Supporting Information

1. GO films characterization.

The exact film used for neutron reflectivity experiments could not be studied using standard diffractometer with available setup due to large size (70*70mm) and thickness of Si plate (10 mm). However, several films deposited from the same water/ethanol solution were deposited on smaller Si plates during test depositions. X-ray diffraction patterns recorded from these films revealed weak but certain reflection with d(001) =7.5-8.1Å depending on how well the film is dried. The film dries very slowly and the cell parameter is changing slowly during approximately 2-3 weeks. The final value of d(001) depend on the level of ambient humidity.

2. Extraction of physical information from experimentally obtained parameters – scattering length density ρ and thickness L of the sample GO film.

compound	**chemical formula**	***B*** **(10^{-4} Å)**
carbon	C	0.6648
oxygen	O	0.5805
hydrogen	H	-0.3740
deuterium	D	0.6674
light water	H_2O	-0.1675
heavy water	D_2O	1.9150
	OH	0.2068
ethanol	C_2H_6O	-0.3339

Table S1. Values of neutron scattering length $B = \sum b_i$ of relevant atoms and molecules. Compounds with negative B are highlighted.

2.1 Introduction of parameters, constants and simple relations

ρ – scattering length density obtained directly from the fit of the neutron reflectivity curve;

L – thickness of the GO film obtained directly from the fit of the neutron reflectivity curve;

d – spacing between GO monolayers in the direction perpendicular to the film surface;

N – number of GO monolayers in the sample film;

$S_0 = 5.246$ Å^2 – area of the carbon hexagon, which assumed to be constant;

b – neutron scattering length (NSL) specific for every isotope (see Table S1);

$B = \sum b_i$ – total NSL of molecules or crystal unit cells consisting of several atoms with corresponding individual b_i (see Table S1);

V – volume of the GO unit cell.

$\rho = B / V$ (1)

$d = L / N$ (2)

$V = d \cdot S_0 = L \cdot S_0 / N$ (3)

2.2 Obtaining of the ground state composition

Experimental values found for the ground state:

$L_0 = 267$ Å

$\rho_0 = 3.57 \cdot 10^{-6}$ Å^2

$d_0 = 8.34$ Å

According to (2) number of layers N = 32

According to (3) $V_0 = 43.75$ Å^3

According to (1) experimentally obtained NSL value of the GO unit cell is $B_0 = 1.562 \cdot 10^{-4}$ Å

Assuming GO formula unit as $C_2O_{0.8}\,H_{0.24}$ it can be found $B= 1.704 \cdot 10^{-4}$ Å which is too high comparing to the experimental B_0. To eliminate this contradiction one has to add in to formula unit of the ground state some elements decreasing B by $0.142 \cdot 10^{-4}$ Å. Choosing from all possibilities (highlighted in Table S1) and eliminated impossible ethanol and hydrogen one conclude that this additional element can be only light water in quantity 0.142 / 0.1675 = 0.85 molecules per GO unit cell.

Thus our ground state can be written as

$C_2O_{0.8}\,H_{0.24} + (H_2O)_{0.85}$

2.3 Qualitative interpretation of the ρ and L variation in terms of type and number of intercalated molecule during vapor exposure.

Experimental data shows that during the vapor exposure both parameters ρ and L change. Obviously it happens because intercalated molecules change *B* and *V* of the GO unit cell.

One can wright again for the ground state

$$\rho_0 = B_0 / V_0 \qquad (4).$$

If some molecules with unknown total NSL B_x are intercalated than GO unit cell transform to a new state with volume V_1 and SLD ρ_1 related as

$$\rho_1 = (B_0 + B_x)/ V_1 \qquad (5).$$

It is easy to see that using Eq-s. (3-5) the unknown additive B_x can be found from four experimentally obtained parameters L_0, L_1, ρ_0 and ρ_1 as

$$B_x = \left(\frac{V_1\rho_1}{V_0\rho_0} - 1\right)b_0 = \left(\frac{L_1\rho_1}{L_0\rho_0} - 1\right)b_0$$

(6).

From obtained in this value B_x and individual NSL B presented in Table S1 one can find exact number *n* of intercalated molecules (atoms etc) as $n = B_x/B$. This answer is trivial and *absolutely decisive* when only one type of the molecules intercalates.

In case of binary mixture it is less obvious. Moreover if both components have the sign of *B* it is almost impossible to distinguish between them. However if sign of *B* is different significant amount of valuable information can be extracted especially if size of the molecules is also different. Therefore for our binary mixtures we used deuterated (heavy) water and ethanol have huge *B* contrast as well as significantly different size – 2 Å and 4 Å respectively.

3. Neutron reflectivity data.

All experimental neutron reflectivity curves together with fits and appropriate model SLD profiles are available on request.