Electronic supplementary Information

Bright-blue-emission nitrogen and phosphorus doped carbon quantum dots as a promising nanoprobe for detection of Cr (VI) and ascorbic acid in pure aqueous solution and in living cell

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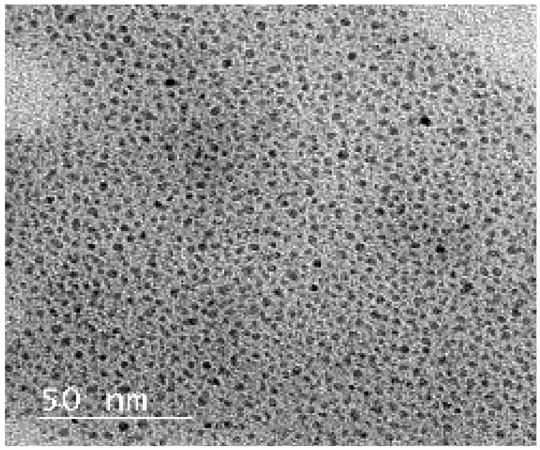


Fig. S1. TEM images showing average particle size approximately with 3.2 nm

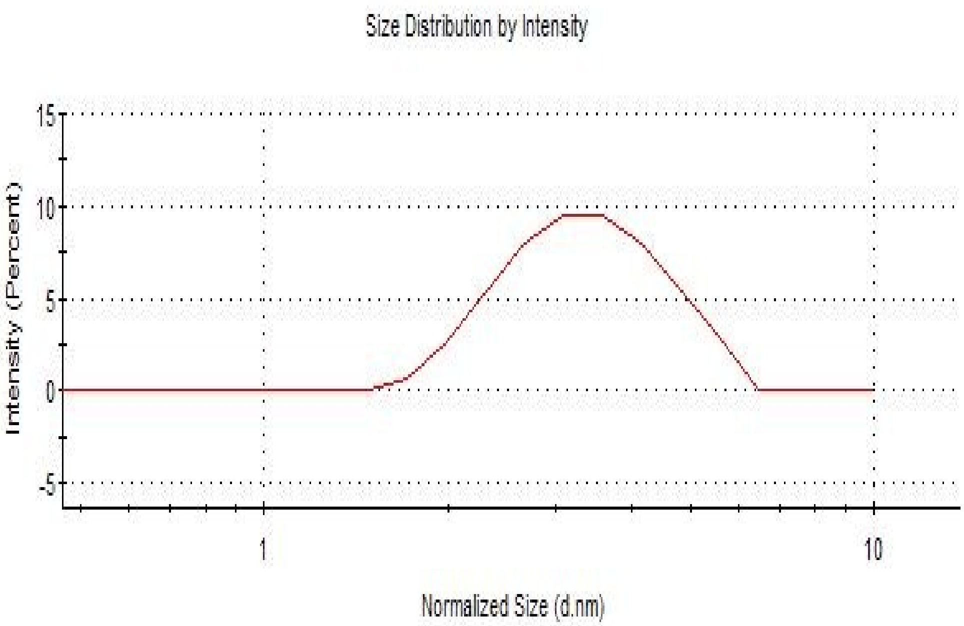


Fig.S2. Size distribution of as synthesized N,P-CQDs in aqueous solution**.**

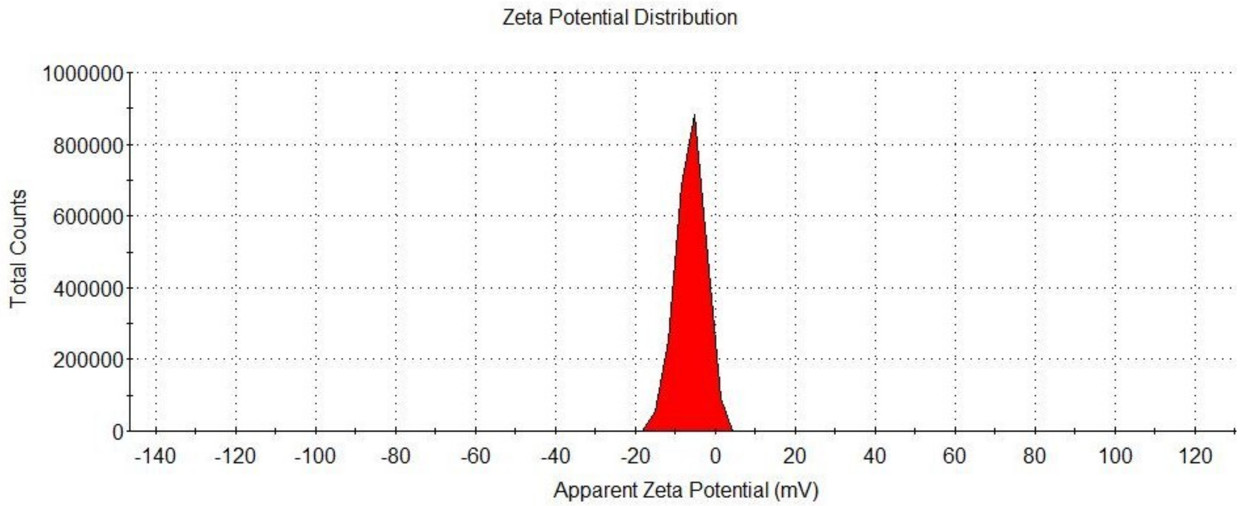


Fig. S3. Zeta potential distribution of as synthesized N,P-CQDs

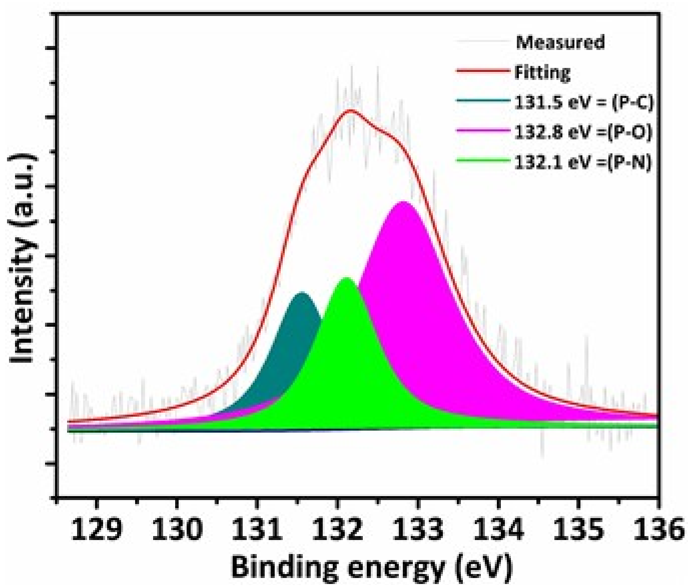


Fig. S4. P2p XPS spectra of as synthesized N,P-CQDs

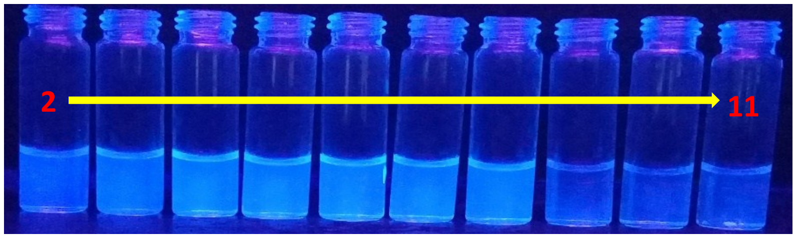
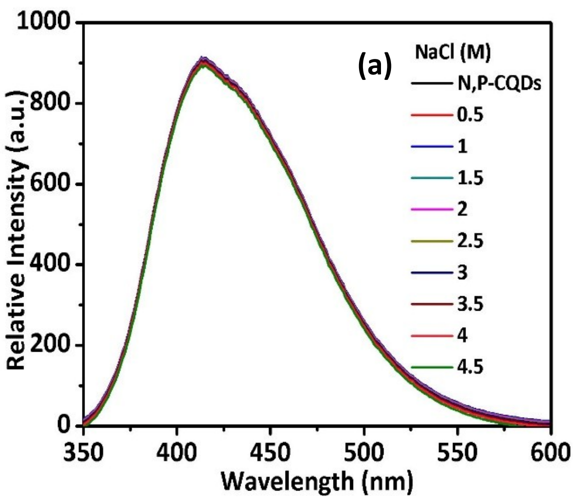


