ELECTRONIC SUPPLEMENTARY INFORMATION

Redox-active ferrocene-modified *Cowpea mosaic virus* nanoparticles

*Alaa A. A. Aljabali,[a] J. Elaine Barclay,[a] Julea N. Butt,[b] George P. Lomonossoff [a] and David J. Evans[a]**

a. Department of Biological Chemistry, John Innes Centre, Norwich Research Park, Colney, Norwich, NR4 7UH

b. School of Chemistry, University of East Anglia, Norwich, NR4 7TJ (United Kingdom)

*E-mail: dave.evans@bbsrc.ac.uk; Fax: +44-(0)1603-450018

- **Dynamic Light Scattering**

- **Randles-Sevcik Equation**

- **Randles-Sevcik Equation Calculations**

Dynamic Light Scattering

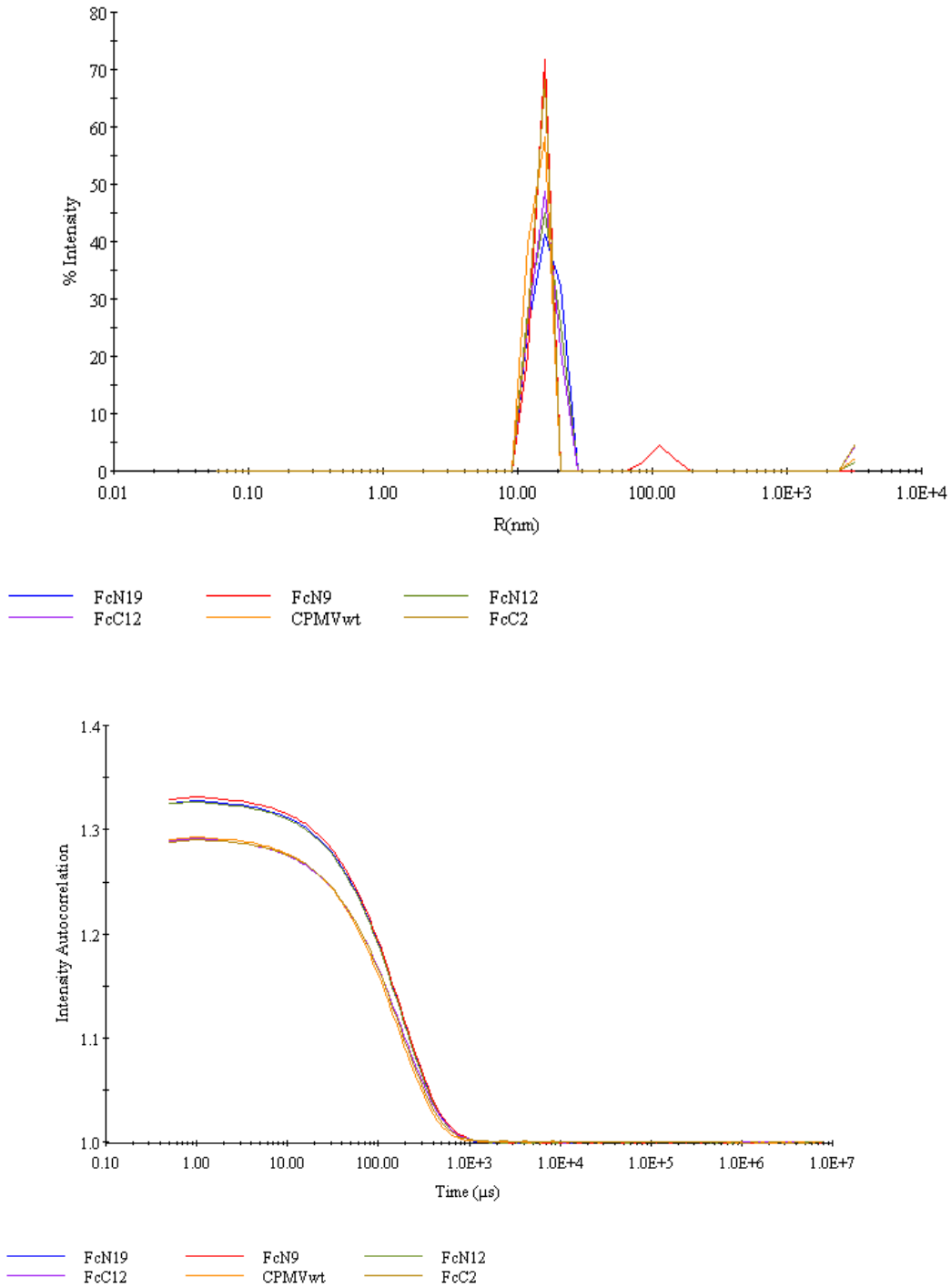


Figure S1. Dynamic light scattering. Comparison of hydrodynamic radii of (top), and correlation plots for (bottom), ferrocene-CPMV particles at approximately 0.5 mg/mL in 10 mM sodium phosphate buffer pH 7.0 after filtration through 0.1 µm filters (Millipore) immediately prior to analysis. Measurements were taken every 10 seconds and 10 measurements were averaged from 3 runs at 21 °C.

