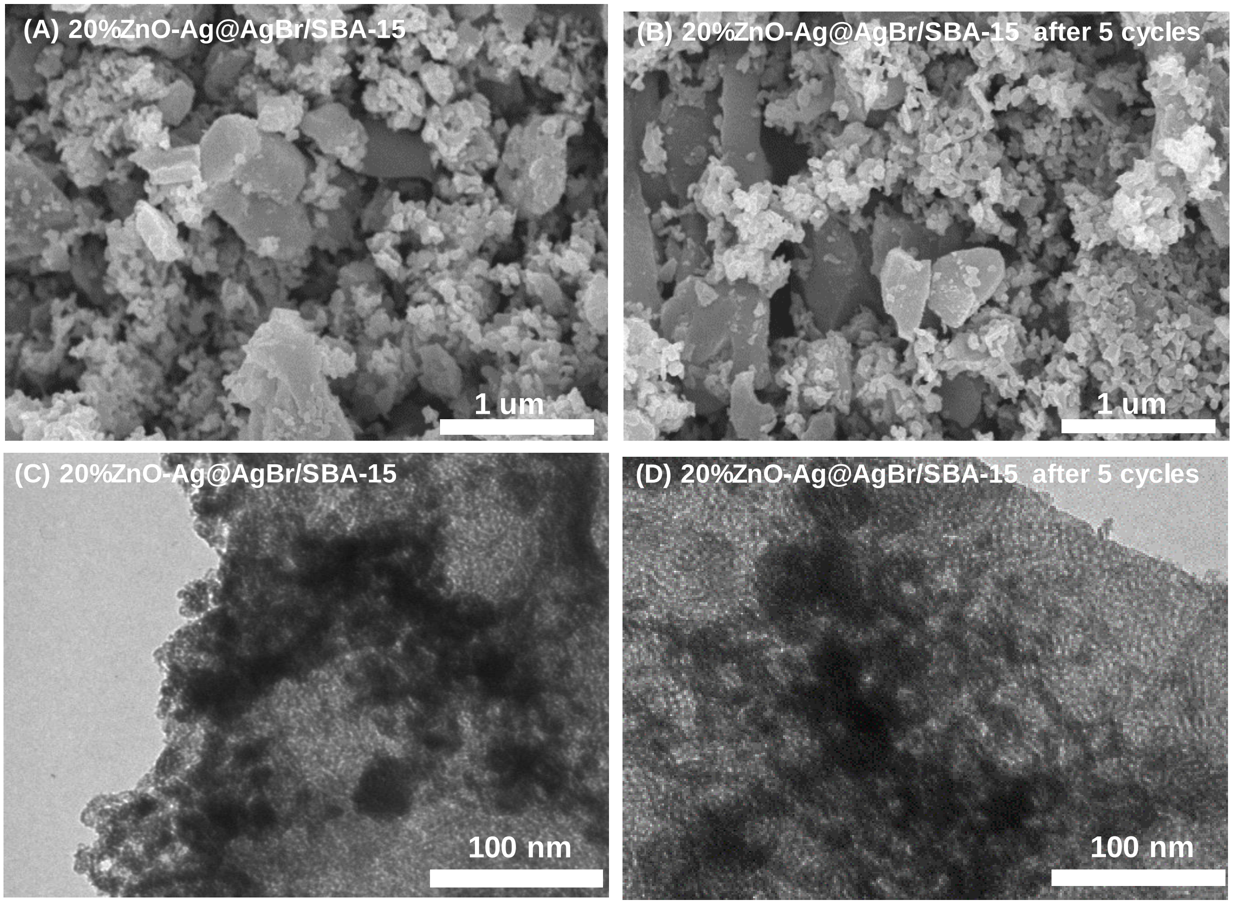
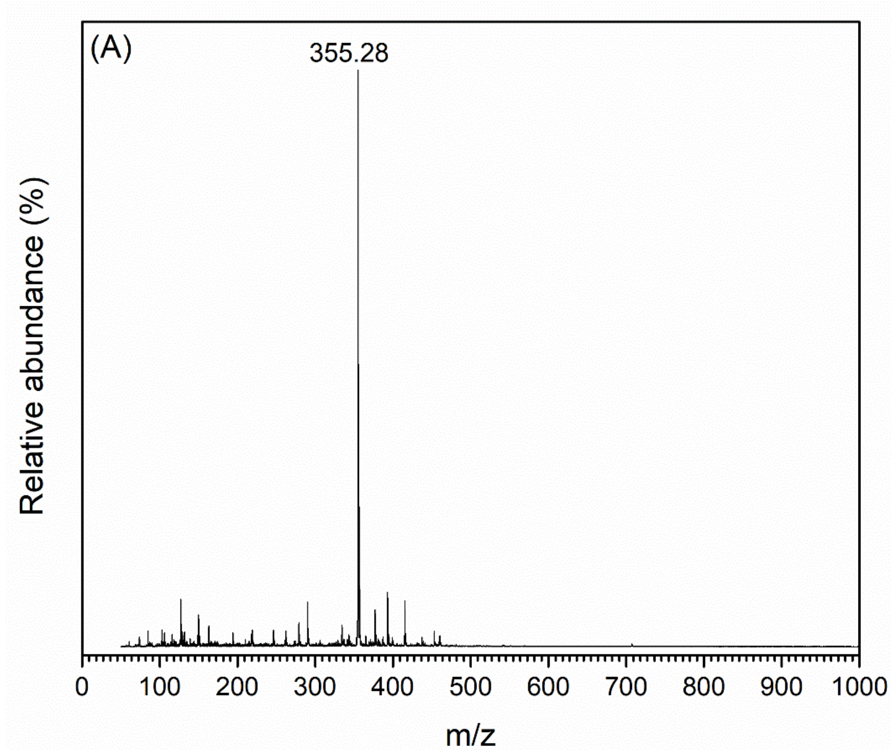


Figure S11. SEM and TEM images of 20%ZnO-Ag@AgBr/SBA-15 before and after 5 cycles reactions.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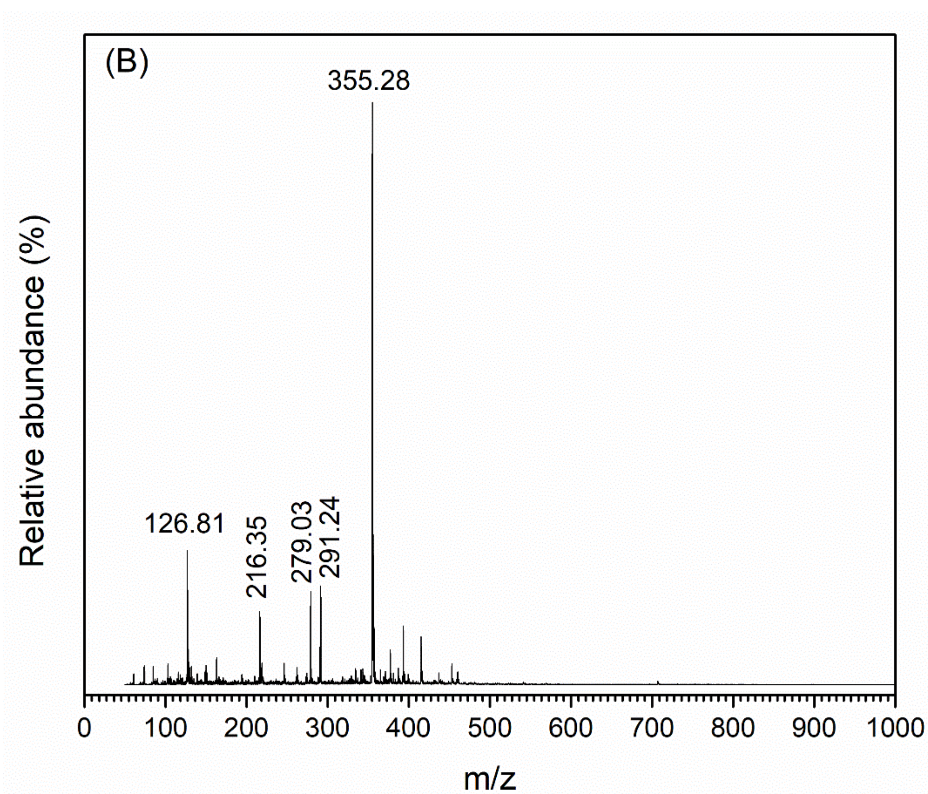
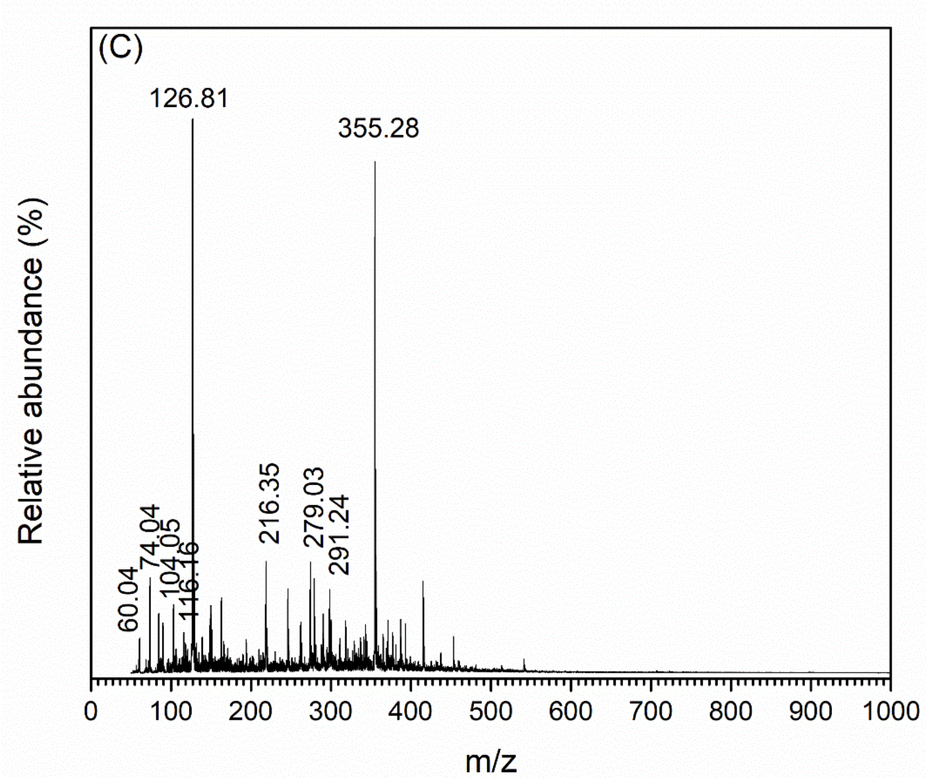
