

# Supporting Information

## High-performance sodium battery with 9,10-anthraquinone/CMK-3 cathode and ether-based electrolyte

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### *Preparation of AQ/CMK-3*

The AQ/CMK-3 with selected mass ratio of AQ to CMK-3 were prepared by a simple impregnation method with the following points, AQ was dissolved into the solvent dimethyl sulfoxide (DMSO), then CMK-3 was added into the the above solution. After ultrasonic treating and vacuum heat, AQ/CMK-3 can be obtained.

Take the preparation of the mass ratio of AQ to CMK-3 is 1:1 as example. Firstly, 50 mg AQ (Aladdin; 98%) was dissolved into 1 mL DMSO. Then, 50 mg CMK-3 (Nanjing JiCang) was added into the solution. After 30 min ultrasonic treating, the solution was heated under vacuum at 110 °C to remove the solvent to obtain the AQ/CMK-3 nanocomposite. Other AQ/CMK-3 with selected mass ratios can be obtained with the similar procedure.

### *Preparation of Electrolyte*

Electrolytes with different salt concentrations (1 M, 2 M, 3 M, 4 M) were prepared by adding according mass of  $\text{CF}_3\text{SO}_3\text{Na}$  (NaTFS) (Aldrich; 98%) into the corresponding volume of triethylene glycol dimethyl ether

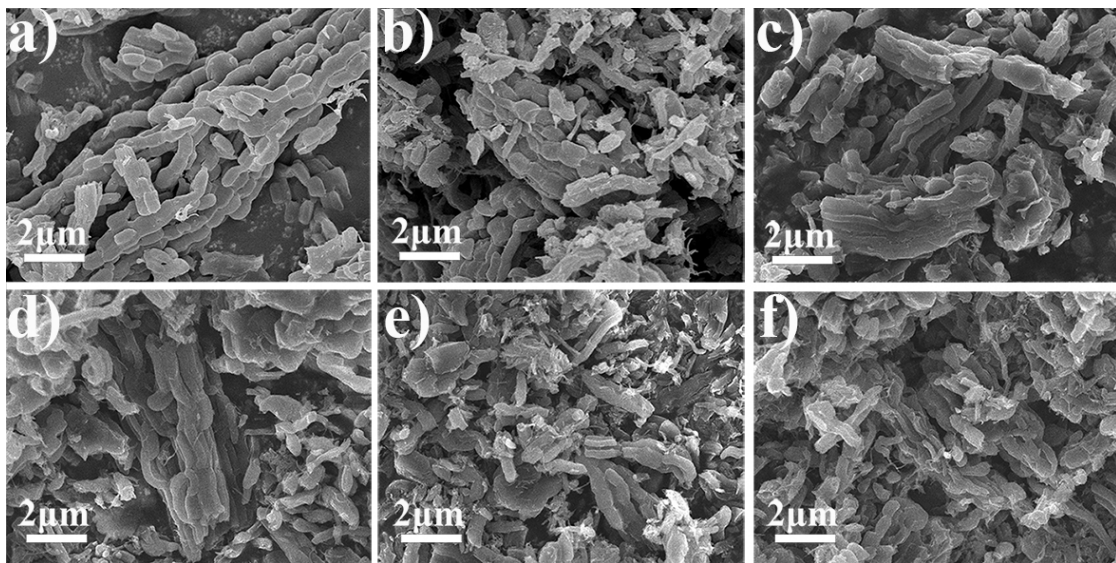
(TEGDME) (Aldrich;  $\geq 99\%$ ) in glovebox filled with argon. The mixture was vigorously stirred for 24 h. The viscosity ( $\eta$ ) of the electrolytes was measured by a digital viscometer (HANGPING SNB-1) at 25 °C. The AQ dissolution experiments were carried out according to the following steps: 300 mg AQ was added in 5 mL different concentrations electrolytes, respectively. Using digital camera to record the colour change of solutions along with time. The NaPF<sub>6</sub> dissolution experiment was performed in a similar way.

