Supporting Information for:

Precise Compositional Control and Systematic Preparation of Multimonomeric Statistical Copolymers

Jeffrey M. Ting,[‡,§] Tushar S. Navale,[†,§] Frank S. Bates, [‡,*] Theresa M. Reineke[†,*]

[†]*Department of Chemistry and* [‡] *Department of Chemical Engineering & Materials Science, University of Minnesota, Minneapolis, Minnesota 55455-0431, United States;* [§] *These authors contributed equally to this work.*

[*]Corresponding Email: bates001@umn.edu, treineke@umn.edu

1 Materials

All experiments were performed in anhydrous solvents under nitrogen atmosphere in oven-dried glassware. Unless otherwise noted, the following reagents were used as received from Aldrich: 1-propanethiol, potassium hydroxide, *p*-toluenesulfonyl chloride, 4,4′-azobis(4-cyanopentanoic acid), acetyl chloride, 4-dimethylaminopyridine (DMAP), magnesium sulfate, carbon disulfide, 2,2′-azobisisobutyronitrile (AIBN), magnesium sulfate ($MgSO_4$), acetone, ethyl acetate, dichloromethane (DCM), dimethylformamide (DMF), diethyl ether, and hexanes.

Methyl acrylate (MA), 2-carboxyethyl acrylate (CEA), 2-hydroxypropyl acrylate (HPA), and 2-propylacetyl acrylate (PAA) were passed through an activated alumina column to remove antioxidants and inhibitors and stored at -20 °C for future use. HPA was obtained from Polysciences Inc. and consisted of a 2:1 mixture of 2-hydroxypropyl acrylate to 1-methyl-2-hydroxyethyl acrylate. PAA was synthesized by a simple acetylation of HPA using DMAP and stored at 0 °C with ~200 ppm of monomethyl hydroquinone (MEHQ) inhibitor (see Section 2.2). Initiator AIBN was crystallized from methanol and stored at -20 °C for future use. The chain transfer agent, 4-cyano-4-(propylsulfanylthiocarbonyl) sulfanylpentanoic acid (CPP), was synthesized (see Section 2.1) according to established literature.[1]

(1) Xu, X.; Smith, A. E.; Kirkland, S. E.; McCormick, C. L. *Macromolecules* **2008**, *41*, 8429-8435.

2 Detailed Synthesis Procedures

2.1 Synthesis of 4-cyano-4-(propylsulfanylthiocarbonyl) sulfanylpentanoic acid (CPP)

CPP, the reversible addition-fragmentation chain transfer (RAFT) agent used for this polymerization, was chosen for its compatibility with acrylate monomers. The reaction scheme is shown below in Figure S-1.

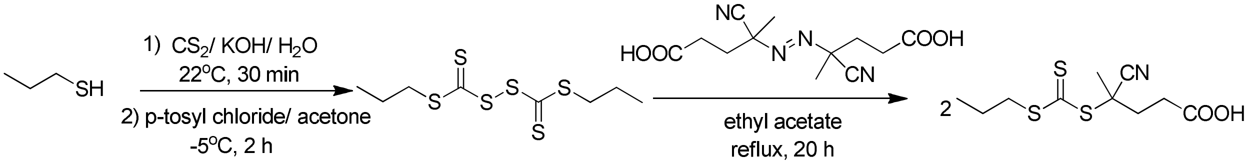


Figure S-1. Synthesis of 4-cyano-4-(propylsulfanylthiocarbonyl) sulfanylpentanoic acid (CPP). Precursor bis(propylsulfanylthiocarbonyl) disulfide was prepared from 1-propanethiol and added to a solution of 4,4′-azobis(4-cyanopentanoic acid) in ethyl acetate under reflux to yield CPP.

In a drop-wise manner, 1-propanethiol (5.07 g, 0.067 mol) was added to an aqueous solution of potassium hydroxide (4.67 g, 0.083 mol in 30 mL water). Carbon disulfide (5.07 g, 0.067 mol) was then carefully added at once to the well-mixed solution. The mixture was allowed to stir constantly at room temperature for ~ 30 min. After cooling the reaction vessel to -5 °C, *p*-tosyl chloride (6.35 g, 0.033 mol) in acetone (30 mL) was slowly added over 10 min, followed by vigorous stirring for 2 h to yield a red solution. The resulting solution was allowed to stir until most of the acetone evaporated. The remaining solution was diluted with water (100 mL) and extracted with dichloromethane (3x100 mL). The organic layer was washed with water (100 mL) and dried over anhydrous $MgSO_4$ overnight.

Next, removal of $MgSO_4$ by filtration and dichloromethane with rotary evaporation yielded bis(propylsulfanylthiocarbonyl) disulfide (9.0 g) as a red solid-like liquid; this material was dissolved in ethyl acetate (100 mL), and 4,4′-azobis(4-cyanopentanoic acid) (7.3 g, 0.033

mol) was added. The resultant mixture was heated under reflux for 20 h, followed by evaporation under vacuum. Lastly, the crude product was purified by silica gel column chromatography with an ethyl acetate/hexane (1/2, *v*/*v*) solvent mixture to afford purified CPP product (8.5 g, 45% yield). ^{1}H NMR (CDCl$_3$): δ 1.01 (t, 3H, **CH_3**-CH_2); 1.73 (m, 2H, CH_3-**CH_2**-CH_2-); 1.88 (s, 2H, **CH_3**-) 2.35-2.57 (m, 2H,-**CH_2**-CH_2-COOH); 2.64-2.74 (m, 2H, CH2-**CH_2**-COOH); 3.31 (t, 2H, -S-**CH_2**-) ppm.

