Electronic Supplementary Information

Mechanistic insight into an azo-radical promoted dehydrogenation of heteroarene towards N-heterocycles.

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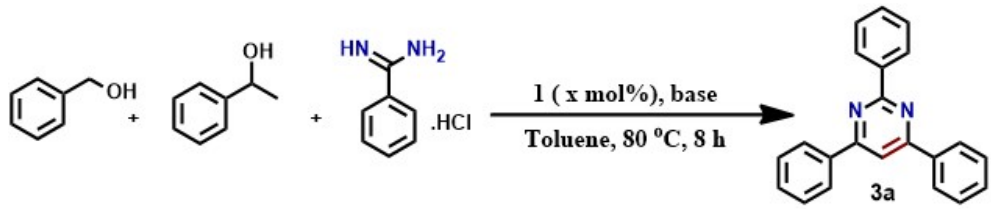
Table of Contents

1. Optimization table

Table S1: Optimization of reaction conditions for pyrimidine synthesis

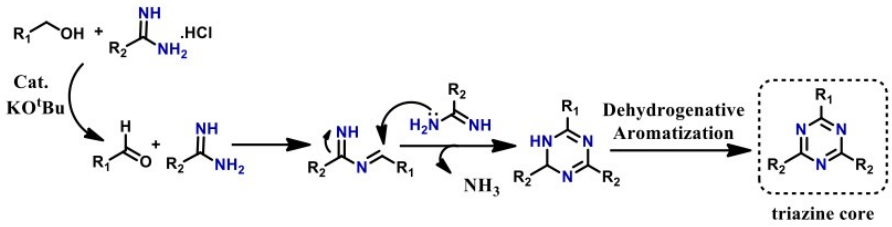


			Yield (%)
Entry	**Catalyst**	**Base**	**3a**
1	-	KO^tBu	15
2	**1**	KO^tBu (0.1eq)	33
3	**1**	KO^tBu (0.25eq)	66
4	**1**	KO^tBu (0.5eq)	90
5	**1** (2.5 mol%)	KO^tBu	61
6	**1** (7 mol%)	KO^tBu	91
7	**1** (5 mol%)	KOH	35
8	**1** (5 mol%)	K_2CO_3	n.r
9[a]	**1** (5 mol%)	KO^tBu	60
10[b]	**1** (5 mol%)	KO^tBu	82
11[c]	**1** (5 mol%)	KO^tBu	19
12[d]	**1** (5 mol%)	KO^tBu	60
13[e]	**1** (5 mol%)	KO^tBu	45
14[f]	**1** (5 mol%)	KO^tBu	92
15	**1**	-	n.r

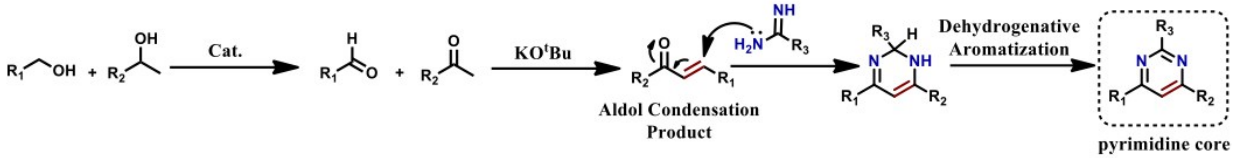
Reaction condition: **1 (5 mol%),** benzyl alcohol (1 mmol), 1-phenyl ethanol (1.25 mmol), benzamidine (1 mmol), base (0.5 mmol), toluene (2 mL), 80 °C, O_2 balloon, 8 h (isolated yield). [a]Reaction temperature 80 °C, without O_2 balloon, [b]Reaction temperature 100 °C, without O_2 balloon, [c]inert atmostphere, [d]oxygenated toluene as solvent, [e]Reaction time: 6 h, [f]Reaction time: 12 h.

2. Control experiments

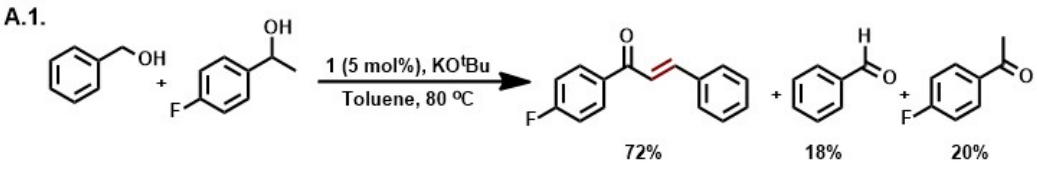
Scheme S1. Plausible pathway for 1,3,5 -triazine formation



Scheme S2. Plausible pathway for pyrimidine formation



2.A. Tracking of intermediates and isolation



In a 5 mL vial, benzyl alcohol (1 mmol), 1-(4-fluorophenyl)ethanol (1 mmol), KO^{t}Bu (0.5 mmol), **1** (5 mol%) were added followed by 2 mL toluene. The reaction mixture was stirred at 80 °C for 5 h. Aldol condensation product (chalcone) was observed in 72% yield.

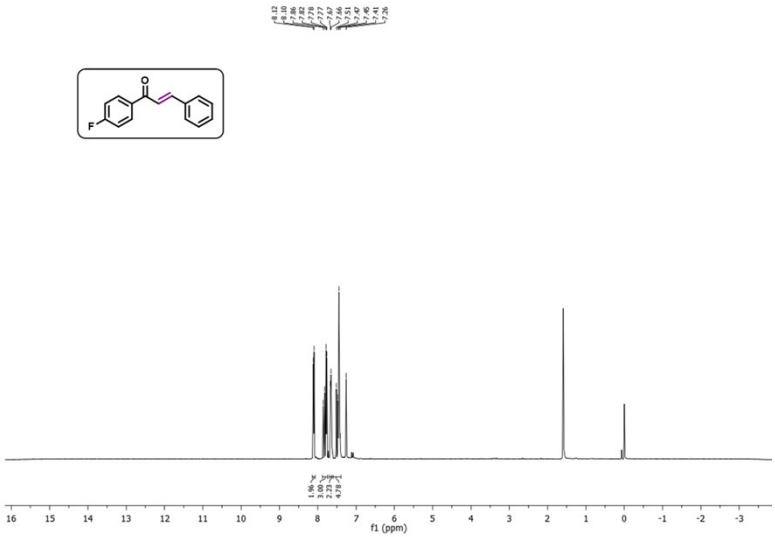
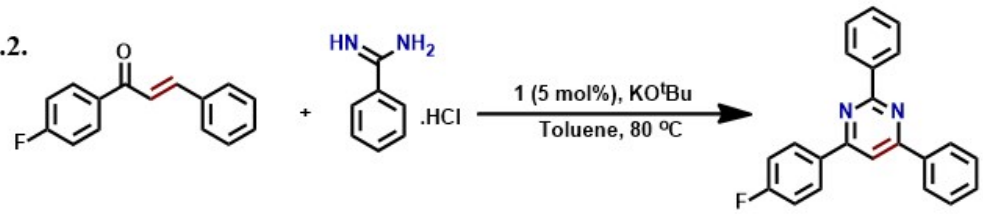


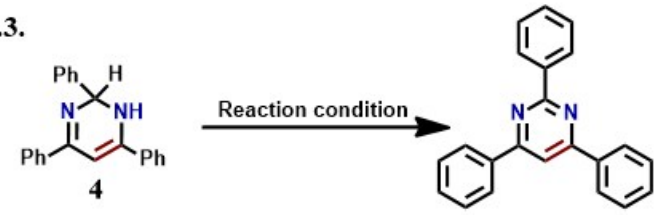
Figure S1. ^{1}H NMR spectrum (400 MHz) of 1-(4-fluorophenyl)-3-phenylprop-2-en-1-one in $CDCl_3$.

A.2.



In a 5 mL vial, pre-synthesized aldol condensation product chalcone (1 mmol), benzamidine (1 mmol), KO^{t}Bu (0.5 mmol), **1** (5 mol%) were added followed by 2 mL toluene. The reaction mixture was stirred at 80 °C for 5 h with O_2 balloon. 2,4,6-triphenyl-pyrimidine was observed as desired product in 89% yield.

A.3.

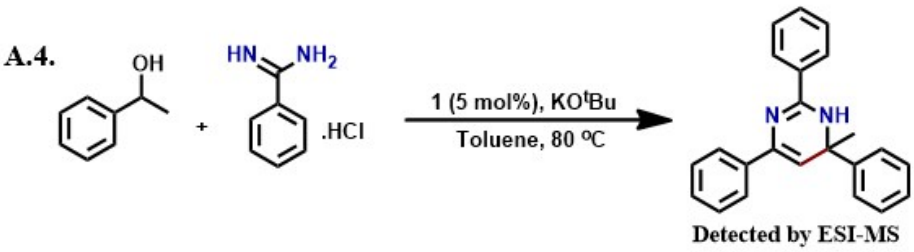


4 (1 mmol), KO^{t}Bu (0.5 mmol), **1** (5 mol%) was taken in 2 mL toluene. The reaction mixture was stirred at 80 °C for 5 h with O_2 balloon. 2,4,6-triphenyl-pyrimidine was isolated in 80% yield, concluding that **4** is the purported intermediate that leads to pyrimidine via dehydrogenative aromatization.

Subsequently, other controls were performed. The observation is given in the following table.

Table S2: Pyrimidine formation under different reaction conditions

S.No	Reaction Condition	(Pyrimidine)Yield (%)
1.	Standard reaction condition	83%
2.	Without catalyst (at 80 °C)	18%
3.	Without base	0%
4.	Inert condition	11%
5.	$NiCl_2$ as catalyst	15%



In a 5 mL vial, 1-phenylethanol (2.25 mmol), benzamidine (1 mmol), KO^{t}Bu (0.5 mmol), **1** (5 mol%) were added followed by 2 mL toluene. The reaction solution was stirred at 80 °C for 8 h with O_2 balloon. Desired product 2-methyl-2,4,6-triphenyl-1,2-dihydropyrimidine was characterised by ESI-MS. ($M+H^+ = 325.1710$).

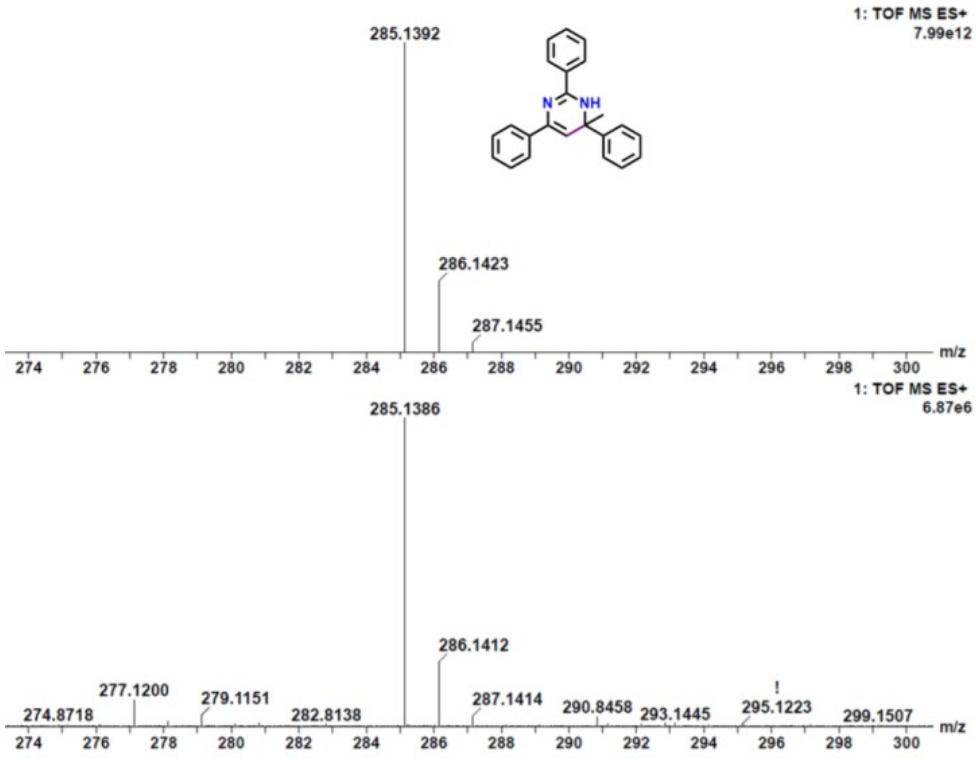


Figure S2. Mass spectrum of 2-methyl-2,4,6-triphenyl-1,2-dihydropyrimidine.

