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Supporting Information

Sustainable and Cost-Effective Ternary Electrolyte $Et_3NHCl-AlCl_3-Mg(DEP)_2$ for High-Performance Rechargeable Magnesium Batteries

Seggem Prabhakar[a,b], Santosh N. Chavan[a], Pratyay Basak[a], Jetti Vatsala Rani[a,*]

a) Polymers and Functional Materials, CSIR-Indian Institute of Chemical Technology, Hyderabad-500007, India.
b) Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002, India

Table S1. Anodic and cathodic current in the peak of Mg dissolution and deposition

Molar concentration	**Anodic current**	**Cathodic current**
0.1 M $Mg(DEP)_2$	430 µm	600 µm
0.2 M $Mg(DEP)_2$	180 µm	260 µm
0.3 M $Mg(DEP)_2$	85 µm	85 µm

Table S2. Arrhenius fitting paraments of conductivity in different concertation of Mg salt in $Et_3NHCl-AlCl_3$ eutectic mixture electrolytes

Electrolytes	**Conductivity (S cm^{-1})**	**Activation Energy (eV)**	**R^2**
1	4.5×10^{-3}	0.23	0.998
2	2.7×10^{-3}	0.27	0.995
3	1.1×10^{-3}	0.28	0.923

Table S3. Temperature dependence of ionic conductivity and fitting in VTF equation:[1]

$\sigma = \sigma_0 e^{\frac{B}{T - T_o}}$				
Electrolytes	***σ_0***	***B (K)***	***T_0 (K)***	***R^2***
1	1.08345	826.2541	145.9243	0.99935
2	39.98513	3187.621	42.31714	0.99753
3	3.51201	1637.95	88.06223	0.98752

