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Electronic Supplementary Information

First-Principles Study of SiC Nanosheet as an Effective Material for Nitrosourea and Carmustine Anti-Cancer Drug Delivery

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S1 Structural and Electronic Properties of SiC Nanosheet, Nitrosourea (NU), Carmustine (BCNU)

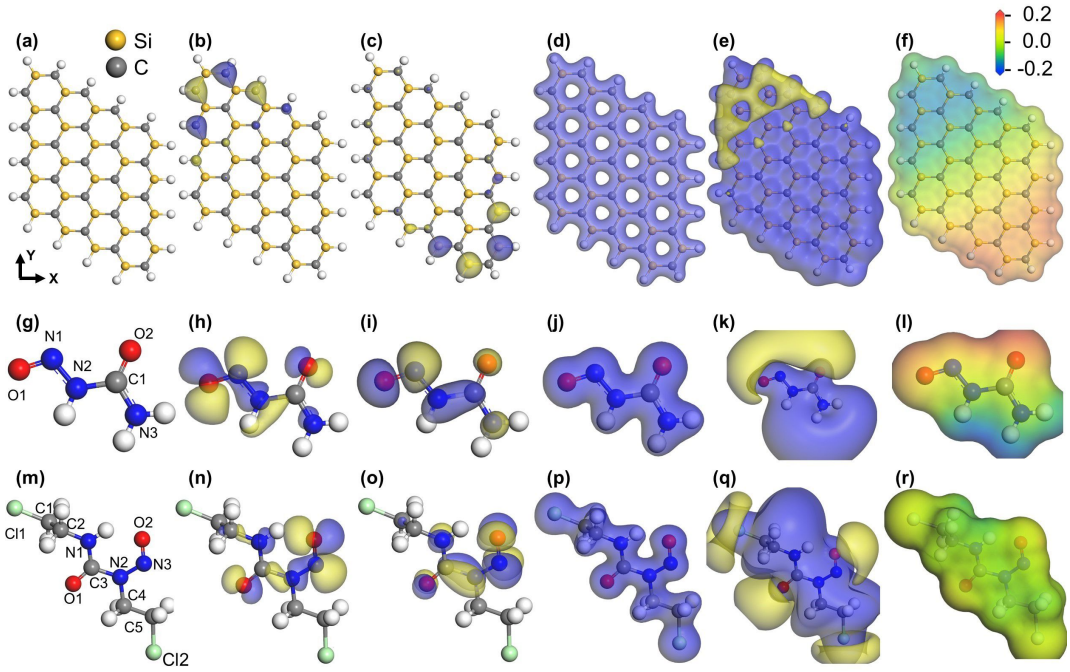

Figure S1: Optimized structure, HOMO (isovalue = 0.03 a.u.), LUMO (isovalue = 0.03 a.u.), electron density (isovalue = 0.3 a.u.), molecular electrostatic potential (isovalue = 0.03 a.u.) and COSMO (isovalue = 0.0 a.u.) isosurfaces of SiC nanosheet ((a)-(f)), Nitrosourea (NU) ((g)-(l)) and Carmustine (BCNU) ((m)-(r)) drug molecule.

We optimized the geometries of isolated SiC nanosheet, NU, and BCNU drug molecules both in water and gas phases. The optimized geometries along with HOMO, LUMO, ED, MEP, and COSMO isosurfaces of SiC nanosheet are shown in Figs. S1(a)-(f). The SiC nanosheet of our study was comprised of 16 hexagonal rings with 9 (Si-H) bonds, 9 (C-H) bonds, and 63 (Si–C) bonds. The computed Si-H and C-H bond distances were 1.485 Å and 1.095 Å, respectively, while Si-C bond distances ranged from 1.774–1.813 Å, showing good consistency with values reported in the existing literature.[1]

