Efficient and Eco-friendly route for the Solvent Free Synthesis of 4-Alkoxy-5H-chromen[2,3-d]pyrimidines Using Phosphonic Acid Functionalized KIT-6 Confined Ionic Liquid as Recoverable Catalyst

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- **General information**

All chemicals are analytical-grade reagents and used without further purification and all solvents were purified and dried using standard procedures. ^1H and ^{13}C NMR was obtained on a 400 or 500 MHz Bruker Avance instrument using CDCl_3 as solvent and TMS as internal standard. TLC was conducted on silica gel 250 m, F254 plates. Melting points were measured on a Kofler hot stage apparatus and uncorrected. The powder XRD spectrum was recorded at r.t. with a Philips 1710 diffractometer using $\text{Cu K}\alpha$ ($\lambda = 1.54056 \text{ \AA}$) in Bragg–Brentano geometry (θ – 2θ). The morphologies of the products were observed using SEM (Hitachi S-4800 II, Japan) equipped with energy dispersive X-ray spectroscopy. The IR spectra were taken using Nicolet FT-IR Magna 550 spectrographs (KBr disks). The surface areas were calculated by BET method and the pore size distributions were calculated from the adsorption branch of the isotherms using BJH method.

- ***Preparation of the catalyst***

- ***Synthesis of amine functionalized mesoporous silica KIT-6, [n-PrNH₂-KIT-6]***

The amine functionalized mesoporous silica KIT-6 ([n-PrNH₂-KIT-6]), was prepared according to the procedure reported in literature.^[1] Typically, 4.0 g of *n*-BuOH was added to 4.0 g of P123 dissolved in 144 g of DI water and 7.9 g of HCl (35 wt. %). After 1 h stirring at 35 °C, 8.6 g of TEOS was added to the clear solution, and the mixture was left under vigorous stirring at the same temperature for 24 h. Then the reaction temperature was raised to 100 °C and aged under static condition for 24 h. The white product was filtered off without washing and dried under vacuum at 100 °C overnight. Template material was removed by a brief EtOH/HCl washing after calcination at 550 °C for 6 h.

Then, the as-synthesized KIT-6 (1g) and aminopropyl trimethoxysilane (APTMS) (4 mmol) were suspended in 30 mL toluene and heated at reflux overnight. Finally, the suspension was filtered off and washed several times with acetone, followed by drying under vacuum exhaustively. This support was referred to as aminopropyl-functionalized mesoporous silica [n-PrNH₂-KIT-6].

- *Synthesis of phosphonic acid functionalized Ia3d mesoporous silica nanoparticles*

[Phosphonic acid@KIT-6]

[n-PrNH₂-KIT-6] (0.2 mol amine group), crystalline phosphorous acid (0.4 mol), and conc. HCl (0.6 mol) were dissolved in 200 mL water, and the mixture was refluxed in a three-necked flask fitted with thermometer, condenser, and dropping funnel. During of 1 h, 60 mL of a 40% (w/v) aqueous formaldehyde solution was added drop-wise, and the reaction was refluxed for 1 hour. The solvent was evaporated, and the concentrated residue was neutralized with conc. ammonia solution. Finally, the obtained solid was filtered off and washed with hot dry MeOH for 12 h in a continuous extraction apparatus (Soxhlet) and then dried at 100 °C overnight to furnish the corresponding surface bound phosphonic acid [Phosphonic acid@KIT-6].

- *Synthesis of phosphonic acid functionalized Ia3d mesoporous silica nanoparticles confined ionic liquid, IL@[Phosphonic acid@KIT-6]*

[Phosphonic acid@KIT-6] (1 g) was added to a solution of 1-butyl-3-methylimidazolium tetrafluoroborate (3 mL) in dry acetone (50 mL). The reaction mixture was stirred at room temperature overnight. After stirring, acetone was removed under reduced pressure. The

resulting solid was then dried at 70 °C under vacuum for 24 h, to achieve the designed catalyst IL@[KIT-6-Phosphonic acid].

- ***General procedure for the synthesis of 4-methoxy-5H-chromen[2,3-d]pyrimidine using IL@[KIT-6-Phosphonic acid] as catalyst***

IL@[Phosphonic acid@KIT-6] catalyst (2 mol %) was added gently to a magnetically stirred mixture of iminocoumarine **3(a-c)** (1 mmol), salicylaldehyde **1(a-c)** (1 mmol), and alcohol **4(a-e)** (1.5 mmol). The reaction mixture was stirred for 40 min at room temperature. The progress of the reaction was monitored by TLC. When the spot for the product ($R_f \approx 0.8$ in silica gel, EtOAc: n-hexane (1:5) was visible, the catalyst was separated by filtration or centrifuging, and the final product was purified by column chromatography using EtOAc: n-hexane 1: 6 as eluent and recrystallized from EtOH.