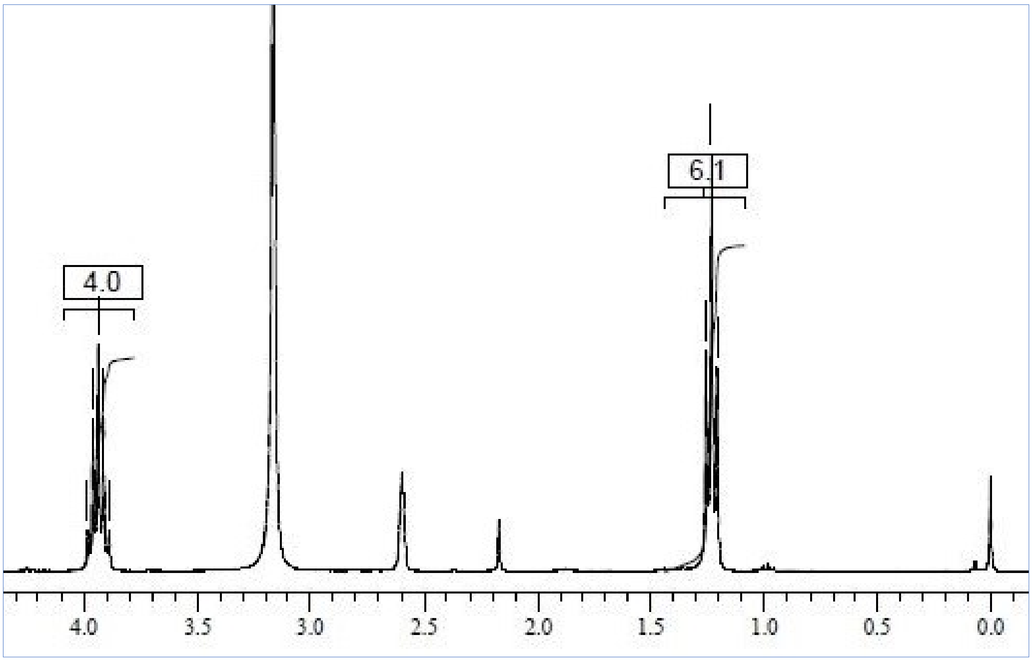

Figure S1. ^{1}H NMR of Magnesium Diethylphosphate (Mg(DEP)$_2$ salt in $CDCl_3$

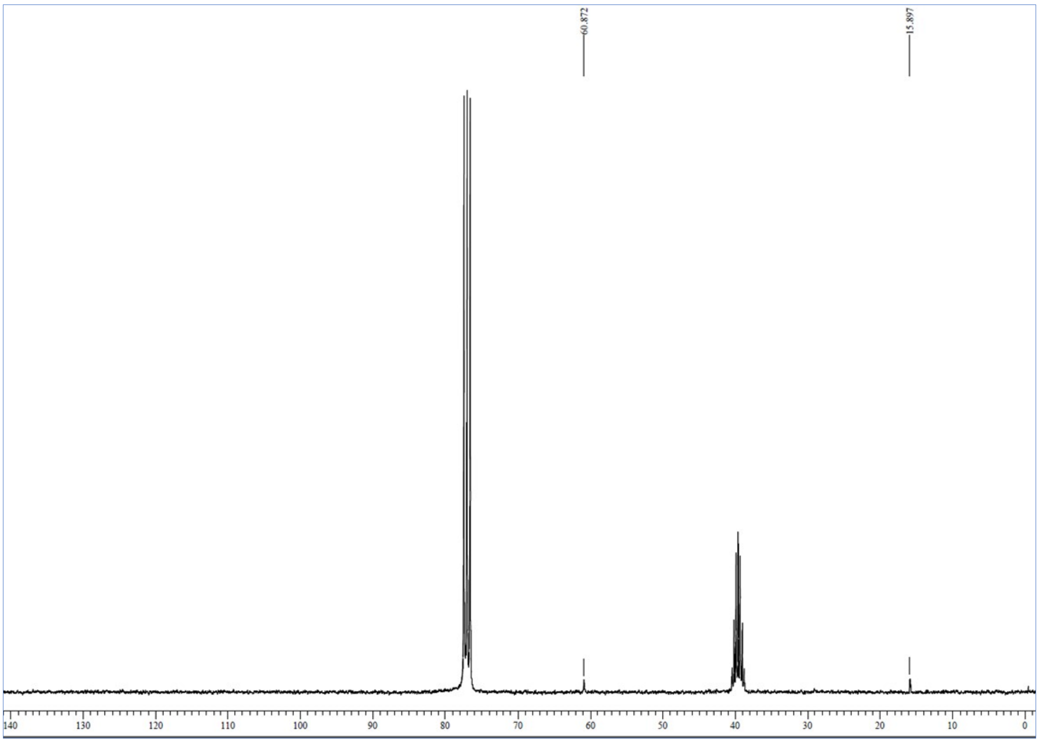

Figure S2. ^{13}C NMR of Magnesium Diethylphosphate (Mg(DEP)$_2$ salt in $CDCl_3$