Fig. S5. Photograph of N,P- CQDs at different pH (2-11) illuminated by UV light at excitation wavelength 365 nm.



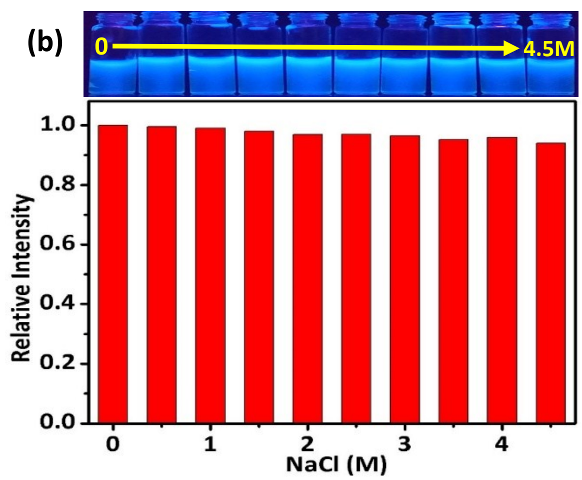


Fig. S6. (a) Effect of Ionic strength on fluorescence intensity of N,P-CQDs (b) photograph (under UV-light = 365 nm) and bar diagram represent negligible change in fluorescence after addition of NaCl solution (0.5 to 4.5 M)

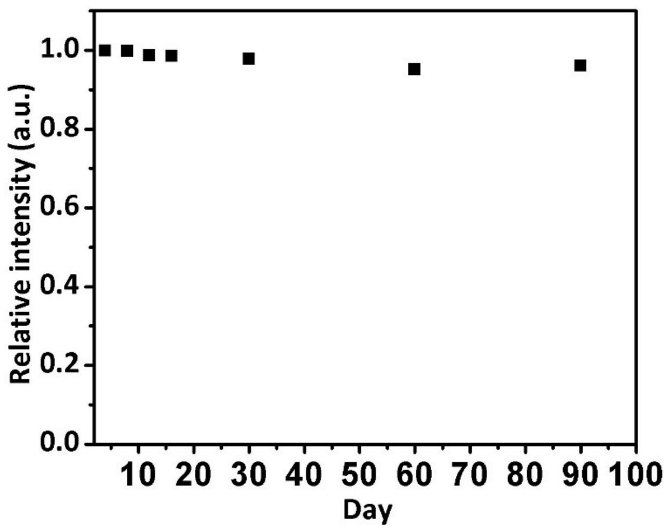


Fig. S7. Photostability of N,P-CQDs under visible light at ambient condition.