- ***The recovery of IL@[Phosphonic acid@KIT-6]***

After the completion of the aforementioned reaction over the IL@[KIT-6-Phosphonic acid] catalyst, the resulting mixture was filtered and washed with EtOH and EtOAc thoroughly. The separated catalyst was then successfully recovered and reused 5 times under the same reaction condition.

- *The Characterization of the Nanocatalyst*
- *X-Ray powder diffraction*

The appeared reflections at $2\theta = 0.87^\circ$, 0.97° , and 1.7° are indicating 211, 220, and 332 reflections, respectively (**Figure S1**), which clearly can be indexed to the reflections of the expected 3D cubic symmetry of the space group *Ia3d*. Except for the decrease in peak intensity, the positions of peaks remained virtually fixed, and no significant changes were observed during the post modification process. These confirm that the functionalization mainly accomplished inside of the pores and the retention of the mesoporous structure of KIT-6, after the functionalization.

Figure S1. The XRD patterns of KIT-6 and [Phosphonic acid@KIT-6]

- **FT-IR spectroscopy**

The presence of the aminopropyl-group and phosphonic acid on the mesopores surface was confirmed by FT-IR spectroscopy (**Figure S2**). The presence of the phosphonic acid moiety corresponds to the absorption bands at 1019 and 948 cm^{-1} for (P-OH) and (P-O) groups, respectively. Also the absorption bands of (P=O) and (Si-O-Si) have overlapped and appeared at $\sim 1030\text{-}1173\text{ cm}^{-1}$.^[2, 3] The very broad band extending from 3300 cm^{-1} to as low as 2500 cm^{-1} is likely to be due to the absorption characteristic of the phosphonic acid hydroxyl group (OH). The N-H stretching band at 3500 cm^{-1} decreased, which reflected the successful amine conversion by the Mannich reaction.

Figure S2. FTIR Spectrum of MSNs

- **Thermal gravimetric analysis (TGA)**

Figure S3 shows the TGA profiles obtained for KIT-6 and [Phosphonic acid@KIT-6]. The loading of aminopropyl functional onto KIT-6 was conclude about 14% (2.4 mmol.g^{-1}) which confirmed by acid-base back titration. Also in the case of [Phosphonic acid@KIT-6], the TGA analysis has showed the weight loss about 44% in the second step, which is attributed to the removal of organo-phosphonic acid. Therefore, the loading of the organo-phosphorous moiety onto the surface of KIT-6 is about 3.5 mmol.g^{-1} . Applying acid–base titration method, ^[3] the exact amount of phosphonic acid groups and ion-exchange capacity of [Phosphonic acid@KIT-6] was 3.6 mmol.g^{-1} .

Figure S3. TGA diagrams of MSNs

- *N₂ sorption isotherm experiment*

The N₂ sorption isotherm experiment has revealed a high pore volume and surface area for the synthesized KIT-6. The calculated multiple-point BET (Barrett–Joyner–Halenda) surface area, Barrett–Joyner–Halenda (BJH) average pore size distributions and primary pore volume for KIT-6 were 821.41 m².g⁻¹, 7.2 nm, and 1.51 cm³.g⁻¹, respectively (**Figure S4 and Table S1**). In the case of IL@[Phosphonic acid@KIT-6], the decrease in the BET surface area and pore volume and the loss of the capillary condensation- evaporation N₂ isotherm demonstrate that the filling of ionic liquid into the meso- channels of [Phosphonic acid@KIT-6] has successfully been occurred.