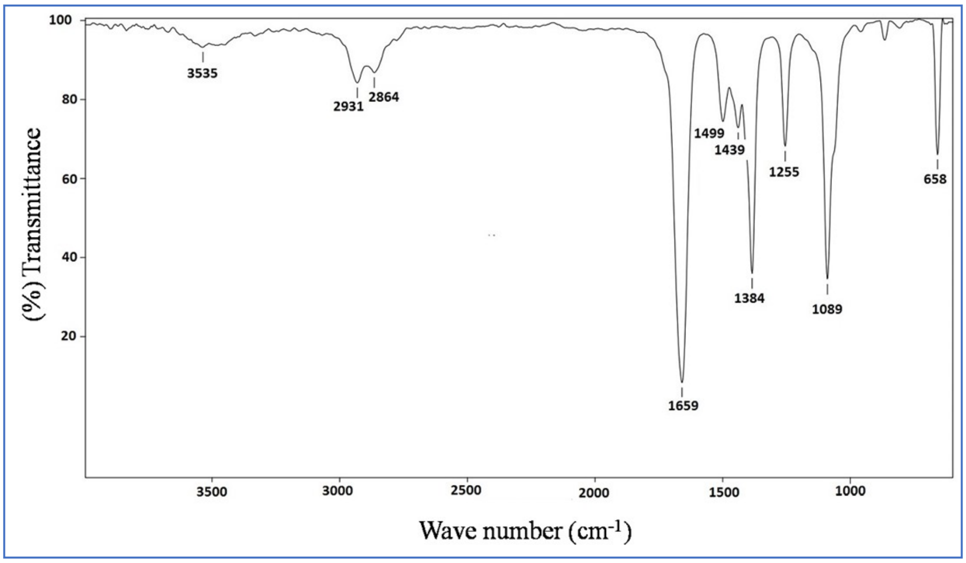

Figure S3. IR spectra of Magnesium Diethyl phosphate $(Mg(DEP)_2$ in DMF salt in $CDCl_3$.

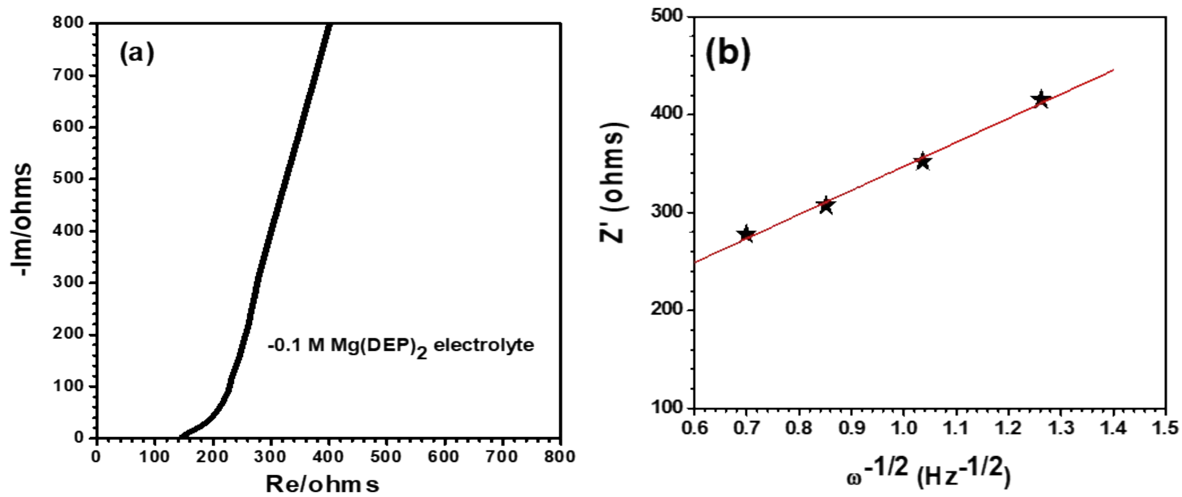

Figure S4: Diffusion coefficient[2, 3] is calculated from Electrochemical Impedance Spectroscopy (EIS) on (a) Mg/**1**/Graphite (b) linear fitting of Z' Vs $w^{-1/2}$.

$$D = \frac{R^2T^2}{2A^2n^4F^4C^2\sigma^2}$$

D is ion diffusion coefficient,

R is molar gas constant (8.314 J mol^{-1} K^{-1}),

T is absolute temperature (298 k),

A is electrode area (0.32 cm^2),

n is electron transfer number (2),

F is Faraday constant (96500 C mol^{-1})

C is the concentration of ion (0.1 M).

σ is Warburg factor, calculated by the formula: $Z' = R_\Omega + R_{ct} + \sigma\omega^{-1/2}$

(Z', R_Ω, R_{ct} and ω represent true resistance, Ohm solution impedance, charge transfer impedance and the frequency at low frequency region, respectively.)

Mg^{2+} ions diffusion coefficient (**D)= 3.15 x 10^{-17} cm^2s^{-1}**

Refferences:

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2. S. Miyoshi, T. Akbay, T. Kurihara, T. Fukuda, A. T. Staykov, S. Ida and T. Ishihara, *J. Phys. Chem. C*, 2016, **120**, 22887-22894.
3. J. Vila, P. Ginés, J. M. Pico, C. Franjo, E. Jiménez, L. M. Varela and O. Cabeza, *Fluid Phase Equilib.*, 2006, **242**, 141-146.