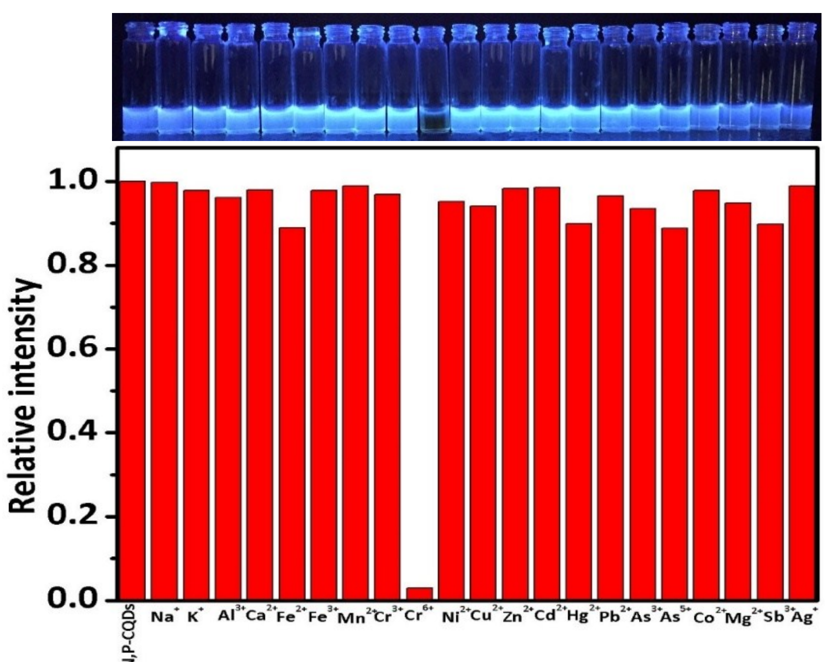


Fig. S8. Photograph showed selective sensing of Cr (VI) and bar diagram represent relative fluorescence intensity of N,P- CQDs (0.35 mg/ML) after addition 50 µL of Cr(VI) (1 x 10^{-3}M) and other metal ions (1x 10^{-2} M) indicated negligible interference of other metal ions.

Table S1. Details of fluorescence lifetime measurement of N,P- CQDs in absence and presence of Cr(VI) and ascorbic acid (AA) along with average lifetime, χ_2 and weightage of tri-exponential best fit components.

Compound	Average life time (ns)	Chi-square	Different life time (ns)	Corresponding Weight %
N,P-CQDs	3.56	1.292	τ_1 = 0.41 (B1= 0.210) τ_2 = 3.14 (B2 = 0.023) τ_3 = 9.05 (B3= 0.006)	40.96 34.20 24.85
N,P –CQDs + Cr(VI)	3.48	1.144	τ_1 = 0.16 (B1=0.379) τ_2 = 1.00 (B2= 0.059) τ_3 = 5.39 (B3=0.033)	35.96 25.21 38.83
N,P- CQDs + Cr(VI) + AA	3.53	1.358	τ_1 = 0.22 (B1=0.250) τ_2 = 1.08 (B2=0.066) τ_3 = 5.30 (B3= 0.035)	29.33 30.44 40.23

The fluorescence decays profile of N,P-CQDs were best fitted with a tri-exponential function. The suitability of the best fit was judged by reduced Chi-square values and the corresponding residual distribution. The acceptable fit has a Chi- square close to unity.
The fitting procedure of the emission intensity decays $I_{(t)}$ uses a tri-exponential model according to the following expression:

$$I_{(t)} = B_1 \exp(-t/\tau_1) + B_2 \exp(-t/\tau_2) + B_3 \exp(-t/\tau_3)$$

Where τ_1, τ_2 and τ_3 are the time constants of the three radiative decay channels; B_1, B_2 and B_3 are the three corresponding amplitudes.

The average life time were calculated from the following equations.

$$<\tau> = \frac{B1\tau^2 + B2\,\tau^2 + B3\,\tau^2}{B1\tau1 + B2\tau2 + B3\tau3}$$