Figure S4. The N₂ adsorption-desorption isotherm and BJH analysis of synthesized solids

Table S1. Typical results obtained from BET and BJH before and after functionalization

Mesoporous material	S_{BET} (m ² g ⁻¹)	V_{total} (cm ³ g ⁻¹)	Pore diameter (nm)
KIT-6	821.41	1.51	7.2
[Phosphonic acid@KIT-6]	575.6	0.485	5.7
IL@[Phosphonic acid@KIT-6]	255.3	0.108	3.9

- **^1H NMR and ^{13}C NMR data of the products**
- ***2-(4-Methoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol (5a)***: Colorless needle crystals; mp 198-200 °C (lit. mp 200 °C)^[4]; ^1H NMR (CDCl_3 , 500 MHz): δ_{H} = 3.97 (s, 2H, CH_2), 4.18 (s, 3H, OCH_3), 6.97 (dt, J = 7.5, 1.0 Hz, 1H), 7.04 (dd, J = 8.0 Hz, 1H), 7.15 (dt, J = 7.5 Hz, 1.0 Hz, 1H), 7.19 (d, J = 7.5 Hz, 1H), 7.23-7.29 (m, 2H), 7.41 (dt, J = 8.0, 1.6 Hz, 1H), 8.46 (dd, J = 8.0, 1.6 Hz, 1H), 12.78 (br s, 1H, OH); ^{13}C NMR (CDCl_3 , 125 MHz): δ_{C} = 21.30, 54.22, 94.41, 116.84, 117.31, 117.86, 118.43, 124.16, 127.76, 128.70, 128.75, 132.62, 136.81, 149.88, 159.78, 161.70, 167.14; Anal. Calcd for $\text{C}_{18}\text{H}_{14}\text{N}_2\text{O}_3$: C, 70.58; H, 4.61; N, 9.15; Found: C, 70.72; H, 4.90; N, 9.38.
- ***2-(4,9-dimethoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol (5b)***: Colorless needle crystals; mp 200-202 °C (lit. mp 205 °C)^[4]; ^1H NMR (CDCl_3 , 400 MHz): δ_{H} = 3.94 (s, 2H, CH_2), 3.95 (s, 3H, OCH_3), 4.18 (s, 3H, OCH_3), 6.80 (d, J = 7.6 Hz, 1H), 6.85 (d, J = 7.6 Hz, 1H), 6.94 (dt, J = 8.0, 0.8 Hz, 1H), 7.01 (dd, J = 8.0, 0.8 Hz, 1H), 7.06 (t, J = 7.6 Hz, 1H), 7.39 (dt, J = 8.0, 1.6 Hz, 1H), 8.48 (dd, J = 8.0, 1.6 Hz, 1H), 12.77 (br s, 1H, OH); ^{13}C NMR (CDCl_3 , 125 MHz): δ_{C} = 21.49, 54.23, 55.58, 94.26, 110.06, 117.27, 118.02, 118.34, 119.47, 120.02, 123.85, 128.97, 132.53, 139.46, 147.76, 159.66, 161.75, 162.66, 167.37; Anal. Calcd for $\text{C}_{19}\text{H}_{16}\text{N}_2\text{O}_4$: C, 67.85; H, 4.79; N, 8.33; Found: C, 68.15; H, 4.99; N, 8.12.
- ***2-(7-bromo-4-methoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol (5c)***: Colorless needle crystals; mp 240-242 °C (lit. mp 245 °C)^[4]; ^1H NMR (CDCl_3 , 500 MHz): δ_{H} = 3.92 (s, 2H, CH_2), 4.18 (s, 3H, OCH_3), 6.95 (dt, J = 8.0, 0.8 Hz, 1H), 7.02 (d, J = 8.0 Hz, 1H), 7.05 (d, J = 8.0 Hz, 1H), 7.36-7.41 (m, 3H), 8.42 (dd, J = 8.0, 1.0 Hz, 1H), 12.70 (br s, 1H, OH); ^{13}C NMR (CDCl_3 , 125 MHz): δ_{C} = 21.69, 54.97, 94.55, 117.00, 117.90,

118.34, 119.05, 119.11, 121.30, 129.19, 131.45, 132.03, 133.37, 134.01, 149.75, 160.23, 161.85, 167.73; Anal. Calcd for C₁₈H₁₃BrN₂O₃: C, 56.12; H, 3.40; N, 7.27; Found: C, 56.25; H, 3.18; N, 7.50.