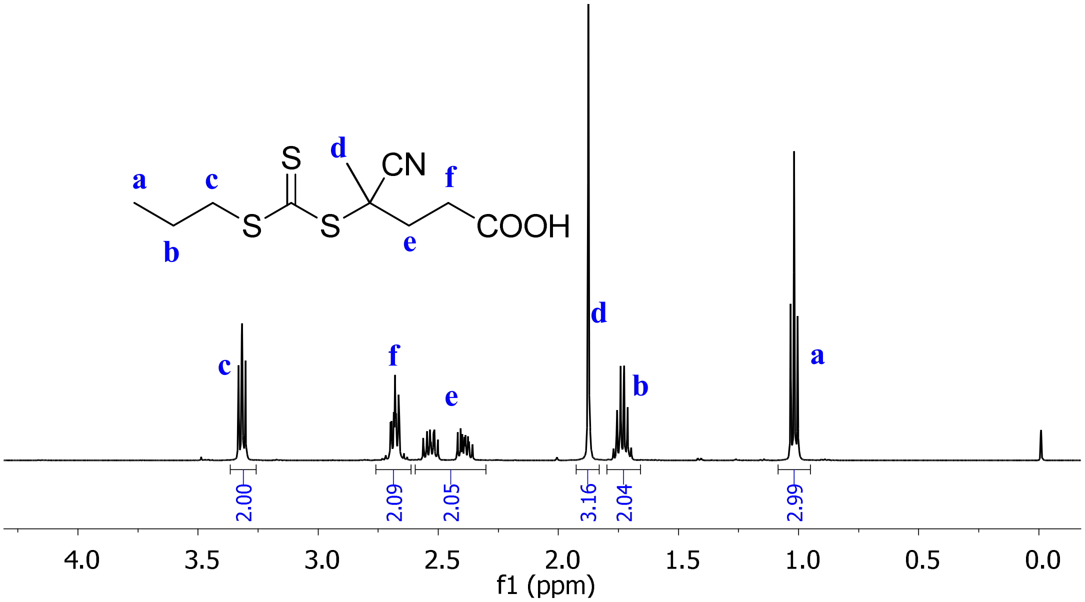


Figure S-2. ^{1}H NMR spectra of CPP.

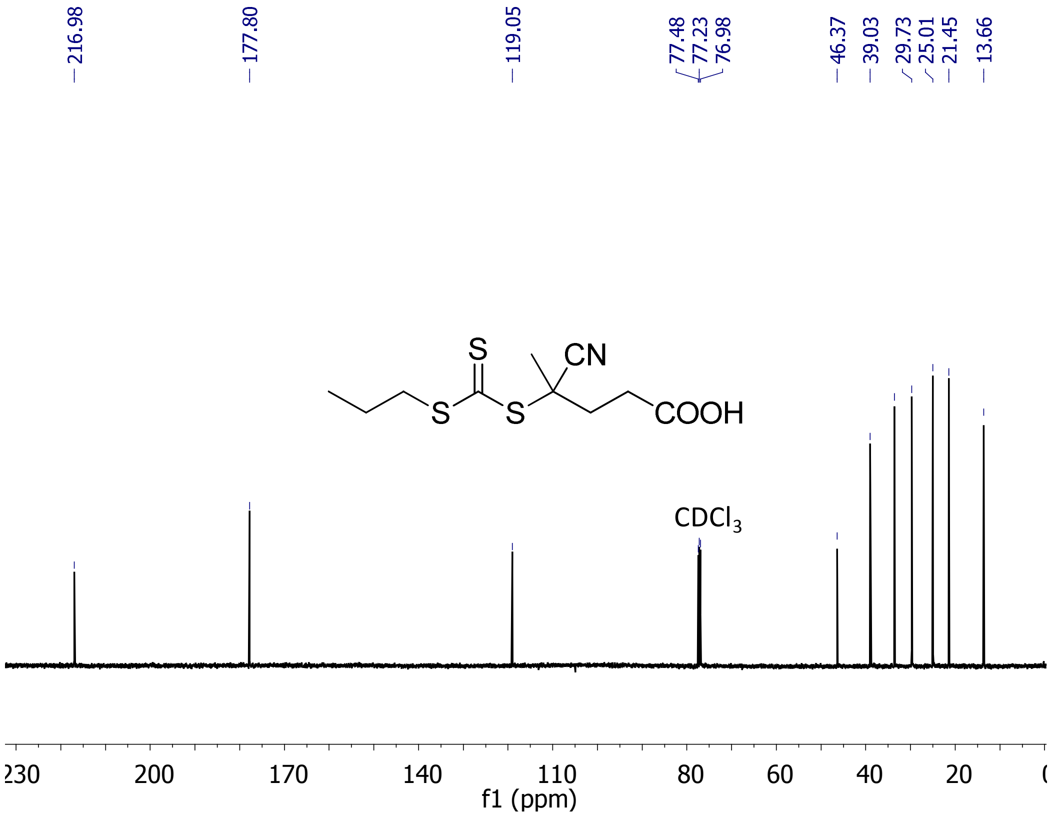


Figure S-3. ^{13}C NMR spectra of CPP.