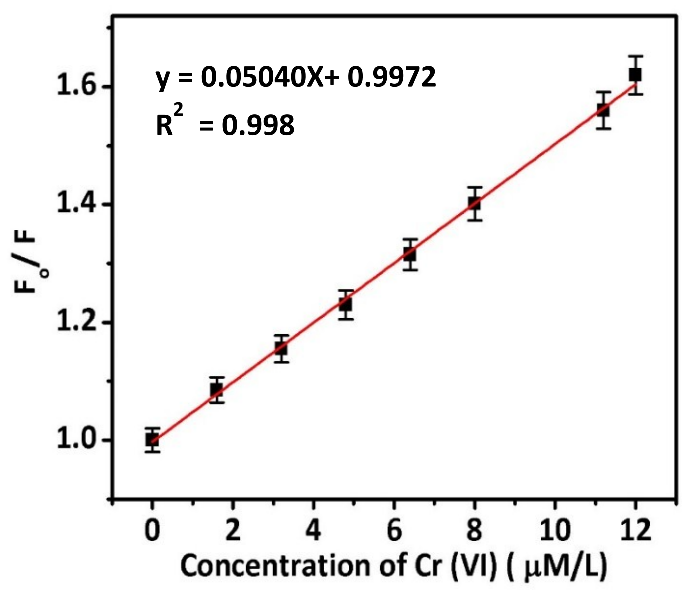


Fig. S9. Stern-volmer plot showing linear dependence of F_o / F with the concentration of Cr (VI) in the range of (0.0 – 12.2 µM/L)

Stern-volmer equation

$$\frac{F_0}{F} = 1 + Ksv\,[Q] \qquad (S1)$$

The change in the fluorescence intensity with concentration of Cr (VI) *viz*. (F_0 /F Vs Cr (VI) concentration), where F_0 and F are the fluorescence intensity of N,P-CQDs in absence and presence of Cr (VI) solution at the excitation of 340 nm respectively

Limit of detection (LOD): It has been calculated based on three times the standard deviation [SD] rule.

LOD = 3*SD/m

Where, m is the slope of the linearly fitted graph and SD is standard deviation

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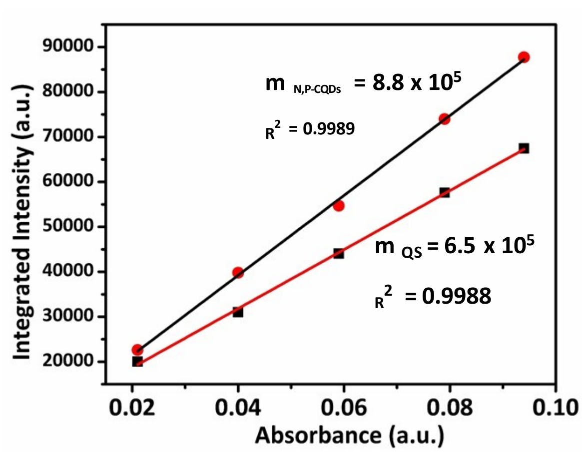


Fig. S10. Integrated intensity and absorbance of quinine sulphate and N,P-CQDs for measurement of fluorescence quantum yield at (λ_{ex} = 340 nm).

Quantum yield was calculated by using following equation

$$\Phi = \Phi_{ref}\,(m / m_{ref})\,(\eta 2 / \eta 2_{ref}) \qquad 2$$

Where Φ is the quantum yield of N,P-CQDs , m is slope, η is the refractive index of the solvent (H_2O = 1.33) ref. is the reference (quinine sulphate).