Randles-Sevcik Equation

The cyclic voltammetry peak height, ip, is directly proportional to the analyte concentration, C, as described by the simplified Randles-Sevcik equation, if the temperature is assumed to be 25 ºC:

$$i_p = k.n^{\frac{3}{2}}.A.\sqrt{D.\nu}\,.C_{Fc}$$

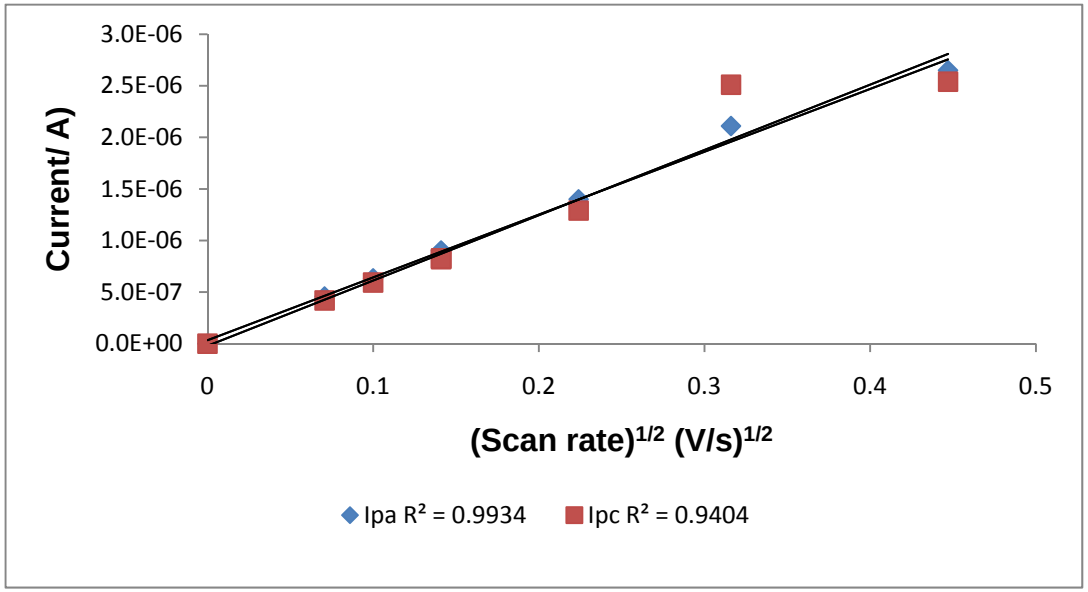
In this equation, k is a constant of 2.69 x 10^5 with units of C mol^{-1} $V^{-½}$, n is the number of electrons appearing in the half-reaction for the redox couple, A is the electrode area (cm^2), D is the analytes diffusion coefficient (cm^2 s^{-1}) and v is the rate at which the potential is swept (V s^{-1}). ν was measured over a range of scan rates from 5 to 200 mV sec^{-1}. From the slope of the plots of current (i_p) versus the square-root of the scan rate, and appropriate substitution and analysis, the ferrocence concentration can be calculated and subsequently the number of ferrocene moieties per virus particle.

$$\text{Slope} = \left(\frac{i_p}{\sqrt{\nu}}\right) = k.n^{\frac{3}{2}}.A\,.\sqrt{D}\,.C_{Fc}$$