2.2 Synthesis of 2-propylacetyl acetate (PAA)

Figure S-4 shows the acetylation reaction of HPA. DMAP (12.22 g, 100 mmol) and acetyl chloride (7.85 g, 100 mmol) were added to a well-mixed solution of HPA (13.01 g, 100 mmol) in 200 mL of DCM. The solution was stirred overnight at room temperature. The reaction

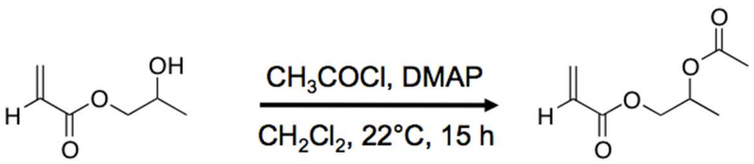


Figure S-4. Synthesis of 2-propylacetyl acetate. Precursor 2-hydroxypropyl acrylate is acetylated with acetyl chloride (CH_3COCl) in the presence of DMAP in DCM (CH_2Cl_2) at 22 °C for 15 h.

mixture was diluted with ~300 mL water. The organic layer was separated, washed twice with 150 mL 5% hydrochloric acid (HCl) and 200 mL brine, dried with anhydrous MgSO$_4$, and evaporated under vacuum to afford 2-propylacetyl acetate as a clear colorless liquid (16.5 g, 96% yield). ^{1}H NMR (CDCl$_3$): δ 1.26 (m, 3H, -CH-**CH$_3$**); 2.04 (s, 3H, CO-**CH$_3$**); 4.02-4.26 (m, 2H, O-**CH$_2$**-), 5.08-5.24 (m, 1H, O-**CH**-CH3); 5.78-5.87 (m,1H, =**C-H**), 6.02-6.17 (m, 1H, **=C-H**); 6.34-6.44 (m, 1H, **=C-H**) ppm.

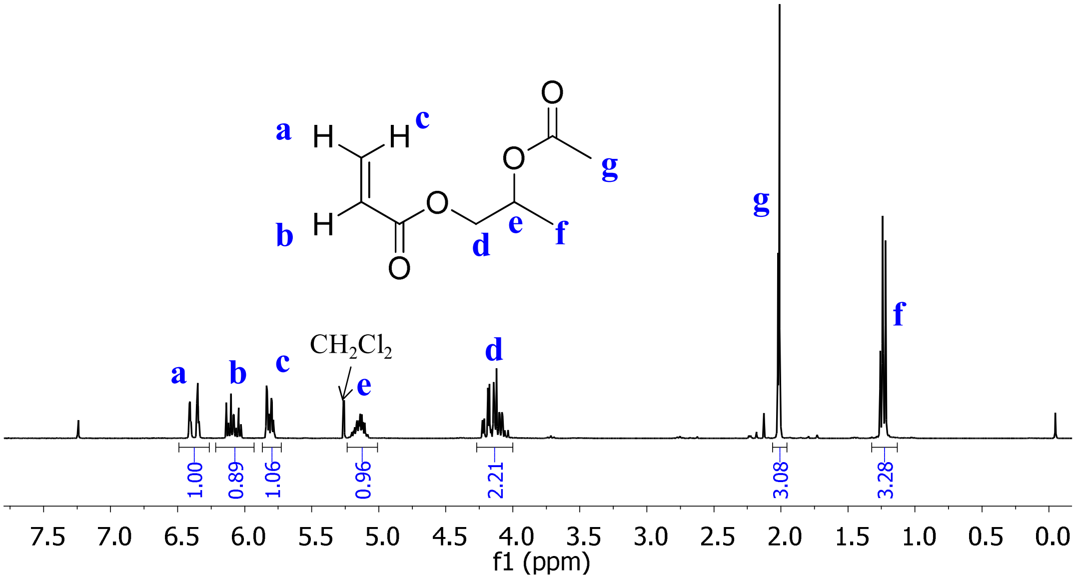


Figure S-5. ^{1}H NMR spectra of PAA.

Note: as seen in Figure S-6, commercial HPA was a 2:1 mixture of the constitutional isomers 2-hydroxypropyl acrylate and 1-methyl-2-hydroxyethyl acrylate. Thus, the acetylated product was also a mixture, but the predominate isomer PAA is assumed for all further experiments.

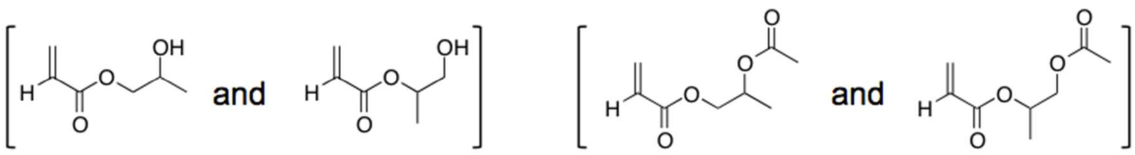


Figure S-6. Structural isomers of 2-hydroxypropyl acrylate and 2-propylacetyl acrylate.