2.B. Radical quenching experiment

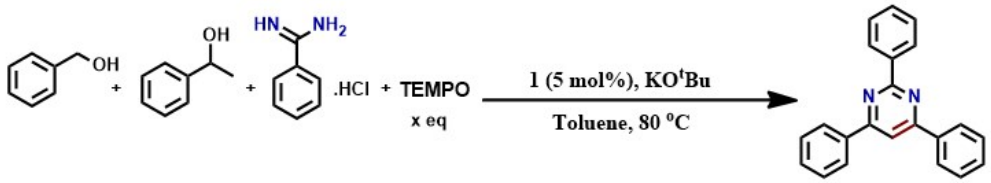
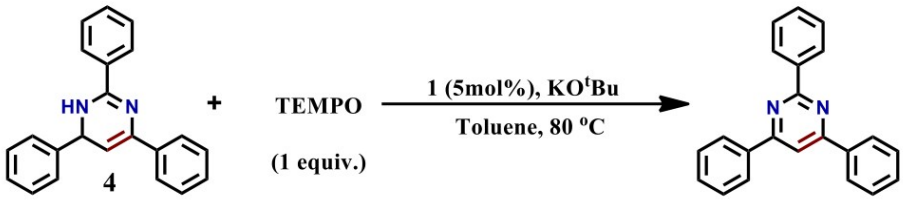


Table S3: Product yield upon varying equivalence of radical quencher

S.No	TEMPO equivalence	Yield (%)
1.	1.0 eq	35%
2.	2.0 eq	18%

Benzyl alcohol (1 mmol), 1-phenylethanol (1.25 mmol), benzamidine hydrochloride (1 mmol), KO^{t}Bu (0.5 mmol), **1** (5 mol%) and varying equivalent of TEMPO, followed by 2 mL toluene were added. The reaction mixture was stirred at 80 °C for 8 h under 1 atm of O_2, kept as a O_2-filled balloon. The pyrimidine product yield decreased with addition of TEMPO.

TEMPO quenching during dehydrogenation of 4



In a 5 mL vial, **4** (1 mmol), KO^{t}Bu (0.5 mmol), **1** (5 mol%), and 1 mmol of TEMPO were added followed by 2 mL toluene. The resulting solution was kept under a balloon filled with O_2. The reaction mixture was stirred for 5 h at 80 °C. The reaction mixture was cooled to room temperature and concentrated *in vacuo*. The desired product 2,4,6-triphenyl-pyrimidine was observed in 5% yield.

2.C. Procedure for the pyrimidinyl radical -TEMPO adduct

In a 5 mL vial, **4** (1 mmol), KO^{t}Bu (0.5 mmol), **1** (5 mol%) were taken in 5 mL toluene. After stirring the reaction mixture for 15 minutes, 0.6 equiv TEMPO (0.6 mmol) was added to the reaction mixture and the solution was kept on stirring at 80 ^{o}C for 5 h. The arrested radical by the formation of TEMPO-adduct was characterised by ESI-MS. (M-H$^+$ = 464.2616).

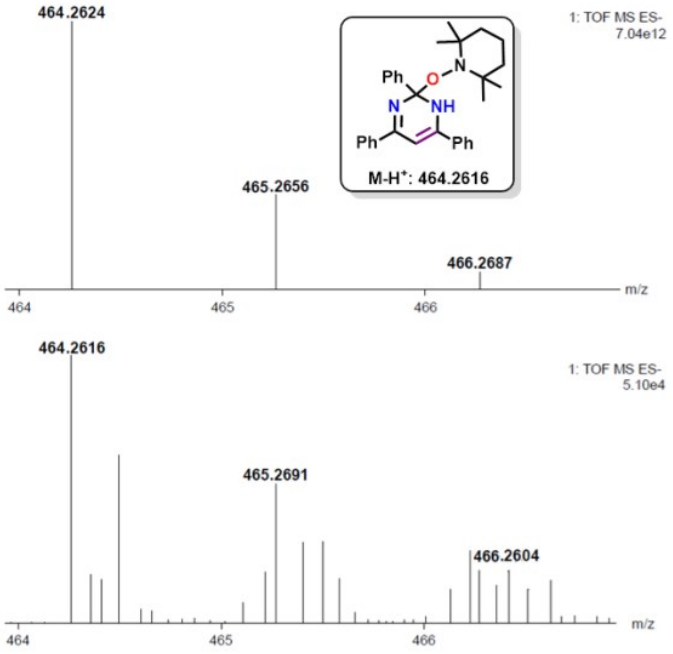


Figure S3. Mass spectrum of pyrimidinyl radical -TEMPO adduct.

2.D. Detection of H_2O_2

For oxidation of alcohols, presence of H_2O_2 in the reaction mixture was analyzed by UV−Vis spectroscopy[s1] using the iodometric assay.

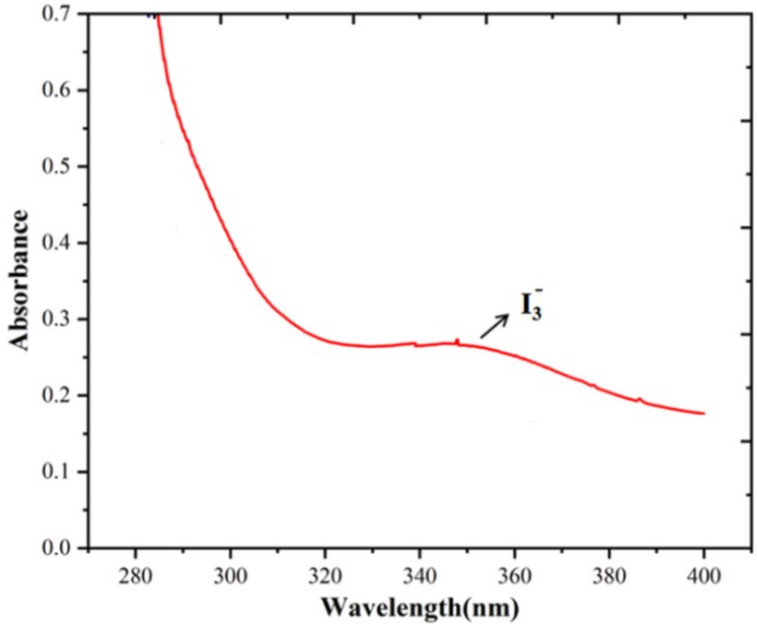
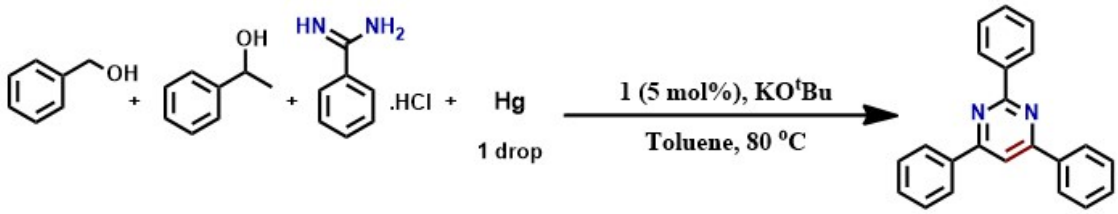


Figure S4. UV-Visible spectrum of I_3^- ion formation in presence of H_2O_2.

2.E. Mercury drop test

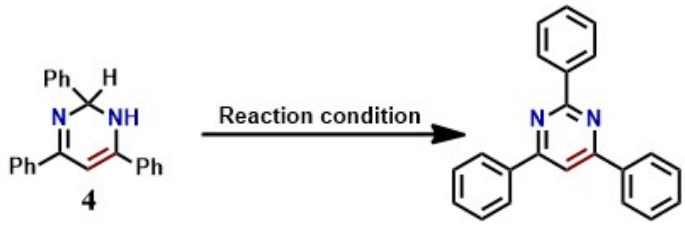


To establish the homogeneous catalytic condition in the reaction, we have carried out mercury drop experiment. In a typical mercury drop test, 5 mL vial was charged benzyl alcohol (1 mmol), 1-phenylethanol (1.25 mmol), benzamidine hydrochloride (1 mmol), KO^{t}Bu (0.5 mmol) and 5 mol% of **1** followed by 2 mL toluene. To this reaction mixture, a drop of mercury was added and was closed with rubber septum. The resulting solution was spurged with O_2. The reaction mixture was stirred at 80 °C for 8 h. The isolation of the product (in 72% yield) after 8 h confirmed the homogeneous behaviour of the catalyst in solution.

3. The kinetics analysis

The kinetic experiments were analyzed by UV−Vis spectroscopy.

3.A. Kinetic analysis for dehydrogenative aromatization of 4 varying reaction conditions



A) ***Reaction conditions:*** **1** (5 mol%), **4** (1 mmol), KO^{t}Bu (0.5 mmol), toluene (2 mL), 80 ^{o}C, O_2 balloon, 8 h. (Optimized reaction conditions)

B) ***Reaction conditions:*** **4** (1 mmol), KO^{t}Bu (0.5 mmol), toluene (2 mL), 80 ^{o}C, O_2 balloon, 8 h. (Absence of catalyst)

C) ***Reaction conditions:*** **4** (1 mmol), KO^{t}Bu (0.5 mmol), toluene (2 mL), 140 ^{o}C, 8 h. (Absence of catalyst and O_2 balloon)

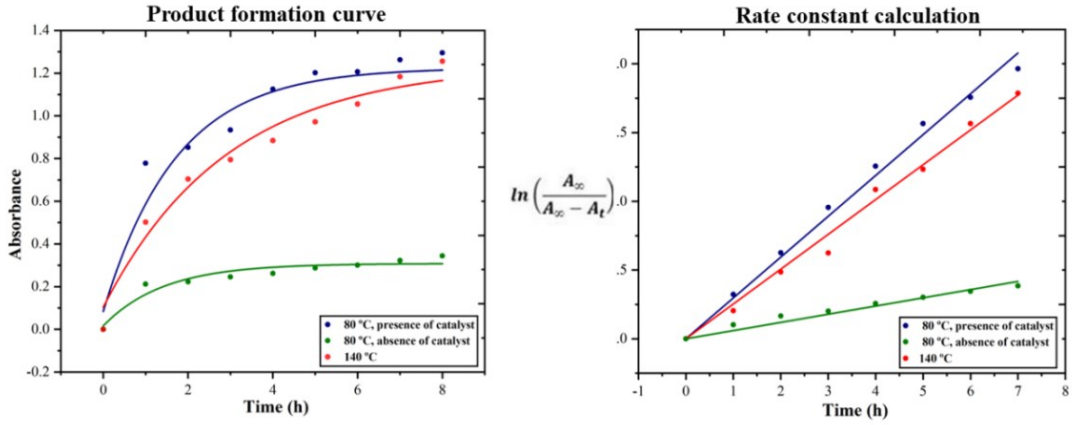


Figure S5. Kinetic analysis (by UV−Vis spectroscopy)for pyrimidine formation.