#### *Characterization of the as-prepared AQ/CMK-3 and Electrolyte*

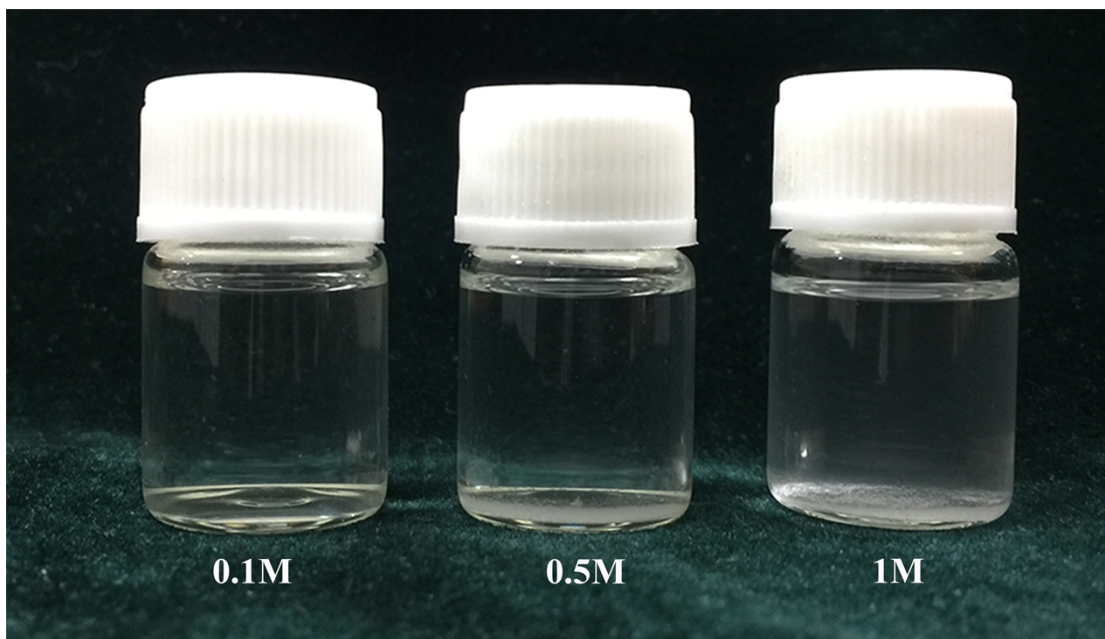
IR spectra were collected at 25 °C with FTIR-650 Spectrometer (Tianjin Gangdong) between 2000 and 600 cm<sup>-1</sup>. Raman spectra were obtained at 25 °C with a confocal Raman microscope (DXR, Thermo-Fisher Scientific) at 532 nm excitation from an argon-ion laser. XRD patterns were collected in the wide  $2\theta$  range of 10–80° (Rigaku MiniFlex600, CuK <sub>$\alpha$</sub>  radiation). Scanning electron microscopy (SEM, JEOL JSM78500F) and transmission electron microscopy (TEM, Philips Tecnai-F20) were used to observe morphologies and microstructures of materials. The conductivity of electrolyte was determined by an impedance analyzer 2273 potentiostat/galvanostat workstation with an amplitude of  $\pm 5$  mV over the frequency range from 100 kHz to 100 mHz over a temperature range of –15 to 55 °C in a homemade thermostatic container.

### *Construction of CR2032 Cells and Measurements*

CR2032 coin-type cells, consisting of a working electrode and a sodium foil counter electrode, were assembled in a glovebox filled with argon. AQ electrodes were prepared by mixing 56 wt% AQ with 34 wt% conductive carbon (super P) and 10 wt% of polyvinylidenedifluoride (PVdF) binder. The AQ/CMK-3 nanocomposite electrodes were made by blending 90 wt% AQ/CMK-3 with 5 wt% super P and 5 wt% PVdF. The electrolytes contained NaTFS and TEGDME with the salt concentration range from 1 to 4 M. Land CT2001A cell testing system was used to test the discharge-charge experiments within the potential range of 1.2–2.8 V using different current rates. The capacity of AQ/CMK-3 nanocomposite were calculated by only considering the active mass of the working electrodes. Impedance measurements were conducted by using 2273 potentiostat/galvanostat workstation with an amplitude of  $\pm 5$  mV over the frequency range from 100 kHz to 100 mHz at 25 °C.