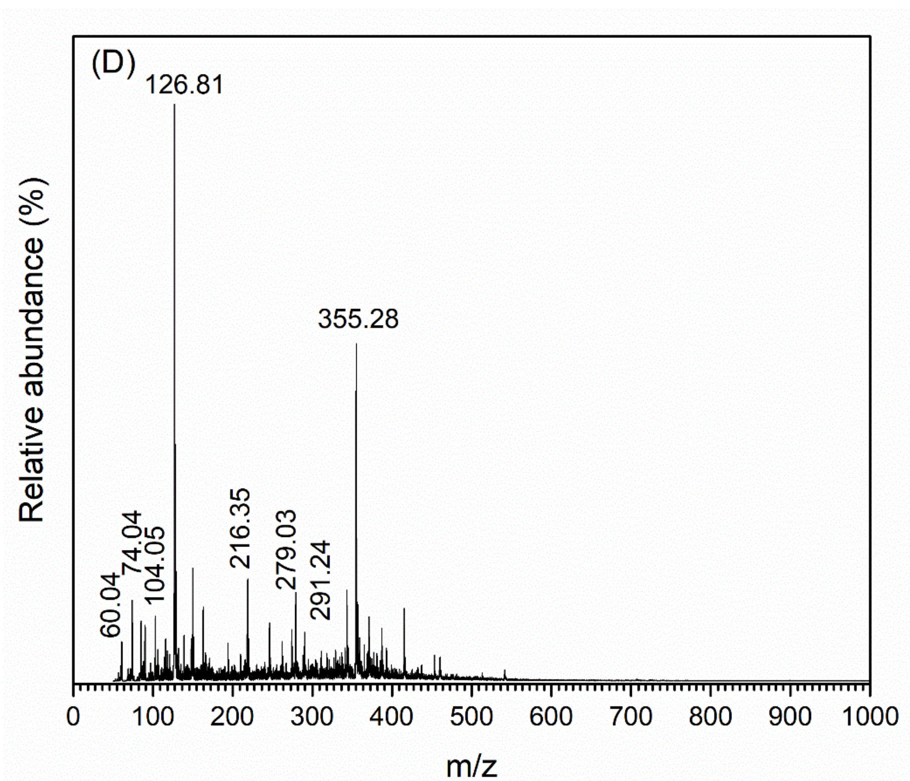
355.28
Relative abundance (%)
0
100
200
300
400
500
600
700
800
900
1000
m/z


(B)
355.28
126.81
216.35
279.03
291.24
Relative abundance (%)
0
100
200
300
400
500
600
700
800
900
1000
m/z


(C)
126.81
355.28
60.04
74.04
104.05
116.16
216.35