- **2-(4-ethoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol (5d):** Colorless needle crystals; mp 197-199 °C (lit. mp 200 °C)^[4]; ¹H NMR (CDCl₃, 400 MHz): δ_{H} = 1.50 (t, J = 7.0 Hz, 3H, CH₃), 3.93 (s, 2H, CH₂), 4.57 (q, J = 7.0 Hz, 2H, OCH₂), 6.94 (t, J = 7.5, 1.0 Hz, 1H), 7.01 (d, J = 8.0 Hz, 1H), 7.11 (t, J = 8.0 Hz, 1H), 7.15 (d, J = 8.0 Hz, 1H), 7.20-7.26 (m, 2H), 7.38 (t, J = 8.0 Hz, 1H), 8.40 (d, J = 8.0 Hz, 1H), 12.79 (br s, 1H, OH); ¹³C NMR (CDCl₃, 125 MHz): δ_{C} = 9.65, 21.38, 64.09, 94.39, 116.23, 117.50, 117.87, 118.48, 118.73, 122.45, 123.96, 127.59, 128.57, 128.71, 133.07, 159.68, 161.53, 161.80, 166.95; Anal. Calcd for C₁₉H₁₆N₂O₃: C, 71.24; H, 5.03; N, 8.74; Found: C, 71.45; H, 5.20; N, 8.51.
- **2-(4-Ethoxy-9-methoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol (5e):** Colorless needle crystals; mp 198-200 °C (lit. mp 200 °C)^[4]; ¹H NMR (CDCl₃, 400 MHz): δ_{H} = 1.52 (t, J = 9.0 Hz, 3H, CH₃), 3.94 (s, 2H, CH₂), 3.95 (s, 3H, OCH₃), 4.59 (q, J = 9.0 Hz, 2H, OCH₂), 6.80 (d, J = 8.0 Hz, 1H), 6.85 (d, J = 8.0 Hz, 1H), 6.94 (dt, J = 7.8, 1.2 Hz, 1H), 7.02 (dd, J = 7.8, 1.2 Hz, 1H), 7.06 (t, J = 8.0 Hz, 1H), 7.38 (dt, J = 7.8, 1.6 Hz, 1H), 8.46 (dd, J = 7.8, 1.6 Hz, 1H), 12.81 (br s, 1H, OH); ¹³C NMR (CDCl₃, 125 MHz): δ_{C} = 14.41, 21.73, 59.03, 63.64, 94.71, 110.54, 117.73, 118.54, 118.82, 120.01, 120.51, 124.82, 129.60, 132.66, 140.06, 148.42, 159.21, 160.27, 162.06, 167.29; Anal. Calcd for C₂₀H₁₈N₂O₄: C, 68.56; H, 5.18; N, 8.00; Found: C, 68.70; H, 5.32; N, 7.78.
- **2-(7-Bromo-4-ethoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol (5f):** Colorless needle crystals; mp 216-219 °C (lit. mp 220 °C)^[4]; ¹H NMR (CDCl₃, 500 MHz): δ_{H} = 1.52 (t, J =

6.5 Hz, 3H, CH₃), 3.90 (s, 2H, CH₂), 4.58 (q, 2H, J = 6.5 Hz, OCH₂), 6.93 (t, J = 8.0 Hz, 1H), 7.01 (d, J = 7.5 Hz, 1H), 7.04 (d, J = 8.0 Hz, 1H), 7.35-7.40 (m, 3H), 8.39 (d, J = 8.0 Hz, 1H), 12.70 (br s, 1H, OH); ¹³C NMR (CDCl₃, 125 MHz): δ_C = 14.49, 21.67, 63.90, 94.24, 117.09, 117.87, 118.71, 118.99, 119.08, 120.01, 122.41, 126.52, 129.28, 131.30, 131.93, 133.37, 149.50, 160.48, 162.58; Anal. Calcd for C₁₉H₁₅BrN₂O₃: C, 57.16; H, 3.79; N, 7.02; Found: C, 57.36; H, 3.39; N, 7.36.