2.3 Synthesis of p(MA-*stat*-CEA-*stat*-HPA-*stat*-PAA)

As seen in Figure S-7, the copolymerization of MA, CEA, HPA, and PAA was performed to synthesize statistical copolymers (SCPs) using RAFT polymerization with initiator AIBN and chain transfer agent CPP.

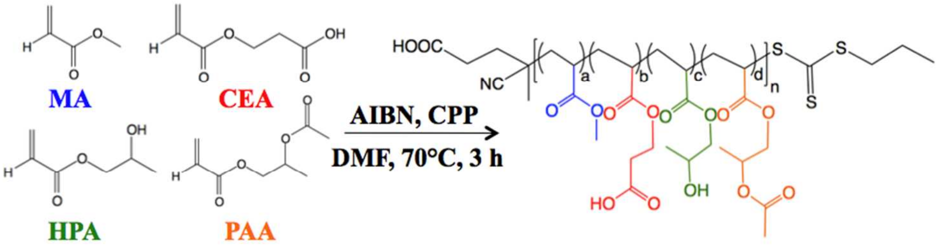


Figure S-7. Synthesis of statistical quarterpolymer poly(MA-*stat*-CEA-*stat*-HPA-*stat*-PAA) via reversible addition-fragmentation chain transfer (RAFT) polymerization at 70 °C.

A dried 50 mL round bottom flask was charged with all monomers (MA, CEA, HPA, PAA), AIBN, and CPP in dimethylformamide (DMF) solvent. The mixture was sealed and degassed under inert nitrogen at room temperature for ~25 min. An initial sample was taken to verify monomeric ratio feed, and the reaction vessel was submerged into a preheated, stirring oil bath maintained at 70 °C. To monitor reaction progress, aliquots were taken periodically over time with a nitrogen-filled syringe via ^{1}H NMR. Polymerizations were quenched after approximately three hours by cooling to 0 °C and opening the flask to air. The resultant SCP was precipitated into diethyl ether with minimum dichloromethane. This process was repeated three times to remove residual monomer and DMF. The precipitated sample was filtered, washed, and dried under vacuum. Molecular weight and dispersity were calculated with size exclusion chromatography (SEC) and end-group analysis, and chemical composition was calculated using quantitative proton nuclear magnetic resonance (^{1}H NMR) spectroscopy.

3 Reactivity Ratio Determination Procedure

Monomer reactivity ratios were determined by free radical polymerization in a pair-wise manner using AIBN as an initiator in DMF at 70 °C. The following provides a representative example of the procedure used to conduct the reactivity ratio experiment between MA and PAA. This process was used to measure all reactivity ratios used in this study.

Seven free radical polymerization runs were carried out for MA and PAA, with the feed monomer mole fraction ranging from 0.10 to 0.90. AIBN molar concentration was kept at 1000 times less than the total monomer concentration. For instance, in run 6 the following was charged to a dried NMR tube: MA (250 µL of 3 M solution in DMF-d_7, 0.75 mmol), PAA (83 µL of 3 M solution in DMF-d_7, 0.25 mmol), and AIBN (10 µL of 0.1 M solution in DMF-d_7, 0.001 mmol). After enclosing the NMR tube with rubber septum, dry nitrogen was bubbled for 15 min to remove dissolved oxygen. The NMR tube was then capped with a polypropylene cap and sealed with high-temperature tape under elevated nitrogen flow.

The sample was analyzed by ^{1}H NMR in a Varian Inova 300 spectrometer at 22 °C to determine the initial monomer feed. The polymerization was then conducted by raising the temperature to 70 °C with the total monomer conversion kept below 15%. The total monomer conversion and molar ratio of MA to PAA in the polymer was calculated by comparing the integration of the three methoxy protons (-OCH_3) in MA (3.77 ppm) to corresponding methoxy protons in the copolymer (3.72 ppm), as well as the integration of the acetyl proton (-$COCH_3$) in PAA (2.01-2.06 ppm) to corresponding acetyl protons in the copolymer (2.07-2.12 ppm). A nonlinear fit $F_1 = (r_{12}f_1^2 + f_1f_2) / (r_{12}f_1^2 + 2f_1f_2 + r_{21}f_2^2)$ was applied to the composition data to determine the resultant reactivity ratios $r_{MA\text{-}PAA}$= 0.30, $r_{PAA\text{-}MA}$= 0.81. The following tables and figures provide the data used to calculate the reactivity ratios for this study.

Table S-1: Experimental runs for determination MA-CEA reactivity ratios in a DMF-d_7 at 70 °C.

Run	**Feed Ratio** [a] **(MA:CEA)**	**MA Conversion** [b] **(%)**	**CEA Conversion** [c] **(%)**	**Polymer Ratio** [d] **(MA:CEA)**
1	9:91	09	11	7:93
2	13:87	10	12	09:91
3	22:78	11	14	18:82
4	37:63	10	16	27:73
5	42:58	11	13	39:61
6	52:48	08	11	45:55
7	69:31	11	15	62:38
8	87:13	10	15	81:19

[a] MA: CEA molar ratio in the feed as determined by ^{1}H NMR spectroscopy at 22 °C. [b,c] Percent molar conversion of MA and CEA, respectively, as determined by ^{1}H NMR spectroscopy. The total monomer conversion was kept less than 15% in all runs, and the composition drift was considered to be negligible. [d] MA:CEA molar ratio in the polymer as determined by ^{1}H NMR spectroscopy.