3.B. Aromatic dehydrogenation of 4 at three different temperature

Reaction conditions: **1** (5 mol%), **4** (1 mmol), KO^{t}Bu (0.5 mmol), toluene (2 mL), 70-90 ^{o}C, O_2 balloon, 8 h.

Set 1:

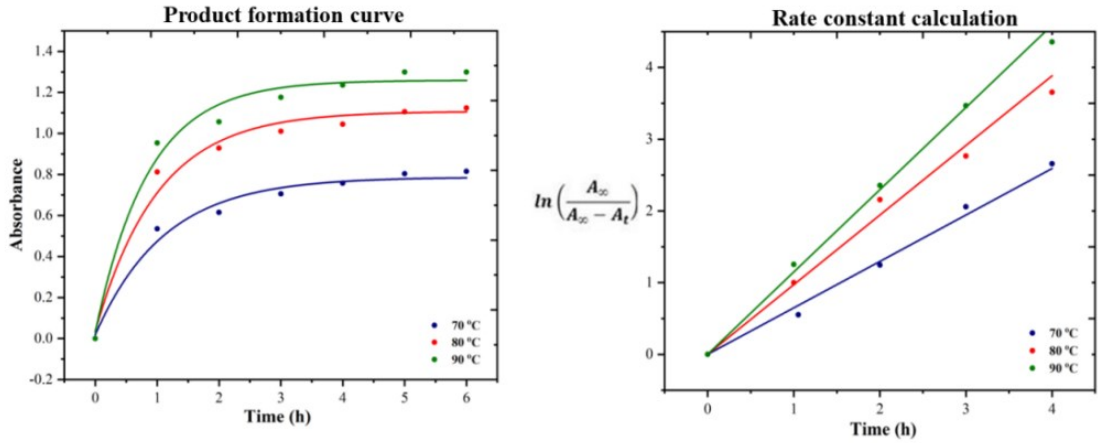


Figure S6. Kinetic analysis (by UV−Vis spectroscopy) for pyrimidine formation at 70 ^{o}C, 80 ^{o}C and 90 ^{o}C.

Set 2:

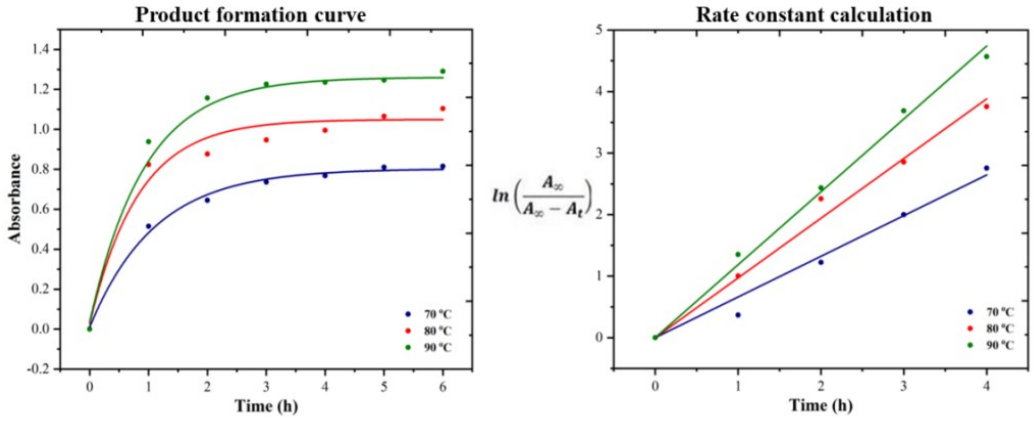


Figure S7. Kinetic analysis (by UV−Vis spectroscopy) for pyrimidine formation at 70 ^{o}C, 80 ^{o}C and 90 ^{o}C.

3.C. Saturation kinetics for aromatic dehydrogenation of 4 at three different temperatures

Reaction conditions: **1** (5 mol%), **4** (0.3 M, 0.6 M, 0.9 M, 1.2 M, 1.5 M), KO^{t}Bu (0.5 mmol), toluene (2 mL), 70 ^{o}C, 80 ^{o}C, 90 ^{o}C, O_2 balloon, 8 h.

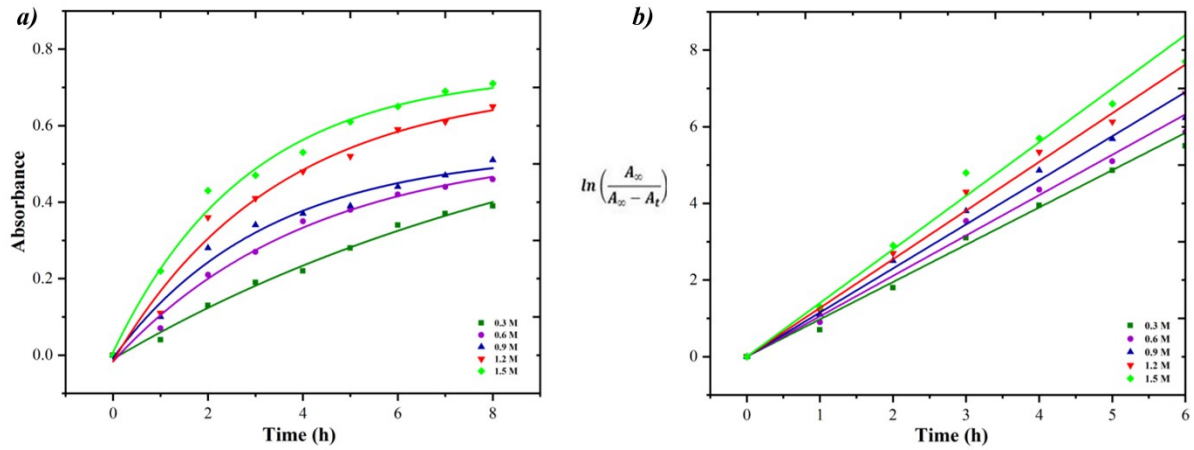


Figure S8. Kinetic analysis (by UV−Vis spectroscopy) for pyrimidine formation at 70 ^{o}C.

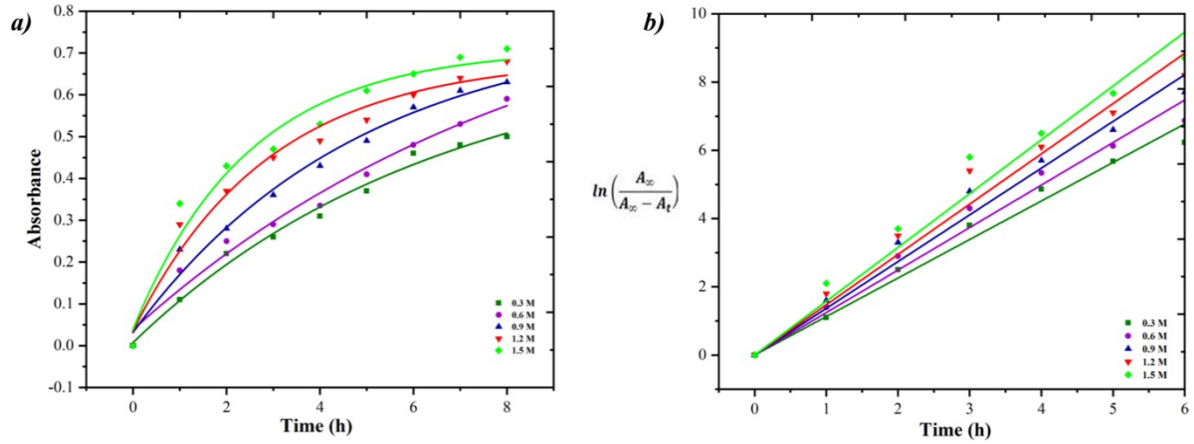


Figure S9. Kinetic analysis (by UV−Vis spectroscopy) for pyrimidine formation at 80 ^{o}C.

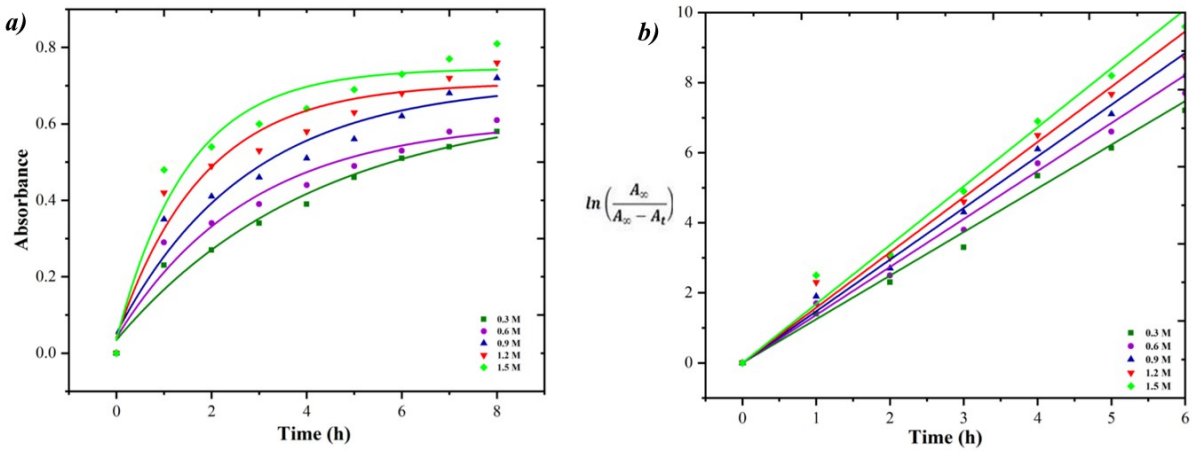


Figure S10. Kinetic analysis (by UV−Vis spectroscopy) for pyrimidine formation at 90 °C.

4. ^{1}H and ^{13}C NMR spectra

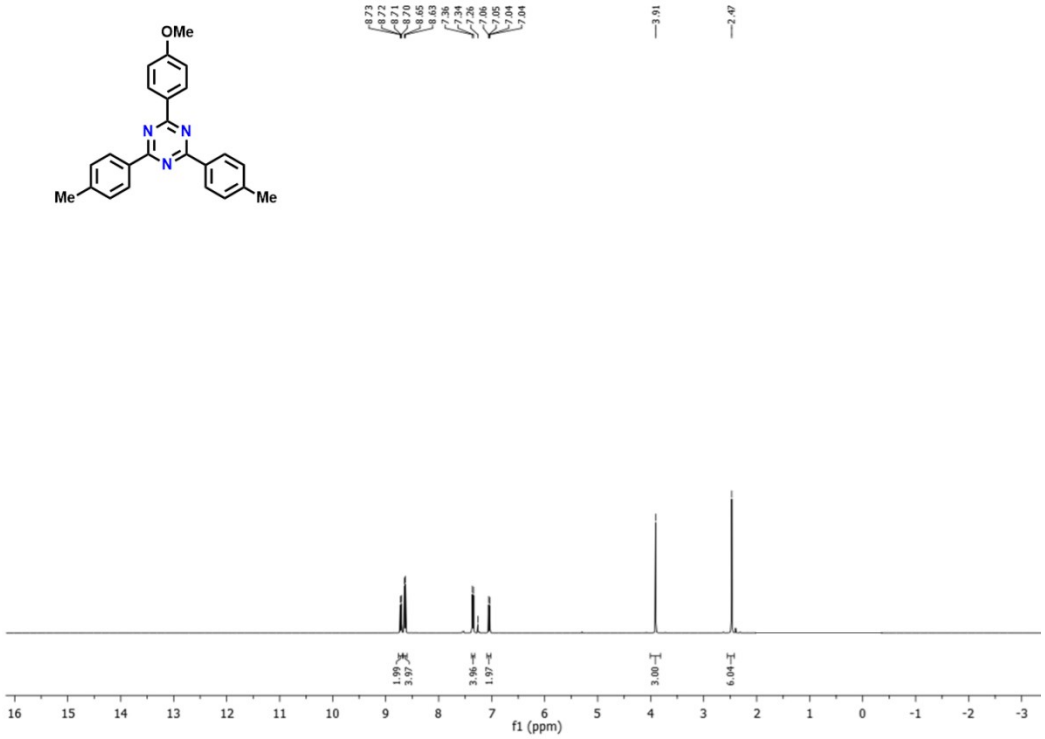


Figure S11. ^{1}H NMR spectrum (400 MHz) of **2b** in $CDCl_3$.