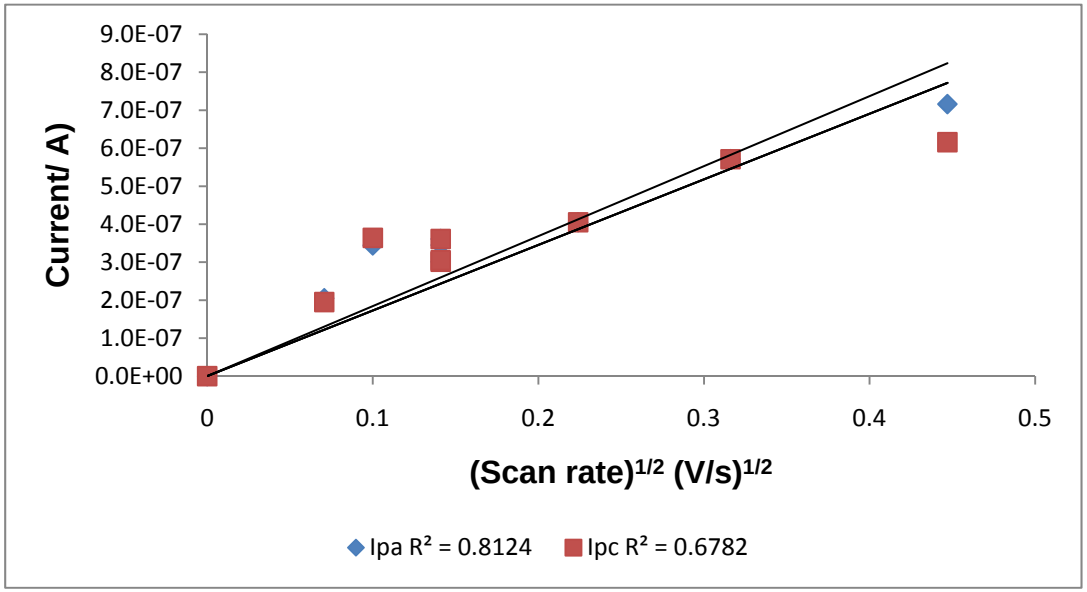
where

$n = 1$ $\quad A = 0.07\ cm^2$ $\quad D = 0.16 \times 10^{-6}\ cm^2\ s^{-1}$

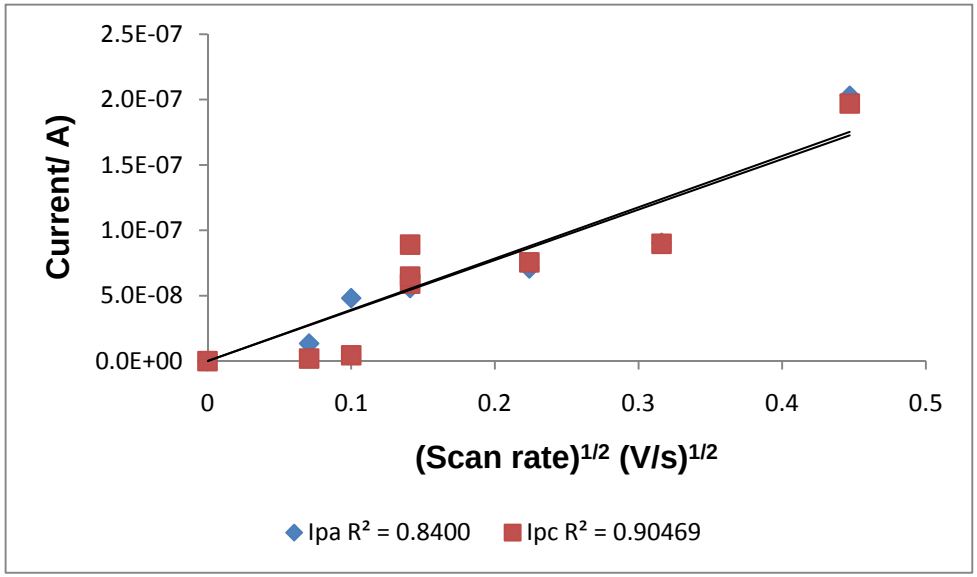
Fc_N9			
Scan Rate V	Square root for scan rate	Ipa (oxidation)	Ipa(reduction)
(V/sec)	√v (√V/sec)	(μA)	(μA)
0.02	1.4100E-01	9.0300E-07	8.1900E-07
0.01	1.0000E-01	6.3300E-07	5.9200E-07
0.005	7.0700E-02	4.5800E-07	4.1900E-07
0.02	1.4100E-01	8.7500E-07	8.2700E-07
0.2	4.4700E-01	2.6500E-06	2.5400E-06
0.1	3.1600E-01	2.1100E-06	2.5100E-06
0.02	1.4100E-01	8.9900E-07	8.2300E-07
0.05	2.2400E-01	1.4000E-06	1.2900E-06
Ferrocene concentration [(Ip/v)= k n3/2 A D1/2]		8.2501E-07	8.30E-07
Ferrocene moieties per virus		245.7	247.3
Ferrocene concentration with A-5%		8.4286E-07	8.8982E-07
Ferrocene moieties per virus		251.06	265.1
Ferrocene concentration with A+5%		7.6259E-07	8.0507E-07
Ferrocene moieties per virus		227.15	239.8
CPMV concentration (10.88 mg/ml)		3.35714E-09	3.35714E-09
Average number of ferrocenes		241.32	250.7
Average ferrocenes from oxidation & reduction		246.0	