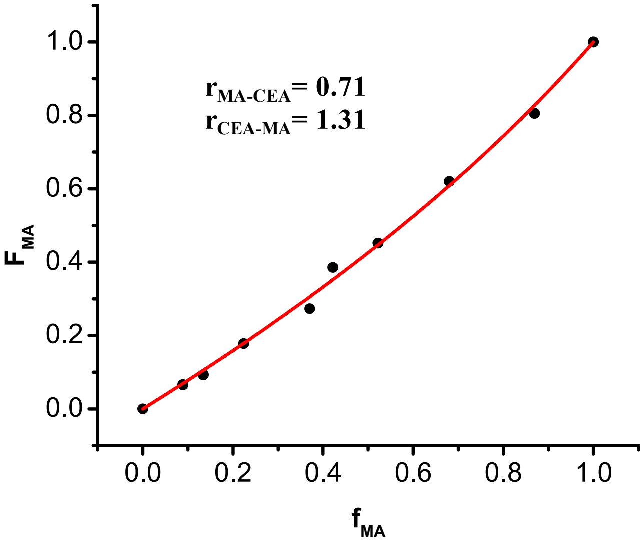


Figure S-8. Reactivity ratio determination of MA with CEA with a nonlinear fit $F_1 = (r_{12}f_1^2 + f_1f_2) / (r_{12}f_1^2 + 2f_1f_2 + r_{21}f_2^2)$ to the experimental runs at 70 °C in DMF.

Table S-2: Experimental runs for determination of MA-HPA reactivity ratios in a DMF-d_7 at 70 °C.

Run	**Feed Ratio** [a] **(MA:HPA)**	**MA Conversion** [b] **(%)**	**HPA Conversion** [c] **(%)**	**Polymer Ratio** [d] **(MA:HPA)**
1	10:90	8	7	11:89
2	13:87	7	7	13:87
3	27:73	11	6	41:58
4	37:63	9	7	44:56
5	38:62	14	7	55:44
6	55: 45	17	8	72:28
7	80:20	12	4	92:8
8	82:18	8	3	91:9

[a] MA: HPA molar ratio in the feed as determined by ^{1}H NMR spectroscopy at 22 °C. [b,c] Percent molar conversion of MA and HPA, respectively, as determined by ^{1}H NMR spectroscopy. The total monomer conversion was kept less than 15% in all runs, and the composition drift was considered to be negligible. [d] MA:HPA molar ratio in the polymer as determined by ^{1}H NMR spectroscopy.

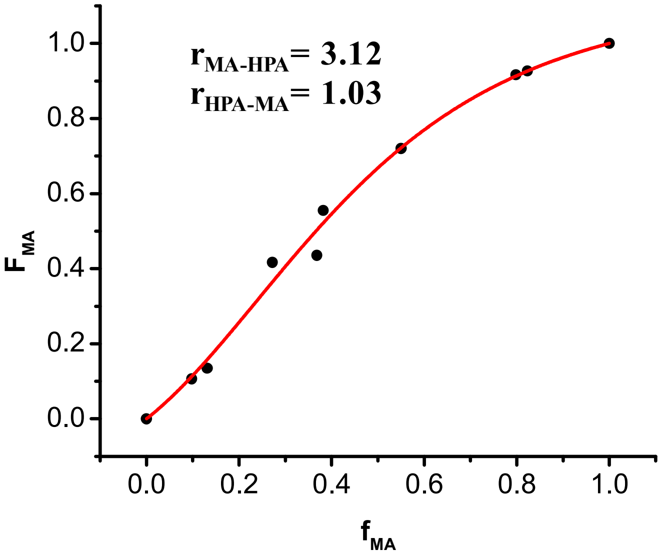


Figure S-9. Reactivity ratio determination of MA with HPA with a nonlinear fit $F_1 = (r_{12}f_1^2 + f_1f_2) / (r_{12}f_1^2 + 2f_1f_2 + r_{21}f_2^2)$ to the experimental runs at 70 °C in DMF.

Table S-3: Experimental runs for determination of MA-PAA reactivity ratios in a DMF-d_7 at 70 °C.

Run	Feed Ratio[a] (MA:PAA)	MA Conversion[b] (%)	PAA Conversion[c] (%)	Polymer Ratio[d] (MA:PAA)
1	08:92	15	11	11:89
2	14:86	14	14	13:87
3	28:72	10	09	30:70
4	48:52	07	10	36:64
5	62:38	10	13	56:44
6	75:25	9	30	53:47
7	89:11	11	22	80:20

[a] MA: PAA molar ratio in the feed as determined by ^{1}H NMR spectroscopy at 22 °C. [b,c] Percent molar conversion of MA and PAA, respectively, as determined by ^{1}H NMR spectroscopy. The total monomer conversion was kept less than 15% in all runs, and the composition drift was considered to be negligible. [d] MA:PAA molar ratio in the polymer as determined by ^{1}H NMR spectroscopy.