- **2-(4-Propoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol(5g):** Colorless needle crystals; mp 147-149 °C (lit. mp 150 °C)^[4]; ¹H NMR (CDCl₃, 400 MHz): δ_H = 1.11 (t, J = 7.4 Hz, 3H, CH₃), 1.92 (m, 2H, CH₂), 3.95 (s, 2H, CH₂), 4.48 (q, J = 6.8 Hz, 2H, OCH₂), 6.95 (dt, J = 8.0, 1.0 Hz, 1H), 7.03 (dd, J = 8.0, 0.8 Hz, 1H), 7.13 (dt, J = 8.0, 0.8 Hz, 1H), 7.17 (dd, J = 8.0, 1.0 Hz, 1H), 7.22-7.27 (m, 2H), 7.38 (dt, J = 8.0, 1.4 Hz, 1H), 8.42 (dd, J = 8.0, 1.4 Hz, 1H), 12.83 (br s, 1H, OH); ¹³C NMR (CDCl₃, 125 MHz): δ_C = 10.48, 21.80, 22.19, 69.45, 94.91, 117.34, 117.76, 118.46, 118.91, 119.07, 124.63, 128.25, 129.20, 133.05, 151.37, 160.22, 162.18, 163.25, 167.34; Anal. Calcd for C₂₀H₁₈N₂O₃: C, 71.84; H, 5.43; N, 8.38; Found: C, 72.05; H, 5.62; N, 8.12.
- **2-(4-Butoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol (5h):** Colorless needle crystals; mp 142-144 °C (lit. mp 145 °C)^[4]; ¹H NMR (CDCl₃, 400 MHz): δ_H = 1.04 (t, 3H, J = 9.5 Hz, CH₃), 1.51-1.61 (m, 2H, CH₂), 1.84-1.91 (m, 2H, CH₂), 3.95 (s, 2H, CH₂), 4.53 (t, J = 6.4 Hz, 2H, OCH₂), 6.95 (dt, J = 8.0, 1.2 Hz, 1H), 7.02 (dd, J = 8.0, 0.8 Hz, 1H), 7.14 (dt, J = 8.0, 0.8 Hz, 1H), 7.17 (d, J = 8.0 Hz, 1H), 7.23-7.27 (m, 2H), 7.39 (dt, J = 8.0, 1.6 Hz, 1H), 8.43 (dd, J = 8.0, 1.6 Hz, 1H), 12.84 (br s, 1H, OH); ¹³C NMR (CDCl₃, 125 MHz): δ_C = 13.57, 19.01, 21.43, 30.41, 56.04, 67.87, 94.50, 110.42, 117.31, 118.06, 118.48, 118.65, 124.21, 127.80, 128.44, 128.78, 132.65, 149.93, 159.79, 161.70, 166.45,

168.73; Anal. Calcd for C₂₁H₂₀N₂O₃: C, 72.40; H, 5.79; N, 8.04; Found: C, 72.61; H, 5.44; N, 8.27.

- **2-(4-Butoxy-9-methoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol (5i):** Colorless needle crystals; mp 151-153 °C (lit. mp 156 °C)^[4]; ¹H NMR (CDCl₃, 400 MHz): δ_H = 1.04 (t, 3H, *J* = 7.5 Hz, CH₃), 1.51-1.60 (m, 2H, CH₂), 1.84-1.91 (m, 2H, CH₂), 3.94 (s, 2H, CH₂), 3.95 (s, 3H, OCH₃), 4.53 (t, 2H, *J* = 6.4 Hz OCH₂), 6.81 (d, *J* = 8.0 Hz, 1H), 6.85 (d, *J* = 8.0 Hz, 1H, 1CH), 6.94 (t, *J* = 7.8 Hz, 1H), 7.01 (d, *J* = 7.8 Hz, 1H), 7.08 (t, *J* = 7.8 Hz, 1H), 7.38 (dt, *J* = 7.8, 1.6 Hz, 1H), 8.47 (dd, *J* = 8.0, 1.6 Hz, 1H), 12.82 (br s, 1H, OH); ¹³C NMR (CDCl₃, 125 MHz): δ_C = 13.92, 19.29, 22.01, 30.79, 56.10, 67.59, 94.77, 110.49, 117.80, 118.56, 118.91, 120.09, 120.66, 124.48, 129.50, 132.09, 140.11, 148.39, 160.20, 162.24, 163.12, 167.68; Anal. Calcd for C₂₂H₂₂N₂O₄: C, 69.83; H, 5.86; N, 7.40; Found: C, 69.51; H, 6.01; N, 7.59.
- **2-(7-Bromo-4-butoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol (5j):** Colorless needle crystals; mp 215-217 °C (lit. mp 220 °C)^[4]; ¹H NMR (CDCl₃, 500 MHz): δ_H = 1.04 (t, 3H, *J* = 7.40 Hz, CH₃), 1.51-1.57 (m, 2H, CH₂), 1.83-1.89 (m, 2H), 3.90 (s, 2H, CH₂), 4.51 (t, 2H, *J* = 6.5 Hz, OCH₂), 6.94 (dt, *J* = 7.8 Hz, 1.0 Hz, 1H), 7.01 (d, *J* = 7.8 Hz, 1H), 7.04 (d, *J* = 8.0 Hz, 1H), 7.35- 7.39 (m, 3H), 8.39 (d, *J* = 7.8 Hz, 1H), 12.70 (br s, 1H, OH); ¹³C NMR (CDCl₃, 125 MHz): δ_C = 13.94, 19.32, 22.01, 30.92, 67.66, 94.31, 117.02, 117.90, 118.12, 118.99, 119.13, 121.41, 129.28, 131.33, 132.08, 133.27, 149.56, 159.89, 162.52, 162.95, 167.67; Anal. Calcd for C₂₁H₁₉BrN₂O₃: C, 59.03; H, 4.48; N, 6.56; Found: C, 59.25; H, 4.23; N, 6.80.
- **2-(4-isobutoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol (5k):** Colorless needle crystals; mp 237-239 °C (lit. mp 240 °C)^[4]; ¹H NMR (CDCl₃, 400 MHz): δ_H = 1.11 (d, *J* =