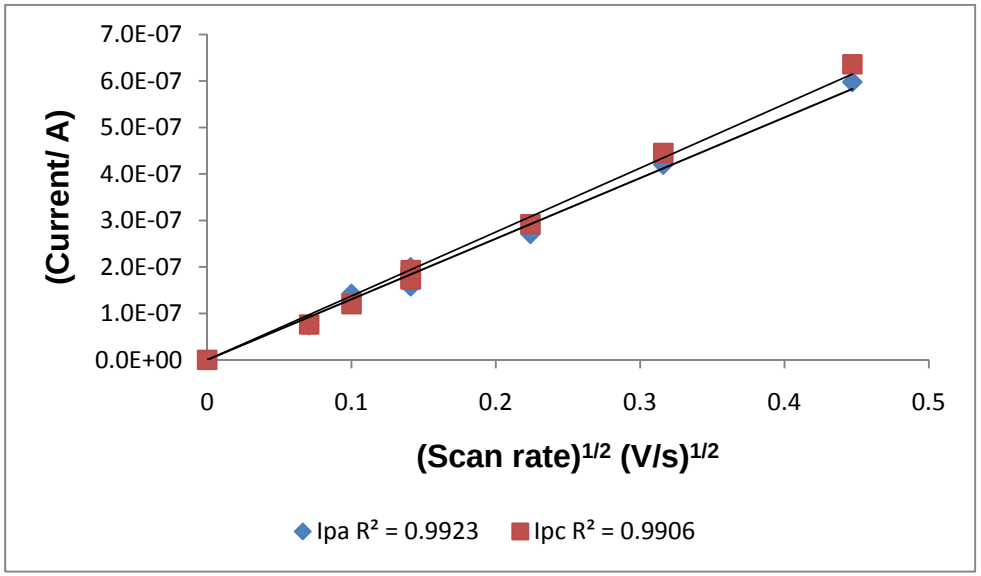
Fc_N12			
Scan Rate V	Square root for scan rate	Ipa (oxidation)	Ipa(reduction)
(V/sec)	√v (√V/sec)	(μA)	(μA)
0.02	1.4100E-01	3.01E-07	3.01E-07
0.01	1.0000E-01	3.44E-07	3.64E-07
0.005	7.0700E-02	2.05E-07	1.95E-07
0.02	1.4100E-01	3.45E-07	3.05E-07
0.2	4.4700E-01	7.16E-07	6.16E-07
0.1	3.1600E-01	5.71E-07	5.71E-07
0.02	1.4100E-01	3.61E-07	3.61E-07
0.05	2.2400E-01	4.05E-07	4.05E-07
Ferrocene concentration [(Ip/v)= k n3/2 A D1/2]		2.4462E-07	2.29E-07
Ferrocene moieties per virus		326.2	305.5
Ferrocene concentration with A-5%		1.7483E-07	1.6757E-07
Ferrocene moieties per virus		233.11	223.4
Ferrocene concentration with A+5%		1.5818E-07	1.5161E-07
Ferrocene moieties per virus		210.91	202.1
CPMV concentration (4.2 mg/ml)		7.5E-10	7.5E-10
Average number of ferrocenes		256.73	243.7
Average ferrocenes from oxidation & reduction		250.2	