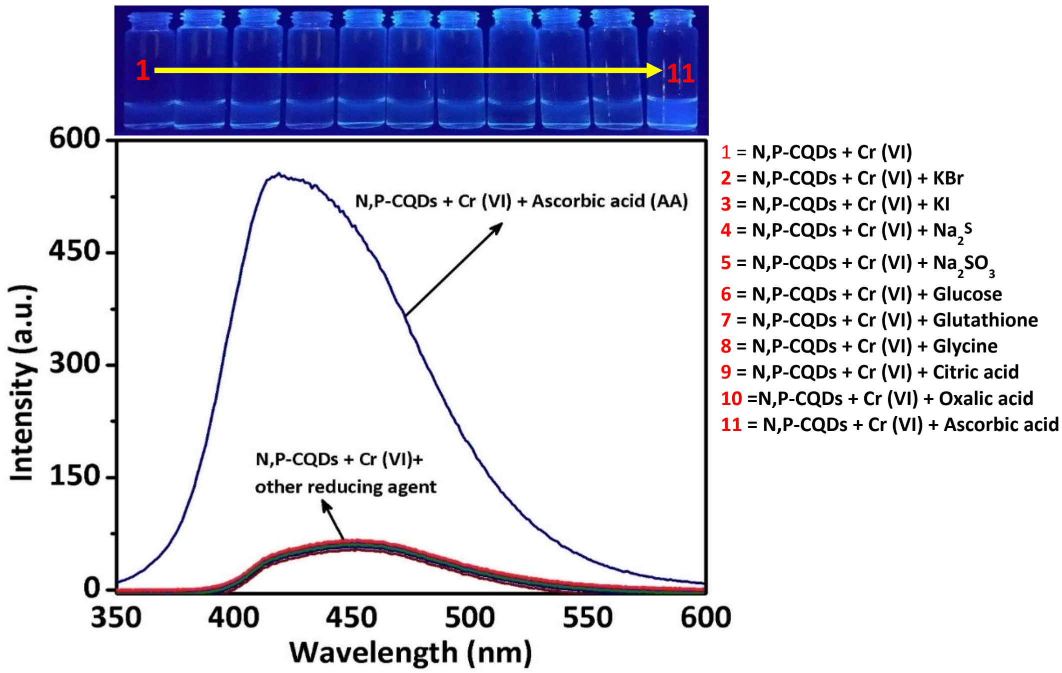


Fig. S11 Selective turn on sensing of ascorbic acid by N,P-CQDs + Cr (VI) system in presence of other reducing agent.

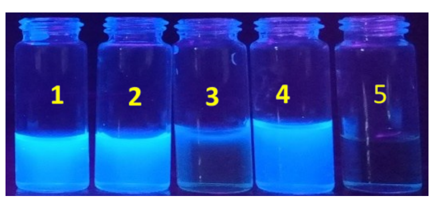
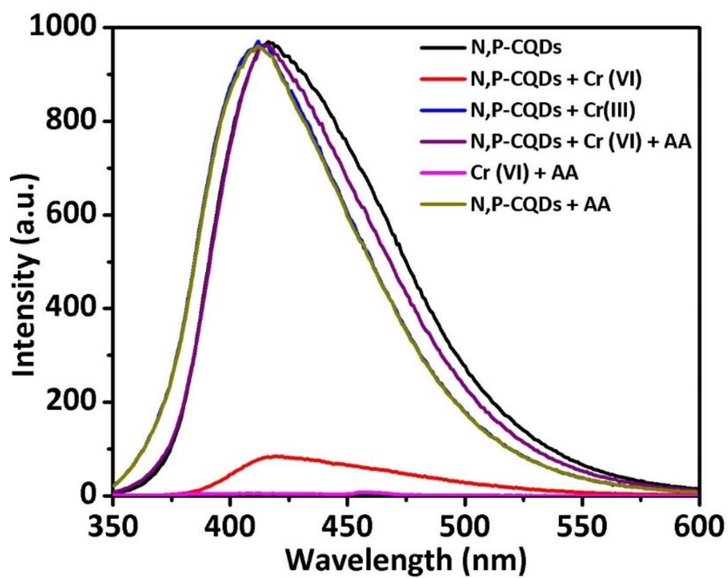


Fig. S12 Photograph (1= N,P-CQDs, 2 = N,P-CQDs + Cr(III), 3 = N,P-CQDs + Cr(VI), 4 = N,P-CQDs + Cr (VI) + AA , 5 = Cr(VI) + AA) under UV- light (λ_{ex} = 365 nm).