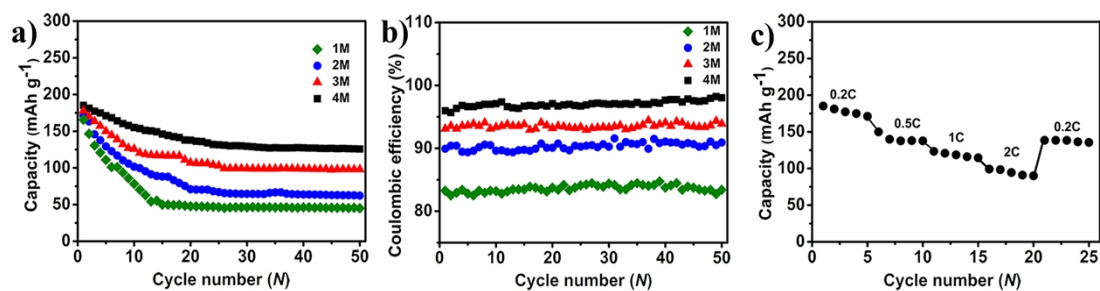


**Fig. S1** SEM images of a) CMK-3, AQ/CMK-3 with the mass ratios of AQ to CMK-3 b) 1:3, c) 1:2, d) 1:1, e) 2:1, f) 3:1.

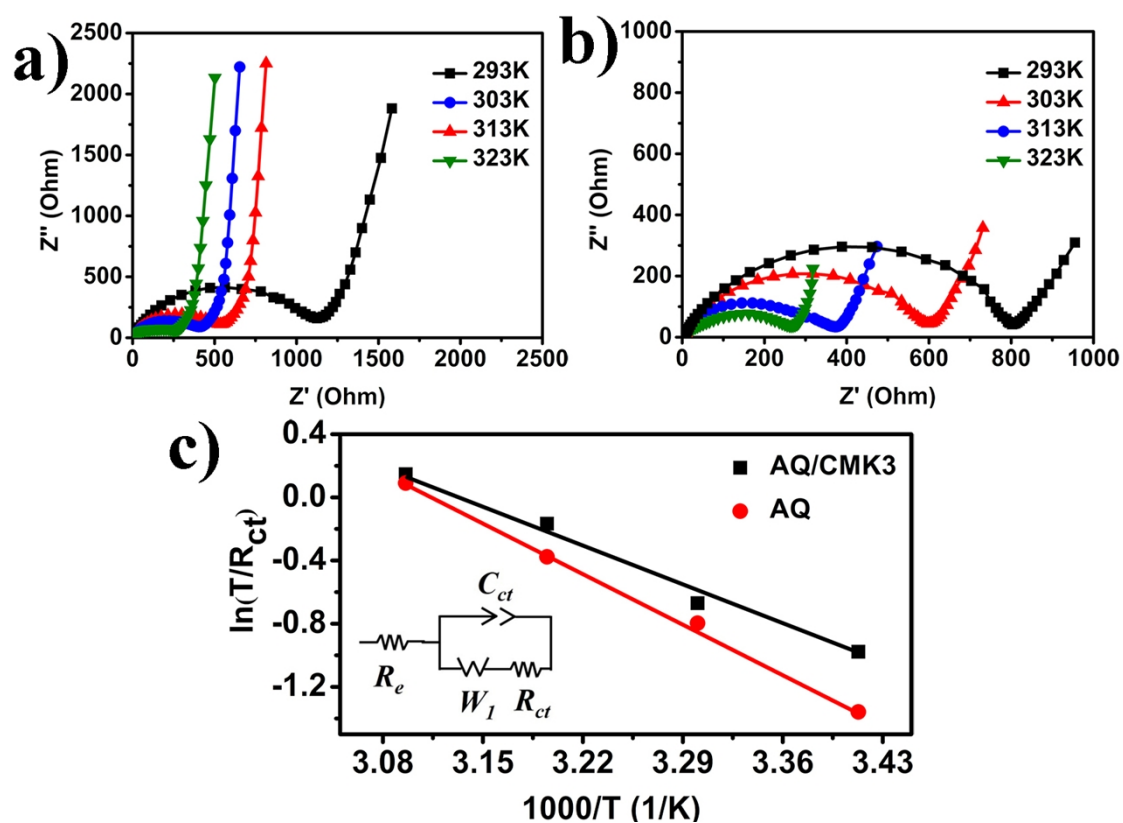


**Fig. S2**  $\text{NaPF}_6$  dissolution experiments in DOL/DME (1:1).

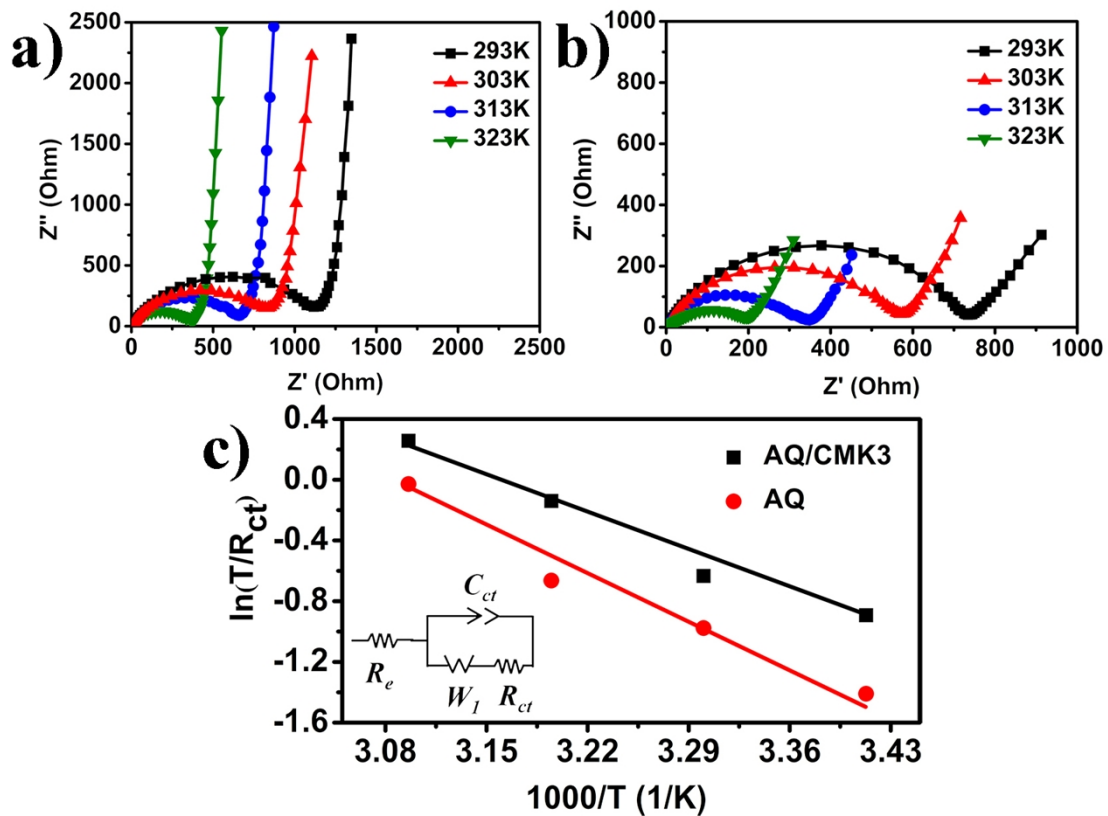
It is clear to see that 0.1M solution is clear with no sediment in it. With increase of salt concentration,  $\text{NaPF}_6$  can no longer dissolve into DOL/DME (1:1), so there is white color sediment in 0.5M and 1M solution. Therefore, the salt concentration of  $\text{NaPF}_6$ / DOL/DME electrolyte cannot reach over 1M.



**Fig. S3** Electrochemical performance of AQ in sodium battery: a) Cyclic performance. b) Coulombic efficiency at a current rate of 0.2C (coulombic efficiency = charge capacity/ discharge capacity). c) Rate capability with 4M electrolyte.