279.03
291.24
Relative abundance (%)
0
100
200
300
400
500
600
700
800
900
1000
m/z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74.04
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291.24
Relative abundance (%)
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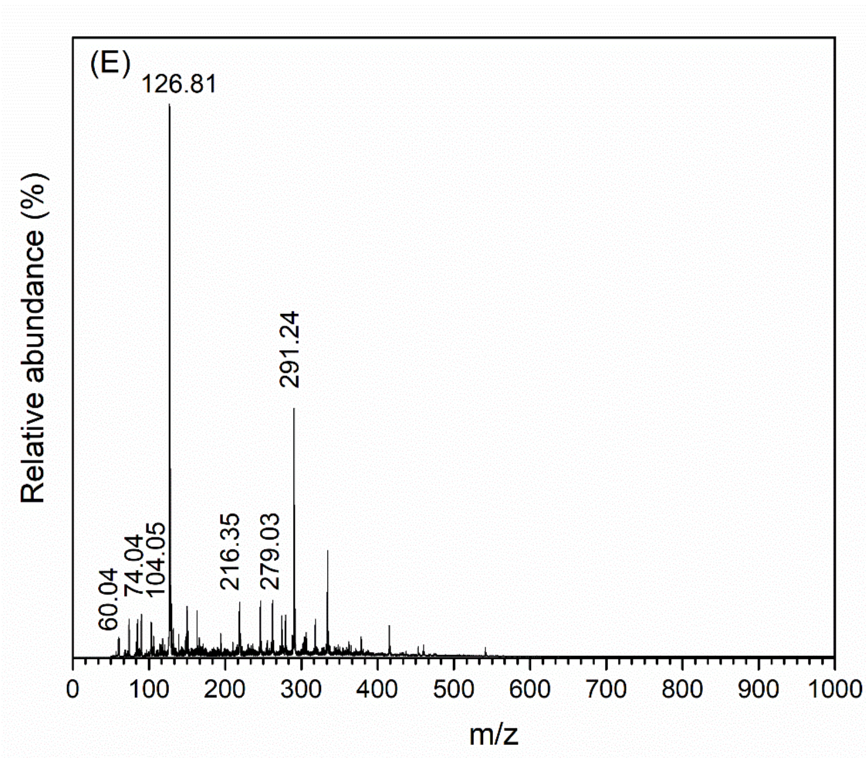