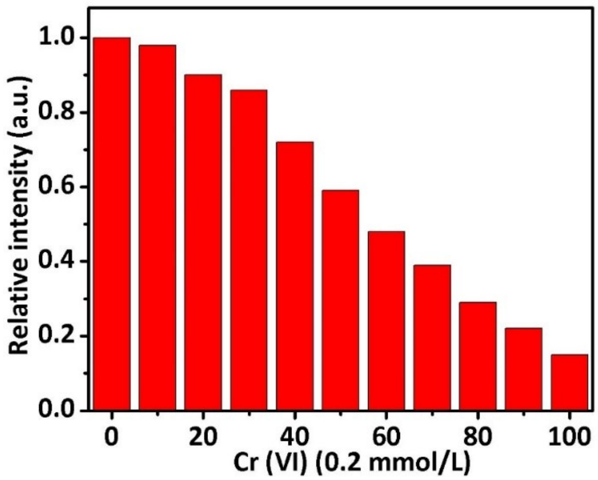


Fig.S13 Fluorescence spectra showing similar emission pattern of N,P-CQDs + Cr(III) and N,P-CQDs + Cr (VI) + AA system.

Fig. S14. Quenching of fluorescence intensity of N,P-CQDs at 414 nm after addition of (0 to 100 µL) of 0.2 mmol Cr(VI) solution.

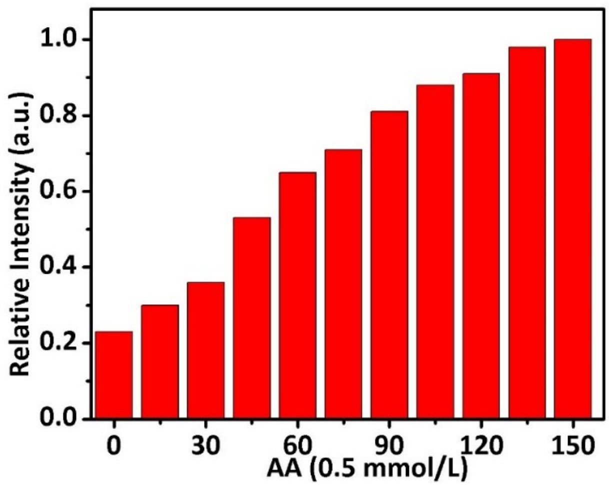


Fig. S15. Fluorescence recovery of N,P-CQDs + Cr (VI) system after addition of (0 to 150 µL) of 0.5mmol ascorbic acid solution.

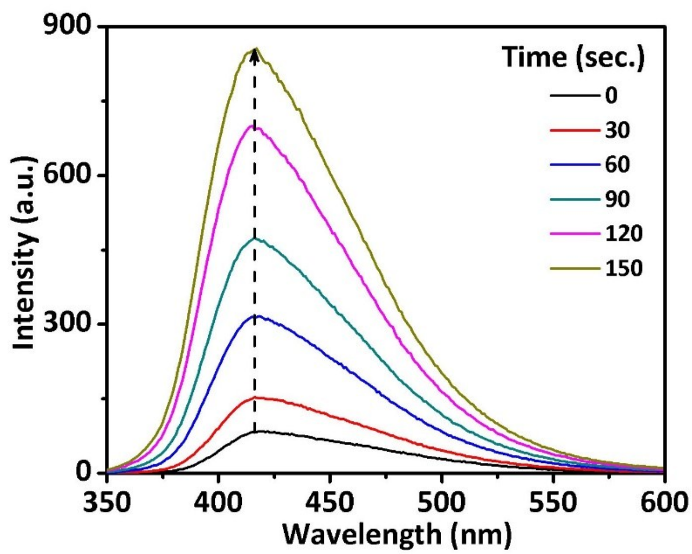


Fig. S16. Fluorescence recovery of N,P-CQDs + Cr(VI) system within 150 second after addition of 150 µL of 0.5mmol/L ascorbic acid solution.