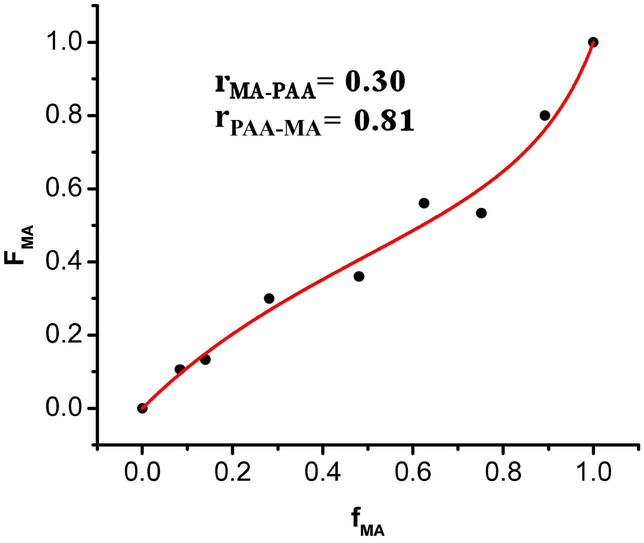


Figure S-10. Reactivity ratio determination of MA with PAA with a nonlinear fit $F_1 = (r_{12}f_1^2 + f_1f_2) / (r_{12}f_1^2 + 2f_1f_2 + r_{21}f_2^2)$ to the experimental runs at 70 °C in DMF.

Table S-4: Experimental runs for determination of CEA-PAA reactivity ratios in a DMF-d_7 at 70 °C.

Run	Feed Ratio [a] (CEA:PAA)	CEA Conversion [b] (%)	PAA Conversion [c] (%)	Polymer Ratio [d] (CEA:PAA)
1	16:84	10	10	16:84
2	33:64	15	12	37:63
3	49:51	11	12	47:53
4	53:47	14	13	54:46
5	60:40	13	10	67:33
6	78:22	13	11	80:20
7	91:09	13	09	93:7

[a] CEA: PAA molar ratio in the feed as determined by ^{1}H NMR spectroscopy at 22 °C. [b,c] Percent molar conversion of CEA and PAA, respectively, as determined by ^{1}H NMR spectroscopy. The total monomer conversion was kept less than 15% in all runs, and the composition drift was considered to be negligible. [d] CEA:PAA molar ratio in the polymer as determined by ^{1}H NMR spectroscopy.

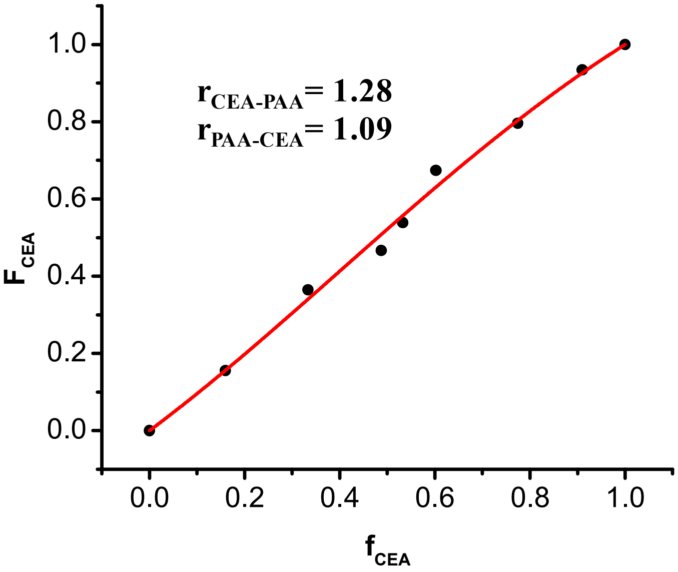


Figure S-11. Reactivity ratio determination of CEA with PAA with a nonlinear fit $F_1 = (r_{12}f_1^2 + f_1f_2) / (r_{12}f_1^2 + 2f_1f_2 + r_{21}f_2^2)$ to the experimental runs at 70 °C in DMF.

Table S-5: Experimental runs for determination of HPA-PAA reactivity ratios in a DMF-d_7 at 70 °C.

Run	Feed Ratio [a] (HPA:PAA)	HPA Conversion [b] (%)	PAA Conversion [c] (%)	Polymer Ratio [d] (HPA:PAA)
1	10:90	8	10	7:93
2	15:85	7	9	11:89
3	29:71	10	15	20:80
4	44:56	11	11	45:55
5	50:50	11	14	44:56
6	59:41	11	16	49:51
7	74:26	11	14	69:31
8	89:11	13	16	87:13

[a] HPA: PAA molar ratio in the feed as determined by ^{1}H NMR spectroscopy at 22 °C. [b,c] Percent molar conversion of HPA and PAA, respectively, as determined by ^{1}H NMR spectroscopy. The total monomer conversion was kept less than 15% in all runs, and the composition drift was considered to be negligible. [d] HPA:PAA molar ratio in the polymer as determined by ^{1}H NMR spectroscopy.