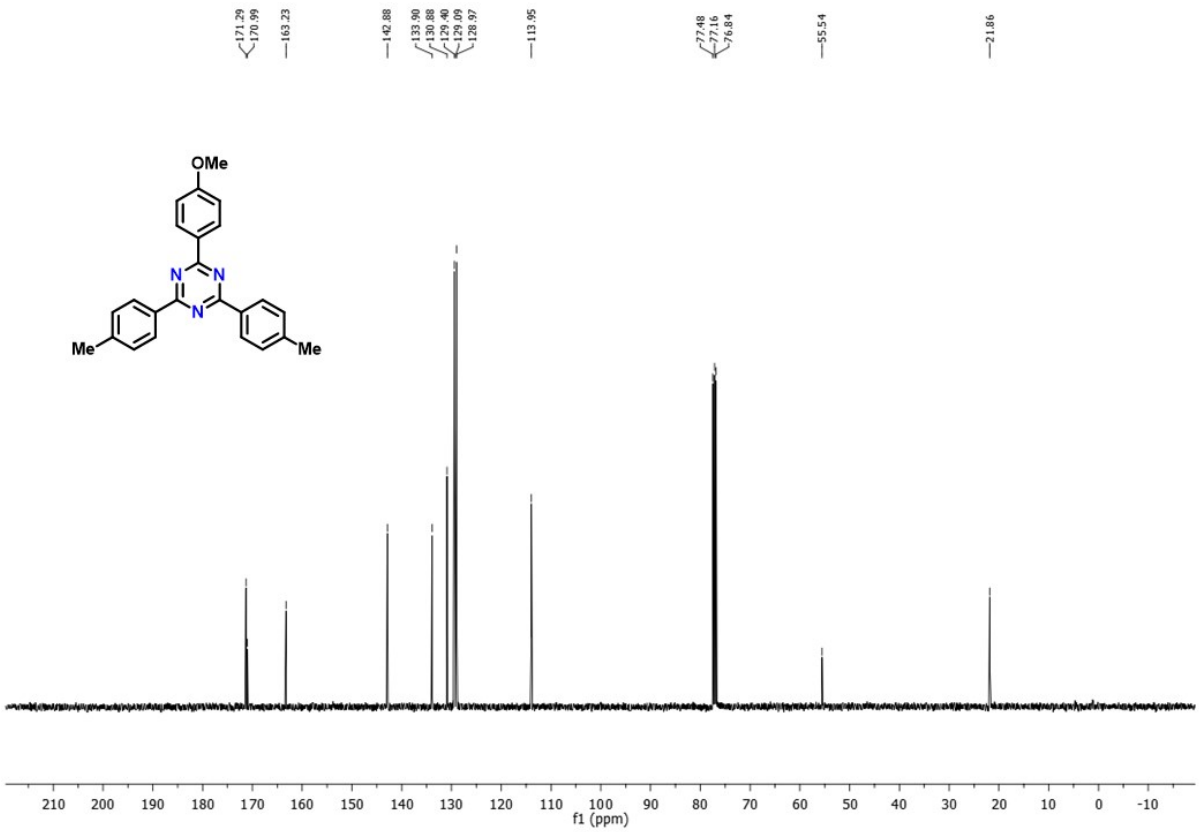


Figure S12. ^{13}C NMR spectrum (100 MHz) of **2b** in $CDCl_3$.

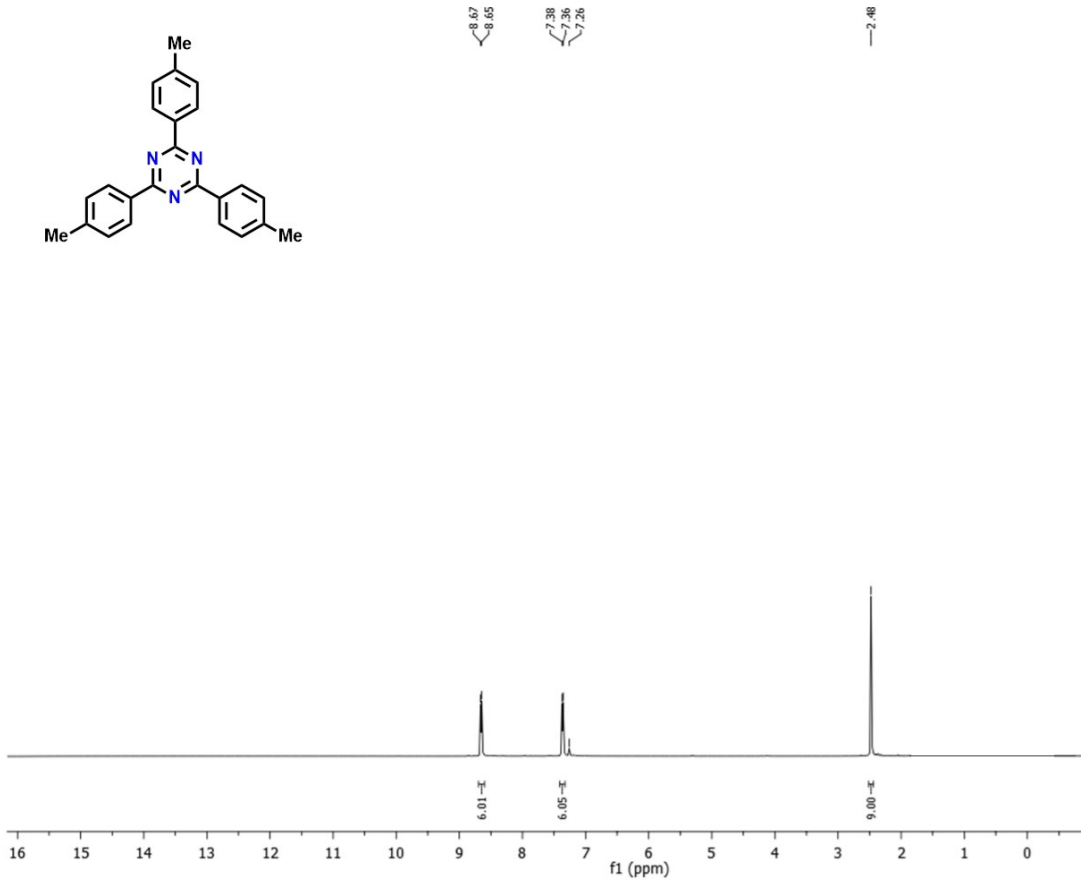


Figure S13. ^{1}H NMR spectrum (400 MHz) of **2c** in $CDCl_3$.

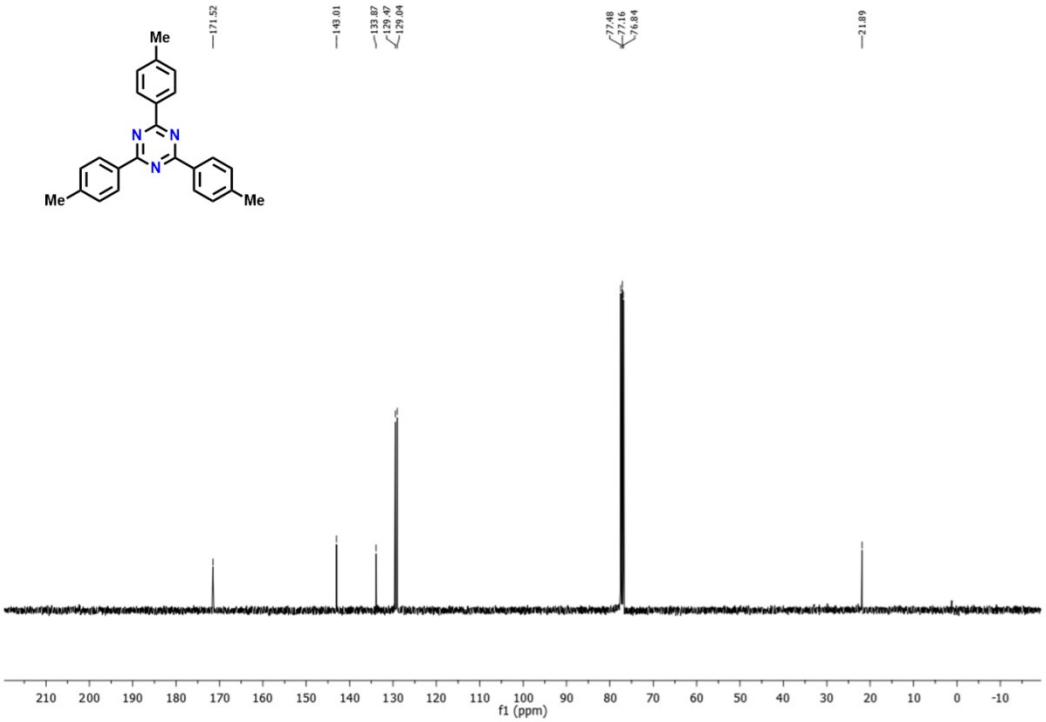


Figure S14. ^{13}C NMR spectrum (100 MHz) of **2c** in $CDCl_3$.

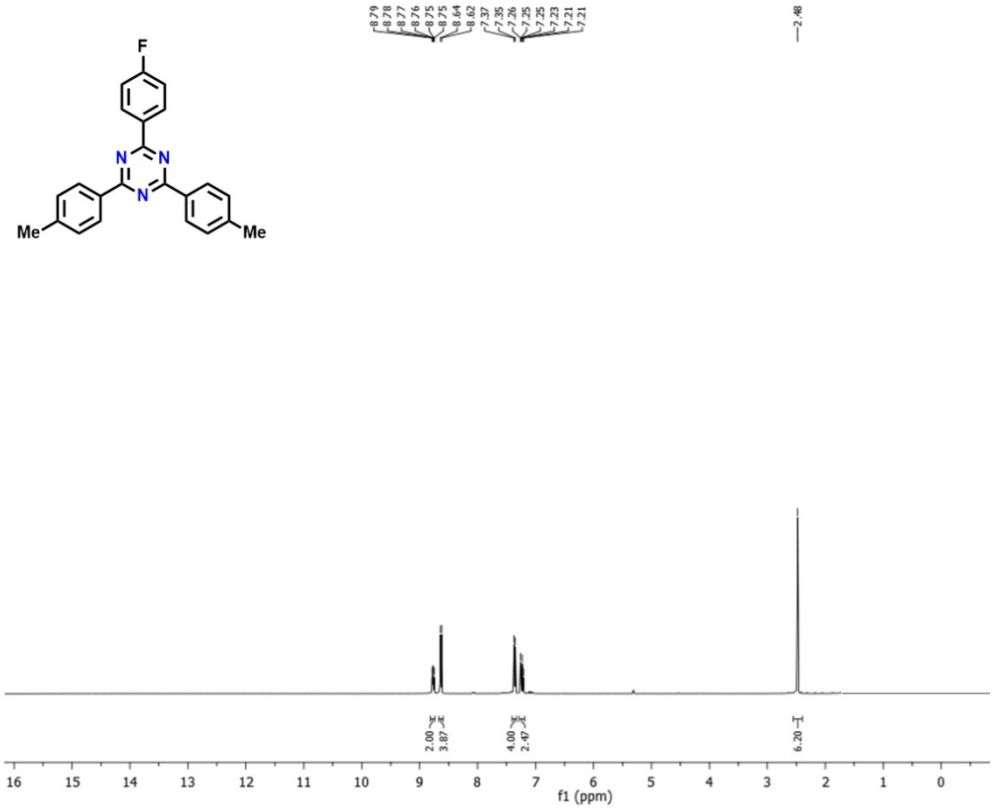


Figure S15. ^{1}H NMR spectrum (400 MHz) of **2d** in $CDCl_3$.