Fc_N19			
Scan Rate V	Square root for scan rate	Ipa (oxidation)	Ipa(reduction)
(V/sec)	√v (√V/sec)	(µA)	(µA)
0.02	1.4100E-01	6.07E-08	5.92E-08
0.01	1.0000E-01	4.82E-08	4.44E-09
0.005	7.0700E-02	1.35E-08	1.92E-09
0.02	1.4100E-01	6.44E-08	6.46E-08
0.2	4.4700E-01	2.03E-07	1.97E-07
0.1	3.1600E-01	9.05E-08	8.97E-08
0.02	1.4100E-01	5.59E-08	8.91E-08
0.05	2.2400E-01	7.09E-08	7.55E-08
Ferrocene concentration [(Ip/v)= k n3/2 A D1/2]		5.1268E-08	5.21E-08
Ferrocene moieties per virus		179.4	182.3
Ferrocene concentration with A-5%		5.8012E-08	6.1087E-08
Ferrocene moieties per virus		203.04	213.8
Ferrocene concentration with A+5%		5.2487E-08	5.5269E-08
Ferrocene moieties per virus		183.71	193.4
CPMV concentration (1.6 mg/ml)		2.85714E-10	2.85714E-10
Average number of ferrocenes		188.73	196.5
Average ferrocenes from oxidation & reduction		192.6	



Fc_C2			
Scan Rate V	Square root for scan rate	Ipa (oxidation)	Ipa(reduction)
(V/sec)	√v (√V/sec)	(µA)	(µA)
0.02	1.4100E-01	1.5800E-07	1.7500E-07
0.01	1.0000E-01	1.4200E-07	1.2000E-07
0.005	7.0700E-02	7.4400E-08	7.6100E-08
0.02	1.4100E-01	1.6300E-07	1.7300E-07
0.2	4.4700E-01	5.9800E-07	6.3600E-07
0.1	3.1600E-01	4.2000E-07	4.4500E-07
0.02	1.4100E-01	1.9900E-07	1.9300E-07
0.05	2.2400E-01	2.7100E-07	2.9200E-07
Ferrocene concentration [(Ip/v)= k n3/2 A D1/2]		1.8255E-07	1.73E-07
Ferrocene moieties per virus		170.4	161.6
Ferrocene concentration with A-5%		1.9104E-07	2.0809E-07
Ferrocene moieties per virus		178.31	194.2
Ferrocene concentration with A+5%		1.7285E-07	1.8828E-07
Ferrocene moieties per virus		161.33	175.7
CPMV concentration (6 mg/ml)		1.07143E-09	1.07143E-09
Average number of ferrocenes		170.01	177.2
Average ferrocenes from oxidation & reduction		173.6	



Fc_C12			
Scan Rate V	Square root for scan rate	Ipa (oxidation)	Ipa(reduction)
(V/sec)	√v (√V/sec)	(µA)	(µA)
0.02	1.4100E-01	1.34E-07	1.75E-07
0.01	1.0000E-01	9.94E-08	1.27E-07
0.005	7.0700E-02	7.03E-08	7.29E-08
0.02	1.4100E-01	1.35E-07	1.76E-07
0.2	4.4700E-01	5.03E-07	5.81E-07
0.1	3.1600E-01	3.48E-07	3.85E-07
0.02	1.4100E-01	1.19E-07	1.77E-07
0.05	2.2400E-01	1.80E-07	3.01E-07
Ferrocene concentration [(Ip/v)= k n3/2 A D1/2]		1.3910E-07	1.69E-07
Ferrocene moieties per virus		87.5	106.5
Ferrocene concentration with A-5%		1.6309E-07	1.8238E-07
Ferrocene moieties per virus		102.62	114.8
Ferrocene concentration with A+5%		1.4756E-07	1.6501E-07
Ferrocene moieties per virus		92.85	103.8
CPMV concentration (8.9 mg/ml)		1.58929E-09	1.58929E-09
Average number of ferrocenes		94.33	108.4
Average ferrocenes from oxidation & reduction		101.3