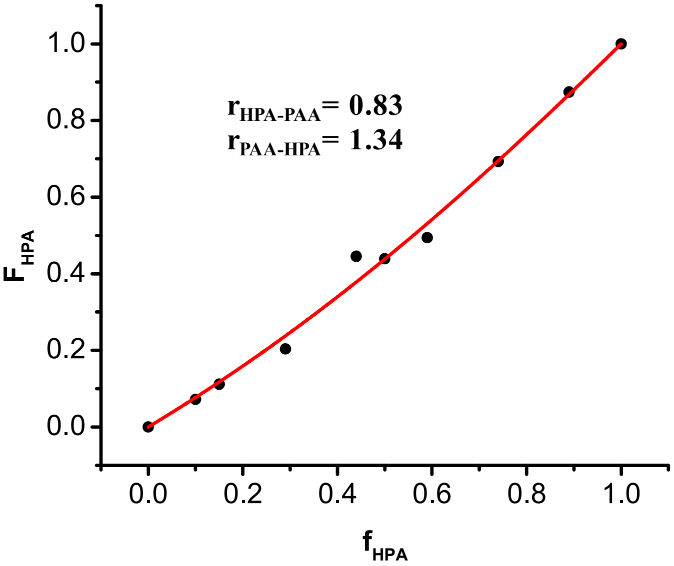


Figure S-12. Reactivity ratio determination of HPA with PAA with a nonlinear fit $F_1 = (r_{12}f_1^2 + f_1f_2) / (r_{12}f_1^2 + 2f_1f_2 + r_{21}f_2^2)$ to the experimental runs at 70 °C in DMF.

Table S-6: Experimental runs for determination of CEA-HPA reactivity ratios in a DMF-d_7 at 70 °C.

Run	**Feed Ratio** [a] **(CEA:HPA)**	**CEA Conversion** [b] **(%)**	**HPA Conversion** [c] **(%)**	**Polymer Ratio** [d] **(CEA:HPA)**
1	13:87	14	12	15:85
2	16:84	12	12	17:83
3	31:69	9	15	22:78
4	45:55	9	18	29:71
5	50:50	8	15	34:66
6	60:40	8	15	46:54
7	74:26	8	19	55:45
8	90:10	10	30	75:25

[a] CEA: HPA molar ratio in the feed as determined by ^{1}H NMR spectroscopy at 22 °C. [b,c] Percent molar conversion of CEA and HPA, respectively, as determined by ^{1}H NMR spectroscopy. The total monomer conversion was kept less than 15% in all runs, and the composition drift was considered to be negligible. [d] CEA:HPA molar ratio in the polymer as determined by ^{1}H NMR spectroscopy.

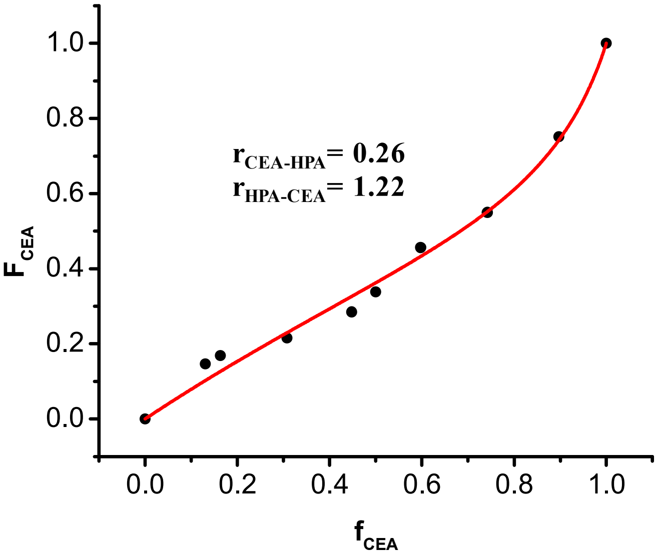


Figure S-13. Reactivity ratio determination of CEA with HPA with a nonlinear fit $F_1 = (r_{12}f_1^2 + f_1f_2) / (r_{12}f_1^2 + 2f_1f_2 + r_{21}f_2^2)$ to the experimental runs at 70 °C in DMF.

4 Representative Molecular Characterization Figures

Polymer characterization was conducted using ^{1}H NMR and SEC instruments. ^{1}H NMR spectroscopy was carried out on a Varian Inova 500 spectrometer at 22 °C. See Figure S-14 for a representative ^{1}H NMR spectra of p(MA-*stat*-CEA-*stat*-HPA-*stat*-PAA) which contains 77.4% MA (3.62 ppm, 3H), 7% CEA (2.63 ppm, 2H), 7.8% PAA (2.02 ppm, 3H), 7.8% HPA (1.21 ppm, 3H).

The number average molecular weight M_n was determined by end-group analysis is based on the ^{1}H NMR spectra of the purified polymer. The proton integrations of RAFT agent end group signal at 0.97ppm for $\underline{CH_3}$-CH_2-CH_2-S (3H) is compared to the characteristic monomer proton signals at 3.62 (O$\underline{CH_3}$, 3H of MA), 2.64 (-$\underline{CH_2}$-COOH, 2H of CEA), 2.02 (-CO-$\underline{CH_3}$, 3H of PAA), and 1.10-1.30 (CH-$\underline{CH_3}$, combined signal for 3H of PAA and HPA).

The percentage of each monomer in the polymer was calculated by comparing the characteristic monomer protons (O$\mathbf{CH_3}$ for MA, -$\mathbf{CH_2}$-COOH for CEA, C-$\mathbf{CH_3}$ for HPA, and $\mathbf{CH_3}$-CO for PAA) integrations with the polymer backbone protons at 1.90 ppm (1H, **-CH-**) and 1.3-2.0 ppm (2H, -$\mathbf{CH_2}$-).