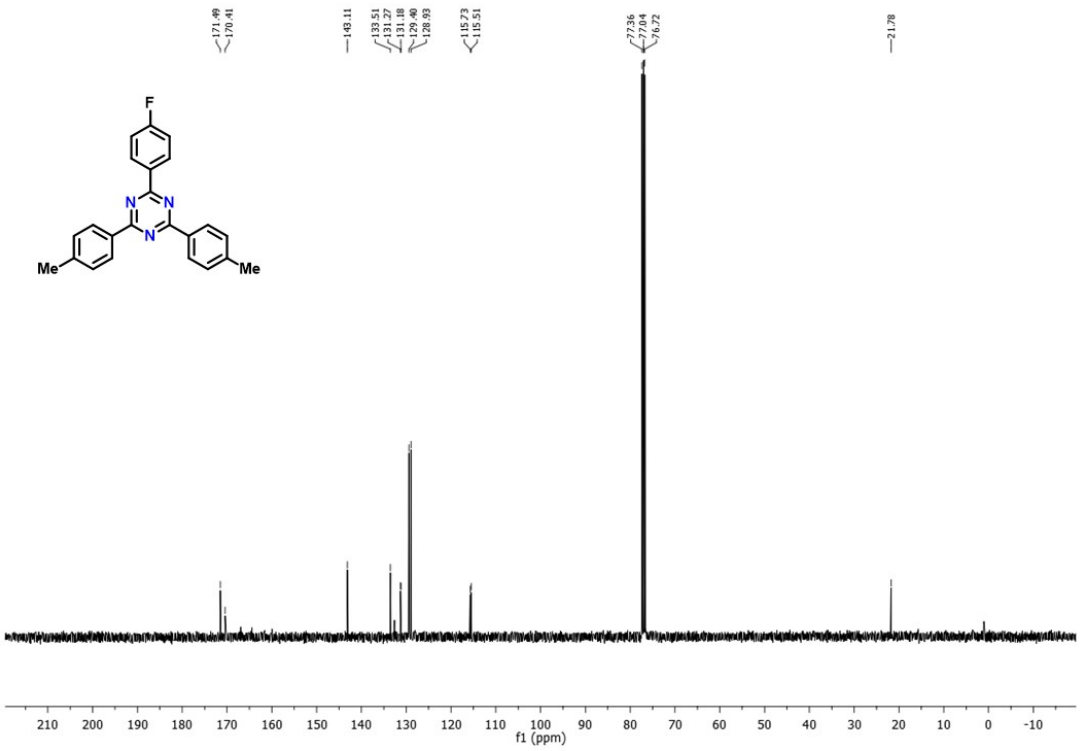


Figure S16. ^{13}C NMR spectrum (100 MHz) of **2d** in $CDCl_3$.

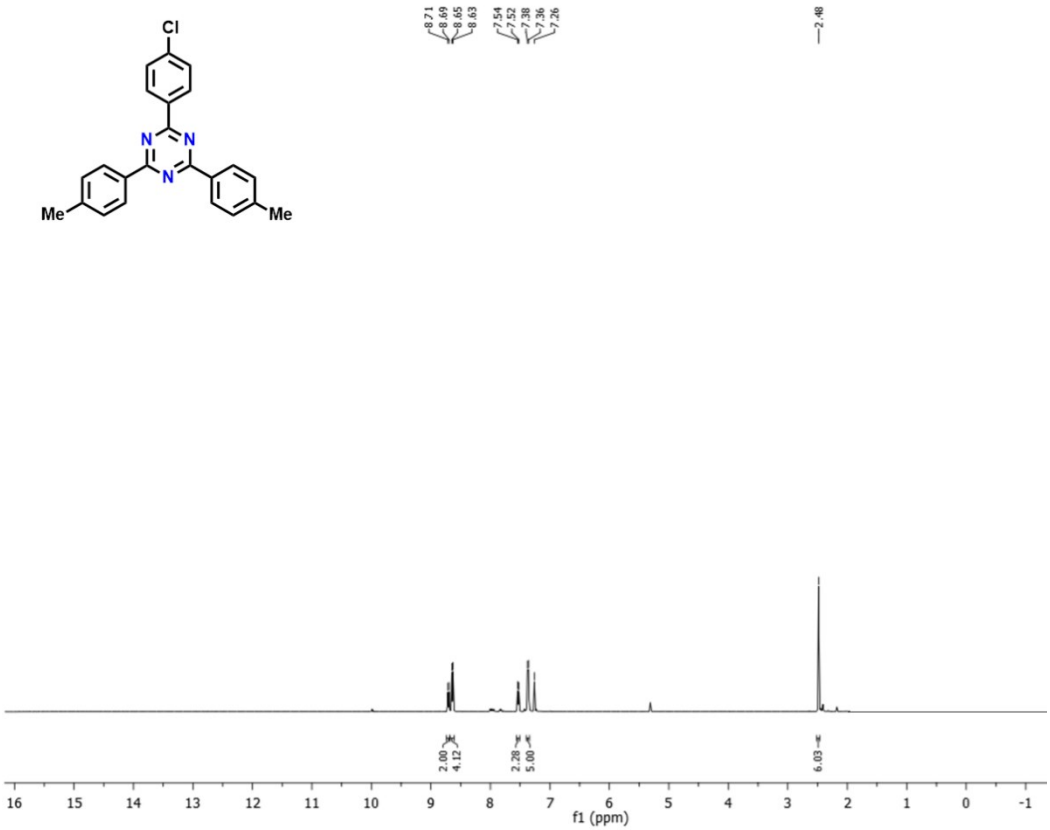


Figure S17. ^{1}H NMR spectrum (400 MHz) of **2e** in $CDCl_3$.

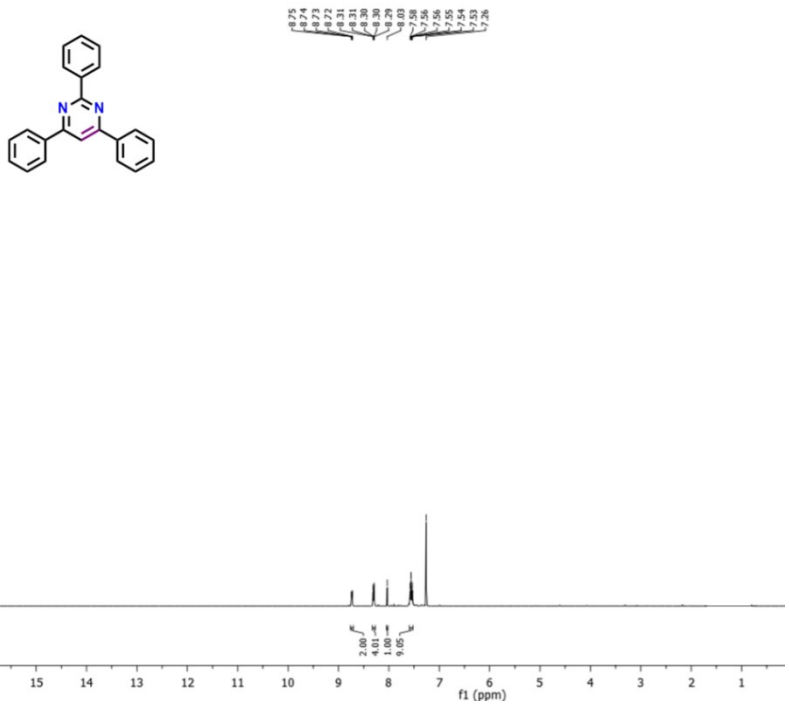


Figure S18. ^{1}H NMR spectrum (400 MHz) of **3a** in $CDCl_3$.

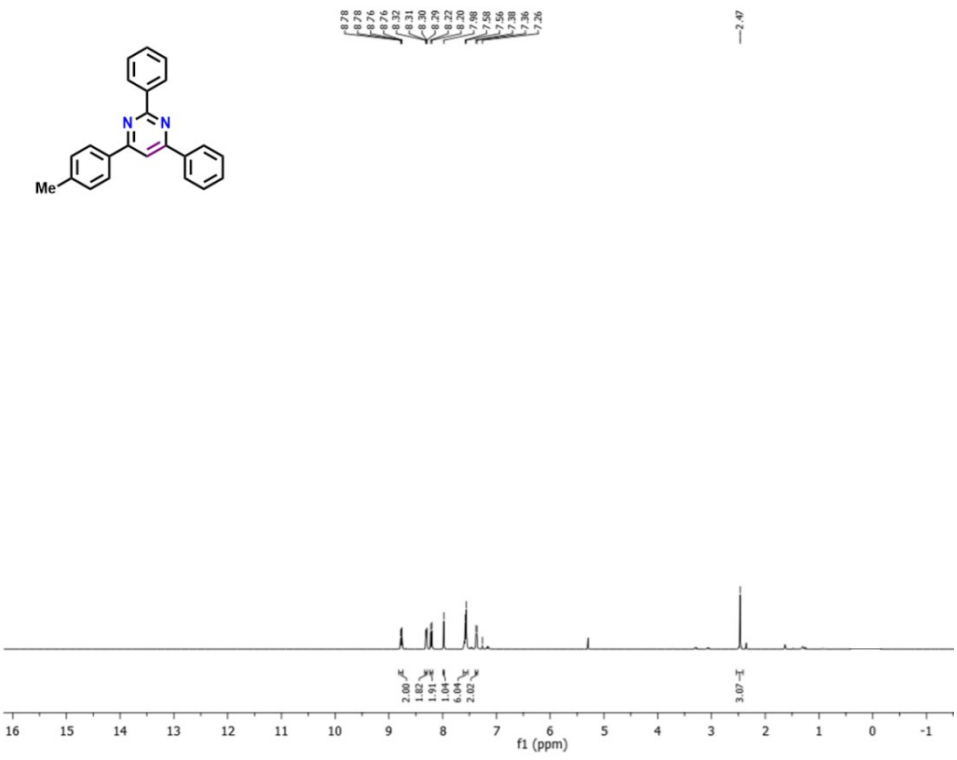


Figure S19. ^{1}H NMR spectrum (400 MHz) of **3b** in $CDCl_3$.