The molecular structure of the nitrosourea (NU) drug is comprised of one carbon atom (C1), two oxygen atoms (O1, O2), and three nitrogen atoms (N1, N2, N3). The geometry-optimized structure of the drug molecule is presented in Fig. S1(g), in which we observed

bond lengths of 1.362 Å, 1.428 Å, and 1.371 Å for the N1-N2, N2-C1, and C1-N3 bonds, respectively. The bond angles of N1-N2-C1 and N2-C1-N3 were calculated to be 120.8° and 111.8°, respectively. These values agree with those found in literature.[2,3] In Figs.S1(h)-(l), HOMO, LUMO, ED, ESP, and COSMO plots of NU drug molecules are presented. We found the HOMO level of the NU drug primarily centered around the O1–N1 bond and N1-N2 bond at an energy of – 5.784 eV whereas the LUMO level at – 3.29 eV is largely contributed to by the N2-C1 bond. This resulted in a HOMO-LUMO gap (E_g) of approximately 2.49 eV for the drug molecule. The ED map reveals how the electrons are distributed in the drug molecule. The ESP map demonstrates the drug molecule's positive and negative charge region, indicated in blue and yellow, respectively. As shown in Fig. S1(k), the ESP isosurface of the NU drug highlights the accumulation of positive charge surrounding the C, N, and H atoms and negative charge near the O atom. High electronegativity of oxygen results in the high reactivity of O atom sites. The COSMO surface of NU, as shown in Fig. S1(l), revealed that the highly electronegative oxygen atoms act as hydrogen bond acceptors (HBA), indicated by the color red.

The carmustine (BCNU) drug molecule contains two oxygen atoms (O1, O2), three nitrogen atoms (N1-N3), two chlorine atoms (Cl1, Cl2), and five carbon atoms (C1-C5). The geometry-optimized BCNU drug is shown in Fig. S1(m), where we observed bond lengths of 1.459 Å, 1.353 Å, 1.466 Å, 1.353 Å, and 1.479 Å for C2-N1, N1-C3, C3-N2, N2-N3, and N2-C4 bonds, respectively. The bond angles of C2-N1-C3, N1-C3-N2, C3-N2-N3, N3-N2-C4, and C3-N2-C4 were 119.9°, 115.2°, 130.1° and 115.1°, respectively, which are in excellent agreement with existing literature on Carmustine.[4] Moreover, the HOMO, LUMO, ED, ESP, and COSMO isosurface maps of BCNU are demonstrated in Figs. S1(m)-(r). At – 6.137 eV, the HOMO of the BCNU drug was primarily contributed to by the O2–N3 and N3-N2 bonds, and the LUMO was largely comprised of C3-N2 and N3-N2 bonds at – 3.574 eV, giving rise to a band gap (E_g) of about 2.563 eV, similar to that of NU. In Fig. S1(q), the ESP isosurface indicates small zones of negative charge around Cl1, Cl2, O1, and O2

due to their high electronegativity. The COSMO surface shown in Fig. S1(r) highlights the highly electronegative chlorine and oxygen atoms by the slightly warmer coloration centered around them.

References

(1) Kadhim, M. M.; Taban, T. Z.; Abdullaha, S. A.; Rheima, A. M.; Hachim, S. K.; Abed, A. M. Potential use of silicon carbide monolayer as an anode in rechargeable Mg-ion batteries. *Journal of Physics and Chemistry of Solids* **2023**, *177*, 111270.

(2) Sapse, A. M.; Allen, E. B.; Fugler-Domenico, L. Ab Initio Studies of the Decomposition of Nitrosourea in the Presence of Cations. *Cancer Investigation* **1987**, *5*, 559–566, PMID: 2832037.

(3) Cui, Y. S.; Zhao, L. J.; Liu, Y. D.; Zhong, R. G. Theoretical Study on Internal Rotation of Nitrosoureas and Toxicological Analysis. *Journal of Theoretical and Computational Chemistry* **2007**, *06*, 245–253.

(4) Hadidi, S.; Shiri, F.; Norouzibazaz, M. A DFT study of the degradation mechanism of anticancer drug carmustine in an aqueous medium. *Structural Chemistry* **2019**, *30*, 1315–1321.