6.8 Hz, 6H, 2CH₃), 2.22(m, H, CH), 3.90 (s, 2H, CH₂), 4.30 (d, 2H, *J* = 6.4 Hz, OCH₂), 6.91 (dt, *J* = 8.0, 1.2 Hz, 1H), 6.98 (dd, *J* = 8.0, 0.8 Hz, 1H), 7.06-7.11 (m, 2H), 7.16-7.21 (m, 2H), 7.35 (dt, *J* = 8.0, 2.0 Hz, 1H), 8.36 (dd, *J* = 8.0, 2.0 Hz, 1H), 12.80 (br s, 1H, OH); Anal. Calcd for C₂₁H₂₀N₂O₃: C, 72.40; H, 5.79; N, 8.04; Found: C, 72.10; H, 5.46; N, 8.25.

- **4-bromo-2-(4-methoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol (5l):** Colorless needle crystals; mp 210-212 °C; ¹H NMR (CDCl₃, 400 MHz): δ_H = 3.96 (s, 2H, CH₂), 4.17(s, 3H, OCH₃), 4.22 (s, 3H, OCH₃), 6.76 (d, *J* = 8.0, 1H), 6.92 (d, *J* = 8.0, 1H), 7.10-7.41 (m, 2H), 8.45 (s, 1H), 12.83 (br s, 1H, OH); ¹³C NMR (CDCl₃, 125 MHz): δ_C = 21.2, 57.0, 94.5, 114.2, 117.8, 118.4, 119.7, 122.4, 123.9, 127.5, 131.2, 132.8, 133.4, 149.9, 153.0, 160.2, 161.8, 167.2; Anal. Calcd for C₁₈H₁₃BrN₂O₃: C, 56.12; H, 3.40; N, 7.27; Found: C, 56.35; H, 3.79; N, 7.04.
- **4-bromo-2-(7-bromo-4-methoxy-5H-chromeno[2,3-d]pyrimidin-2-yl)phenol (5m):** Colorless needle crystals; mp 235-237 °C; ¹H NMR (CDCl₃, 400 MHz): δ_H = 3.97 (s, 2H, CH₂), 4.18 (s, 3H, OCH₃), 6.81 (d, *J* = 8.5 Hz, 1H), 6.97 (d, *J* = 8.5, 1H), 7.26-7.39 (m, 8.42 (s, 1H), 12.58 (br s, 1H, OH); ¹³C NMR (CDCl₃, 125 MHz): δ_C = 21.2, 56.1, 57.5, 94.9, 116.2, 117.8, 118.4, 119.7, 121.4, 123.9, 127.6, 132.2, 133.8, 134.7, 149.8, 154.7, 160.2, 161.5, 168.2; Anal. Calcd for C₁₈H₁₂Br₂N₂O₃: C, 46.58; H, 2.61; N, 6.04; Found: C, 46.73; H, 2.53; N, 6.22.

References

- [1] (a) Falahati, M.; Ma'mani, L.; Saboury, A. A.; Shafiee, A.; Foroumadi, A.; Badiei A. R. *Biochim. Biophys. Acta*, **2011**, *1814*, 1195–1202; (b) Kleitz, F.; Choi, S. H.; Ryoo, R. *Chem. Commun.*, **2003**, *17*, 2136-2137.
- [2] Punyacharoennon, P.; Charuchinda, S.; Srikulkit, K. *J. Appl. Polym. Sci.*, **2008**, *110*, 3336-3347.
- [3] Li, S.; Zhou, Z.; Abernathy, H.; Liu, M.; Li, W.; Ukai, J.; Hase, K.; Nakanishi, M. *J. Mater. Chem.*, **2006**, *16*, 858-864.
- [4] Zonouzi, A.; Hosseinzadeh, F.; Karimi, N.; Mirzazadeh R.; Ng, S. W. *ACS Comb. Sci.*, **2013**, *15*, 240-246.