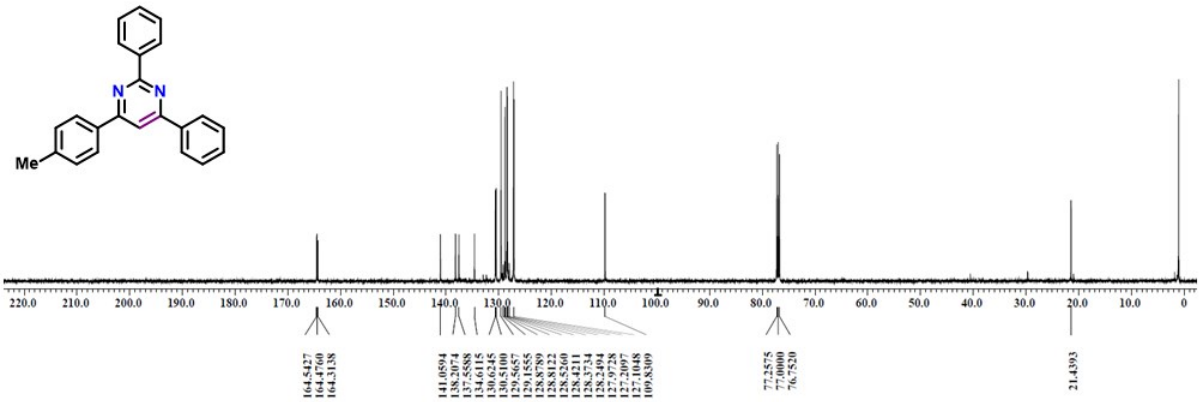


Figure S20. ^{13}C NMR spectrum (100 MHz) of **3b** in $CDCl_3$.

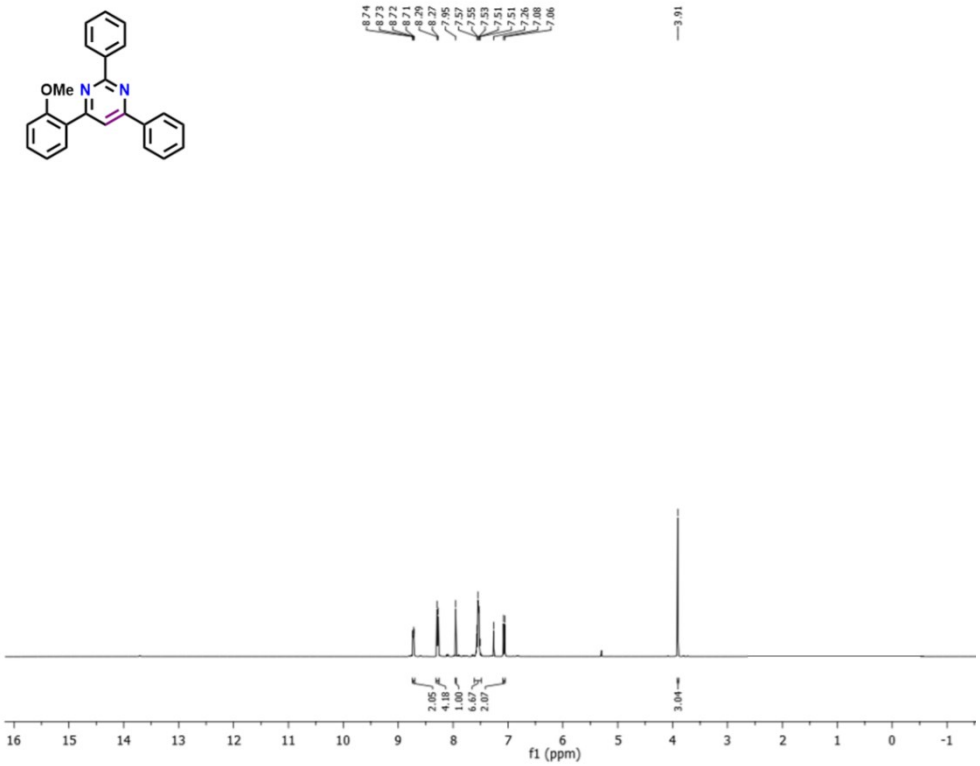


Figure S21. ^{1}H NMR spectrum (400 MHz) of **3c** in $CDCl_3$.

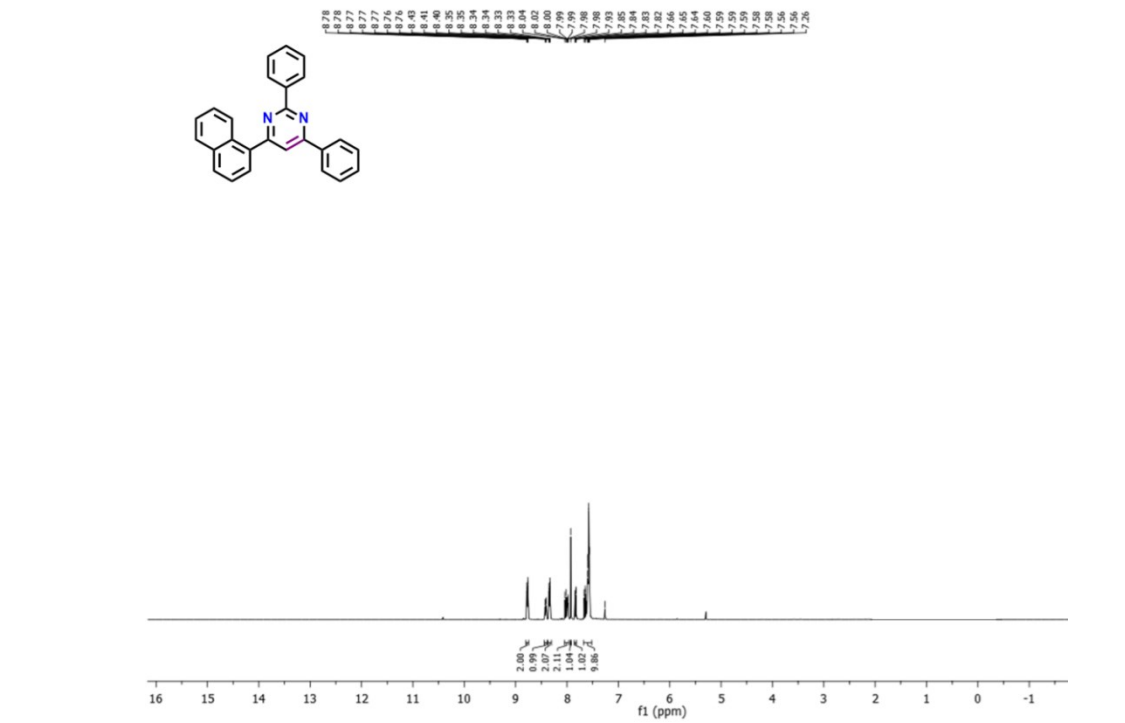


Figure S22. ^{1}H NMR spectrum (400 MHz) of **3d** in $CDCl_3$.

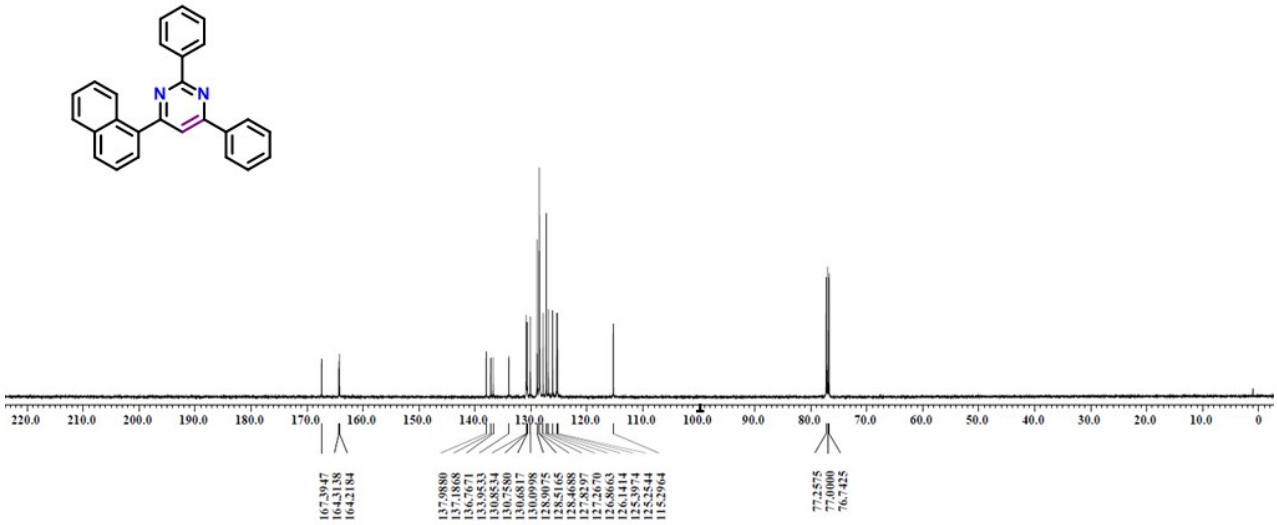


Figure S23. ^{13}C NMR spectrum (100 MHz) of **3d** in $CDCl_3$.

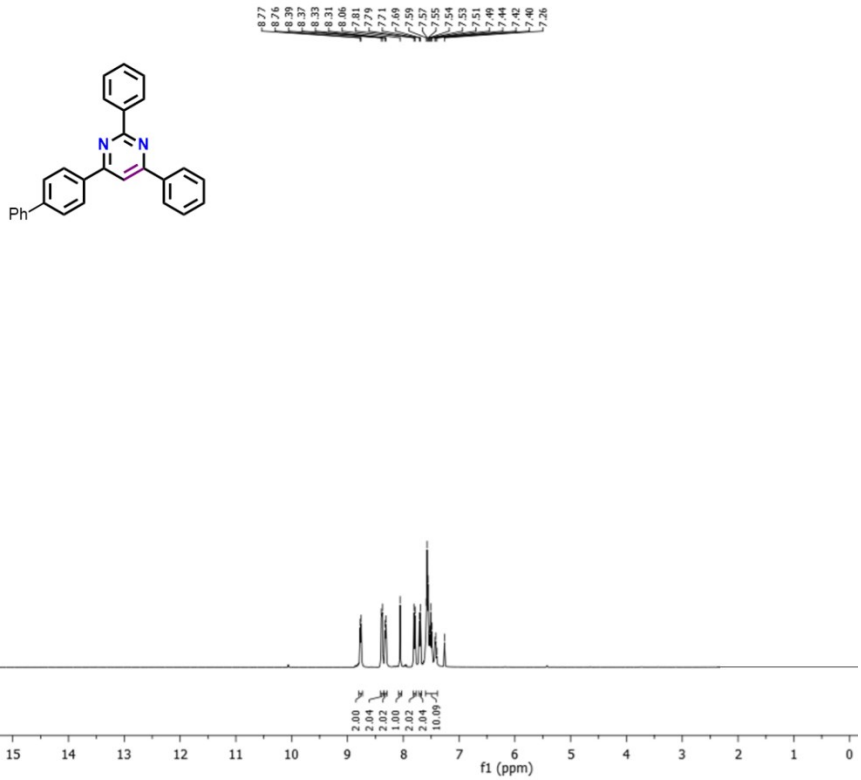


Figure S24. ^{1}H NMR spectrum (400 MHz) of **3e** in $CDCl_3$.