**Fig. S4** Electrochemical impedance spectra (EIS) plots of a) AQ; b) AQ/CMK-3 in 4M electrolyte from 293K to 323K at 1.89 V discharge state in the second cycle; c) Arrhenius plots of  $\ln(T/R_{ct})$  versus  $1/T$  ( $i_0 = RT/nFR_{ct}$ ,  $i_0 = A \exp(-E_a/RT)$ , where  $i_0$  is the exchange currents,  $E_a$  is apparent activation energies). Inset: the equivalent circuits of.  $R_e$  is electrolyte resistance.  $R_{ct}$  and  $C_{ct}$  is the charge transfer resistance and a constant phase element, respectively.  $W_l$  represents the Warburg impedance related to the diffusion of sodium ions.



**Fig. S5** Electrochemical impedance spectra (EIS) plots of a) AQ; b) AQ/CMK-3 in 4M electrolyte from 293K to 323K at 1.57 V discharge state in the second cycle; c) Arrhenius plots of  $\ln(T/R_{ct})$  versus  $1/T$ . Inset: the equivalent circuits of.  $R_e$  is electrolyte resistance.  $R_{ct}$  and  $C_{ct}$  is the charge transfer resistance and a constant phase element, respectively.  $W_l$  represents the Warburg impedance related to the diffusion of sodium ions.