300
400
500
600
700
800
900
1000
m/z



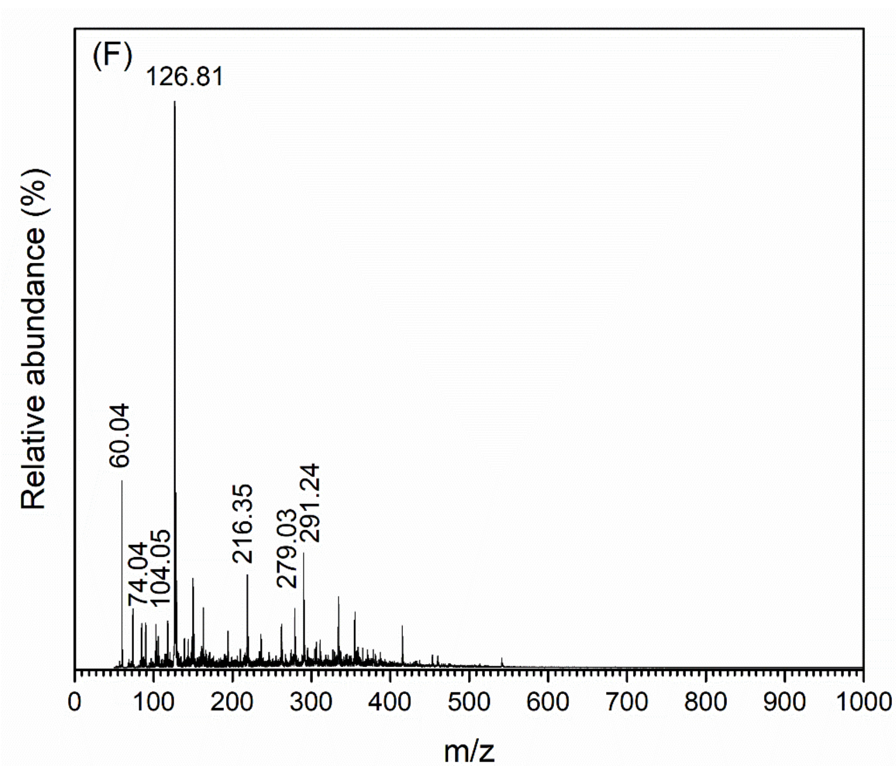


Figure S12. LC-mass spectra of phenol red under visible light (A) 0 min, (B) 15 min, (C) 30 min (D) 45 min, (E) 60 min and (F) 90 min reaction.

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