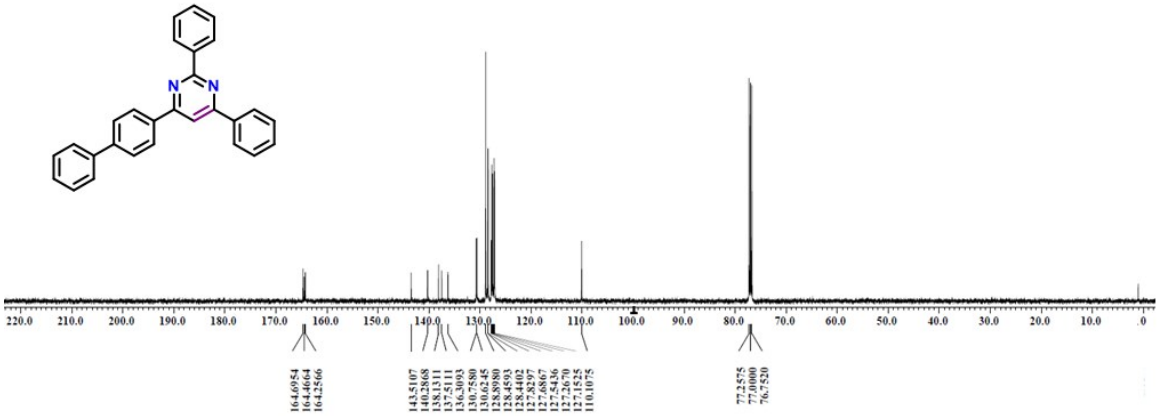


Figure S25. ^{13}C NMR spectrum (100 MHz) of **3e** in $CDCl_3$.

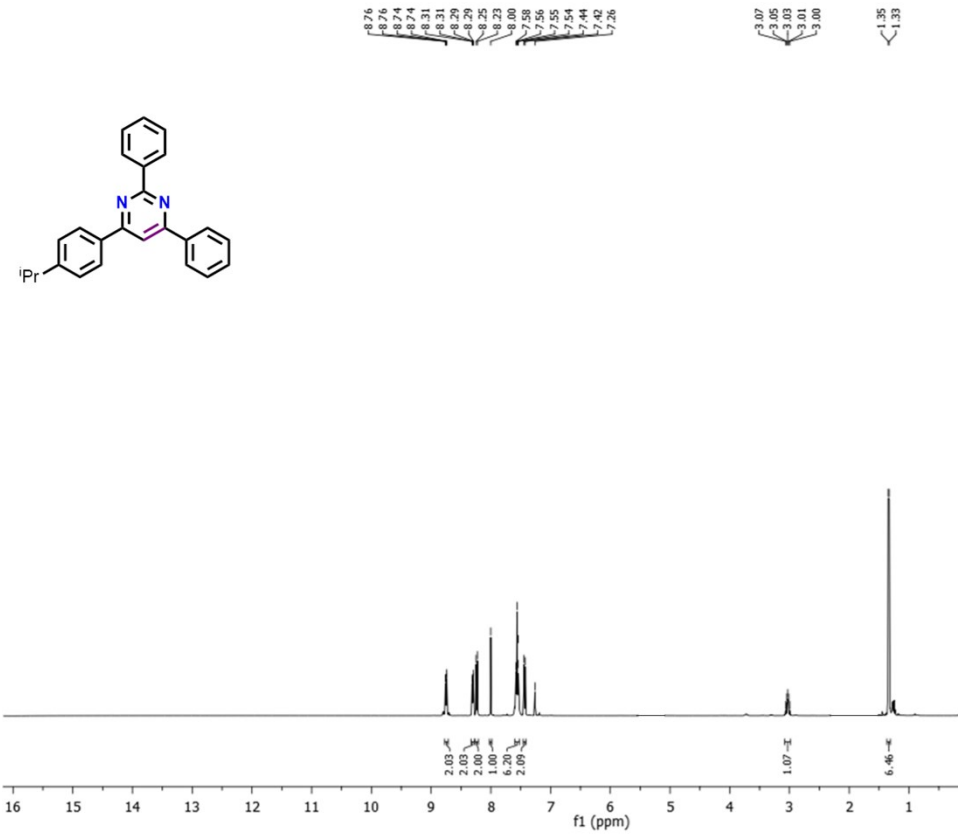


Figure S26. ^{1}H NMR spectrum (400 MHz) of **3f** in $CDCl_3$.

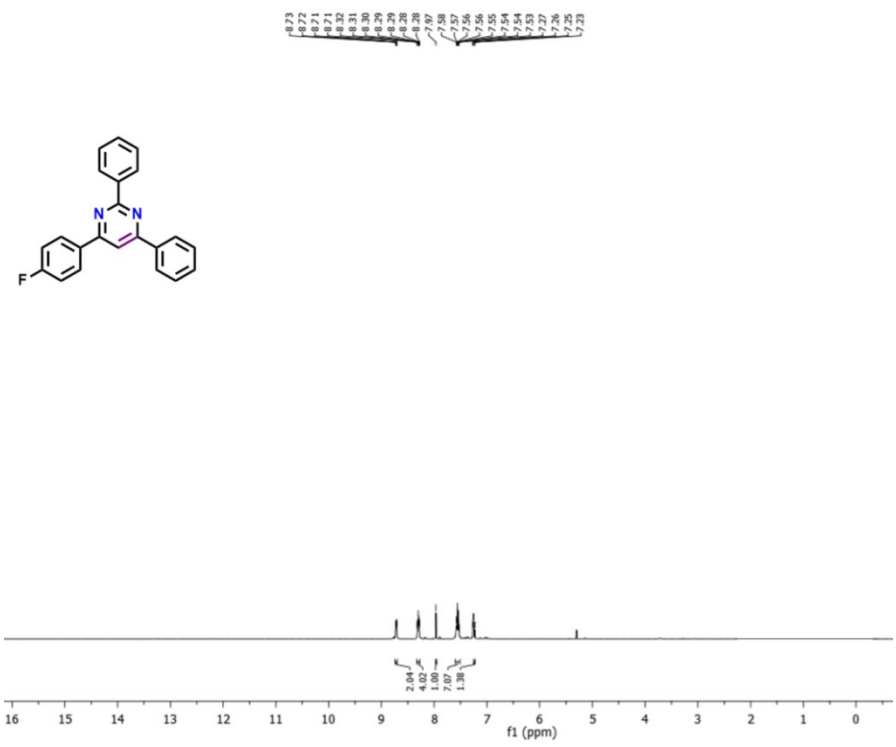


Figure S27. ^{1}H NMR spectrum (400 MHz) of **3g** in $CDCl_3$.

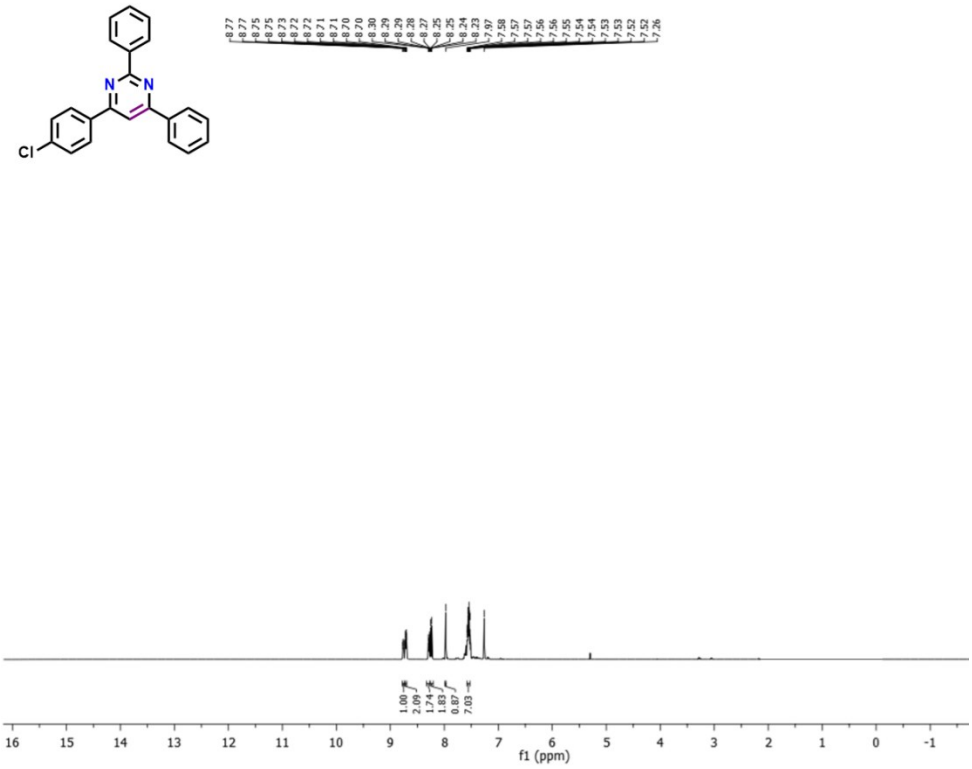


Figure S28. ^{1}H NMR spectrum (400 MHz) of **3h** in $CDCl_3$.

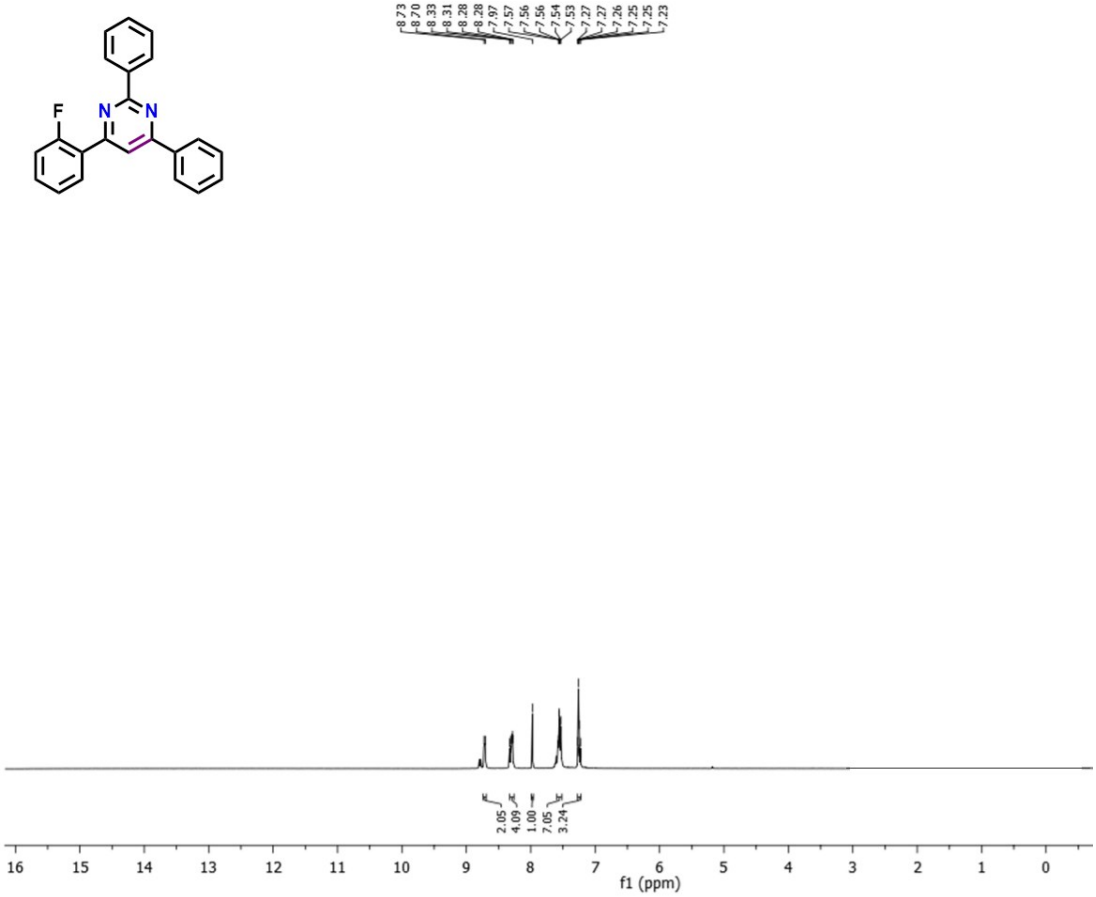


Figure S29. ^{1}H NMR spectrum (400 MHz) of **3i** in $CDCl_3$.

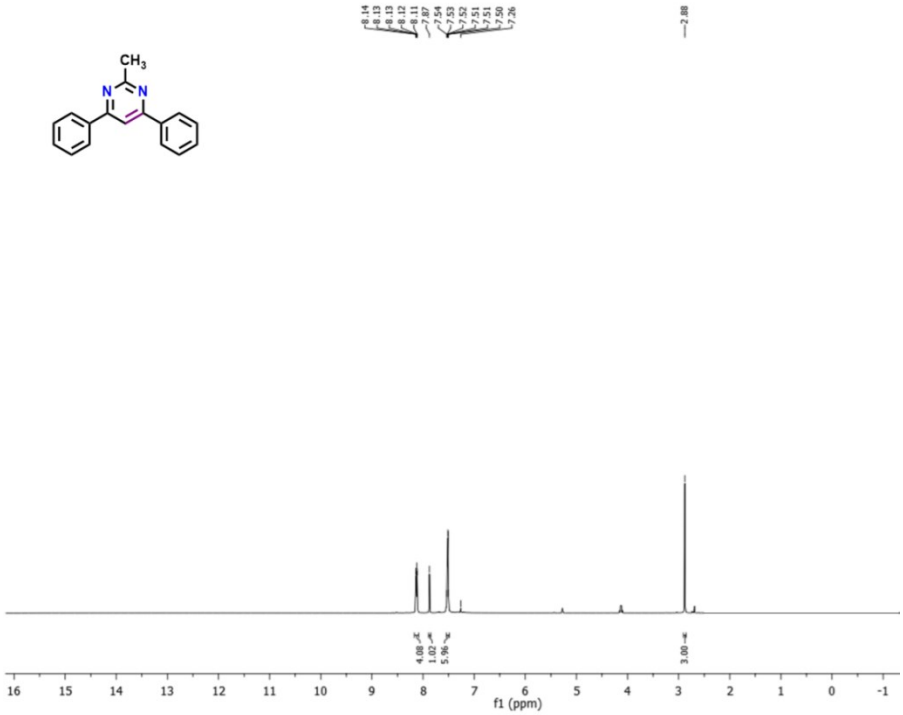


Figure S30. ^{1}H NMR spectrum (400 MHz) of **3j** in $CDCl_3$.

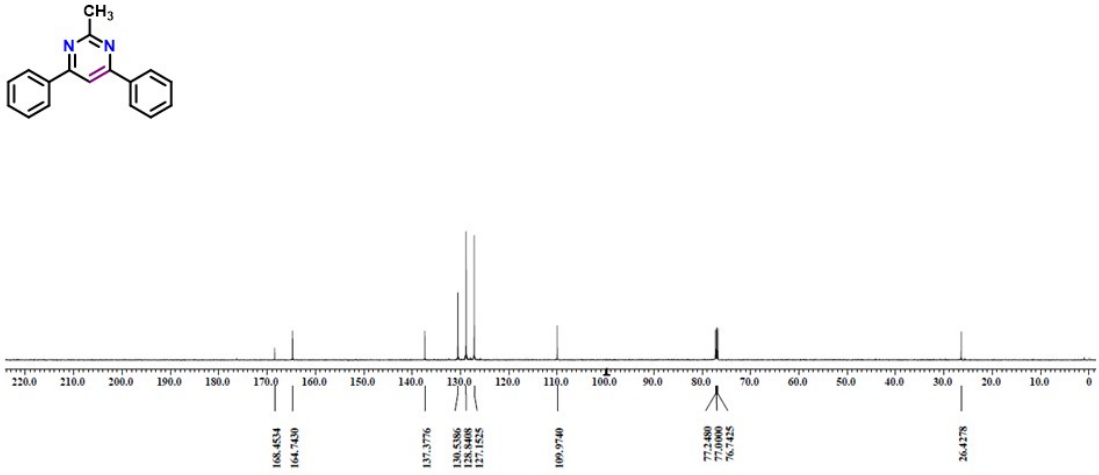


Figure S31. ^{13}C NMR spectrum (100 MHz) of **3j** in $CDCl_3$.

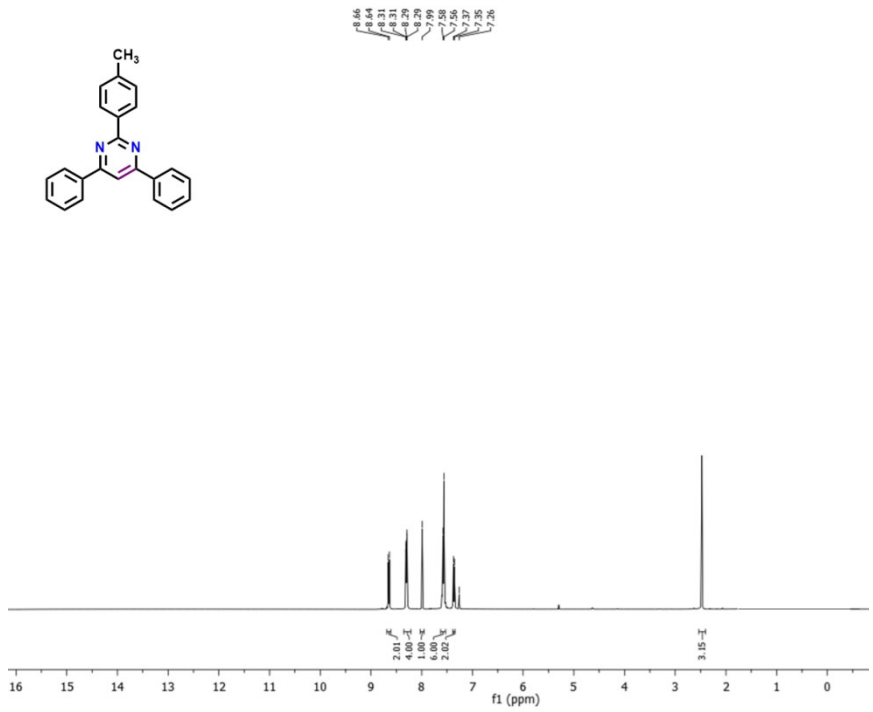


Figure S32. ^{1}H NMR spectrum (400 MHz) of **3k** in $CDCl_3$.

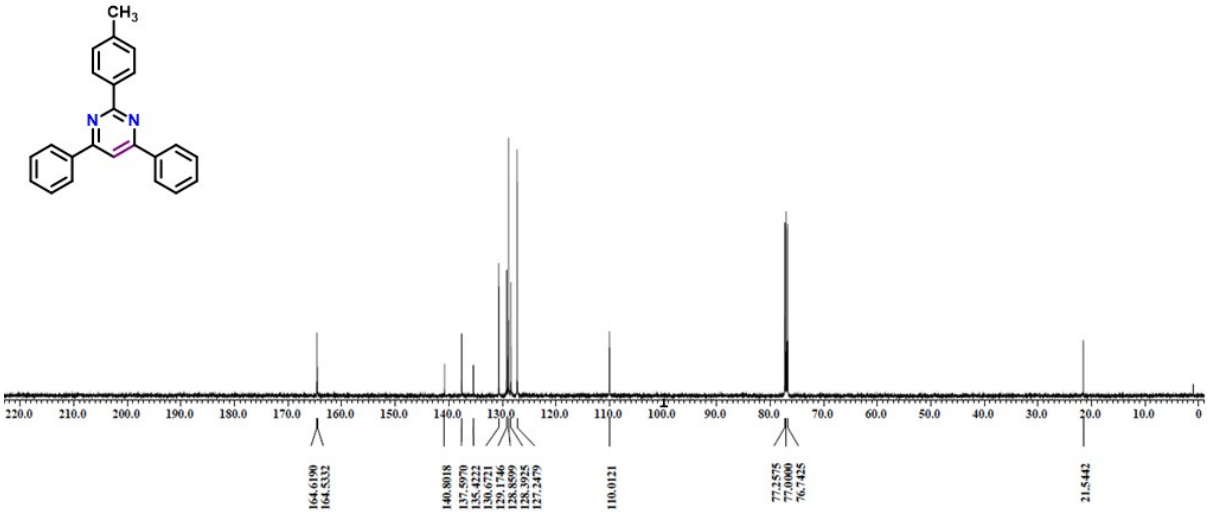


Figure S33. ^{13}C NMR spectrum (100 MHz) of **3k** in $CDCl_3$.

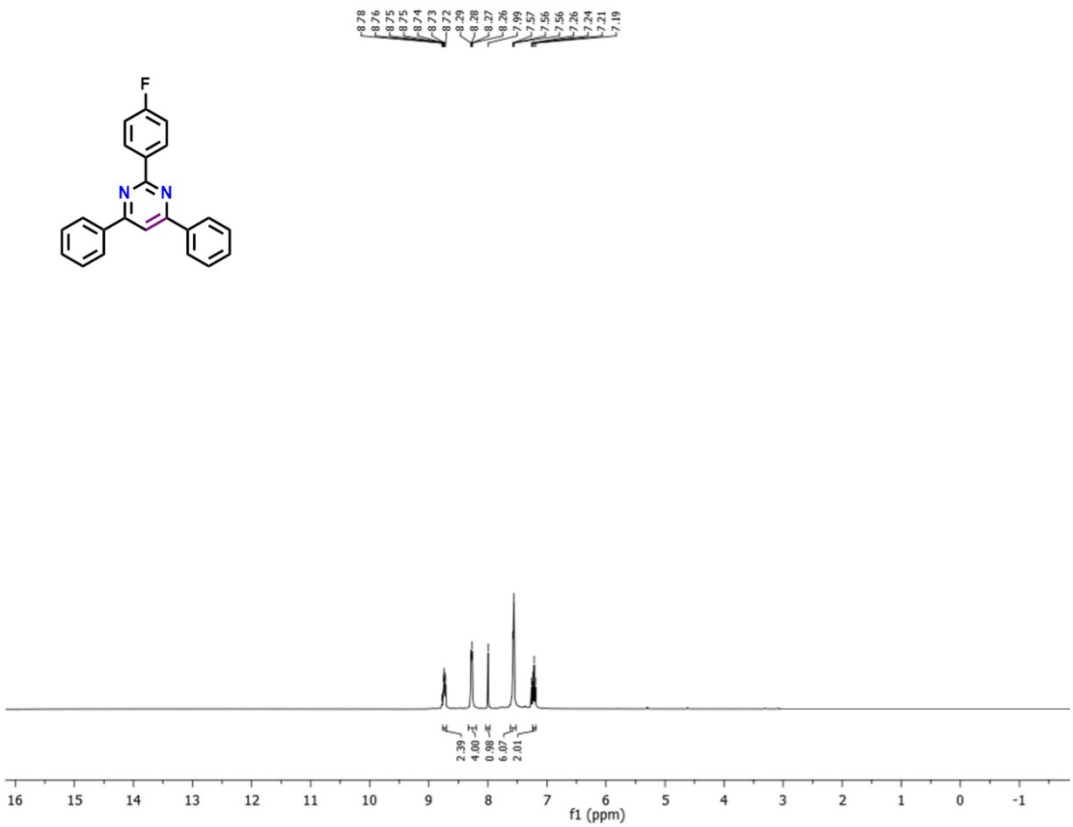


Figure S34. ^{1}H NMR spectrum (400 MHz) of **3l** in $CDCl_3$.

5. Reference

S1) H. Jenzer, W. Jones, H. Kohler. H, *J. Biol. Chem.* **1986**, *261,* 15550-15556.