SEC measurements were conducted on an Agilent 1260 Infinity liquid chromatography system equipped with one Waters Styragel guard column and three Waters Styragel columns (HR6, HR4, and HR1) with pore sizes suitable for materials with effective molecular weights from 100 to 10,000,000 g mol^{-1}. The SEC is equipped with an Agilent 1260 Infinity Variable Wavelength Detector monitoring at 254 nm (80 Hz data collection frequency), a Wyatt Dawn Heleos II light scattering detector at a laser wavelength of 663.6 nm (18 angles from 10° to 160°), and a Wyatt Optilab T-rEX refractive index detector operating at 658 nm. Tetrahydrofuran (THF) was run as the mobile phase at 1.0 mL min^{-1} at 25 °C. The d*n*/d*c* value of

0.0676 mL g^{-1} was measured using an Abbe Refractometer with a red LED as a light source in concentration using the SEC-grade THF at 25 °C. See Figure S-15 for a representative SEC trace.

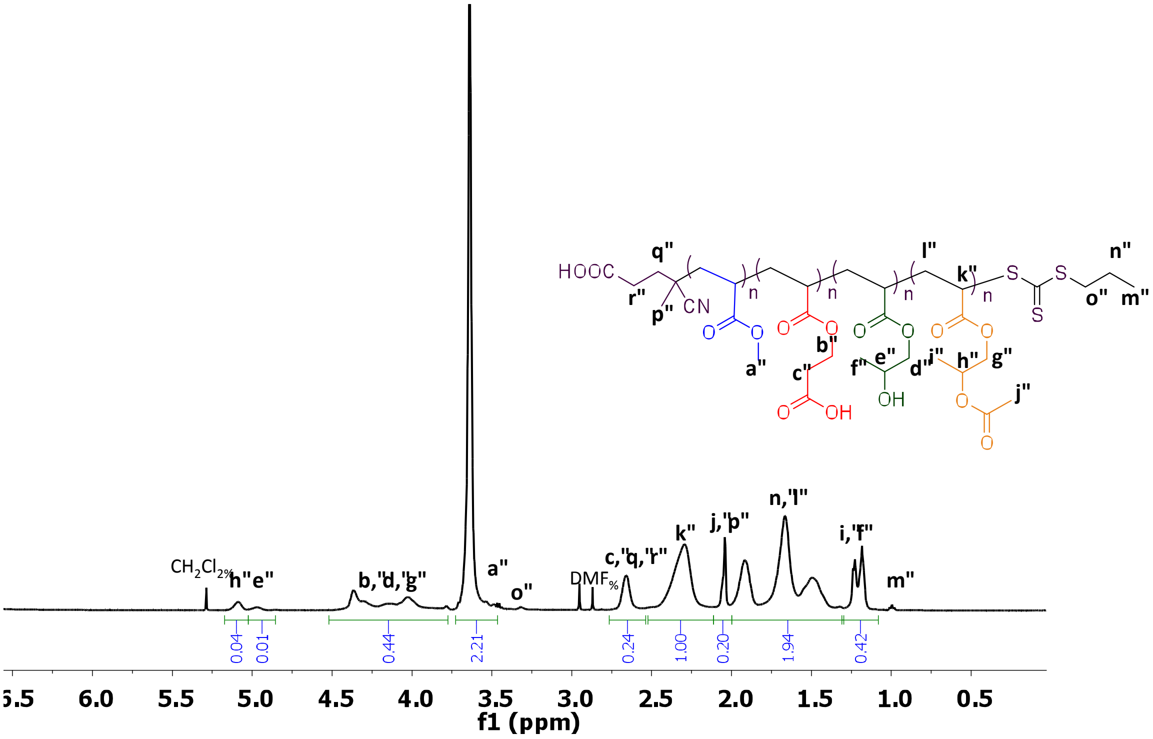


Figure S-14. ^{1}H NMR spectra of p(MA-*stat*-CEA-*stat*-HPA-*stat*-PAA).

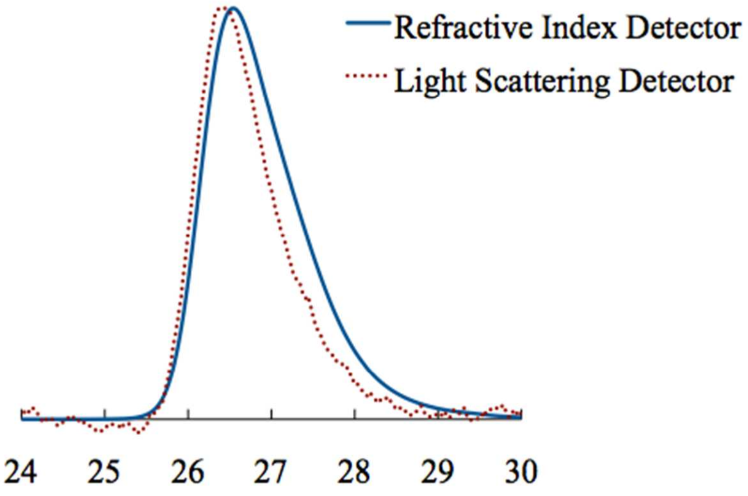
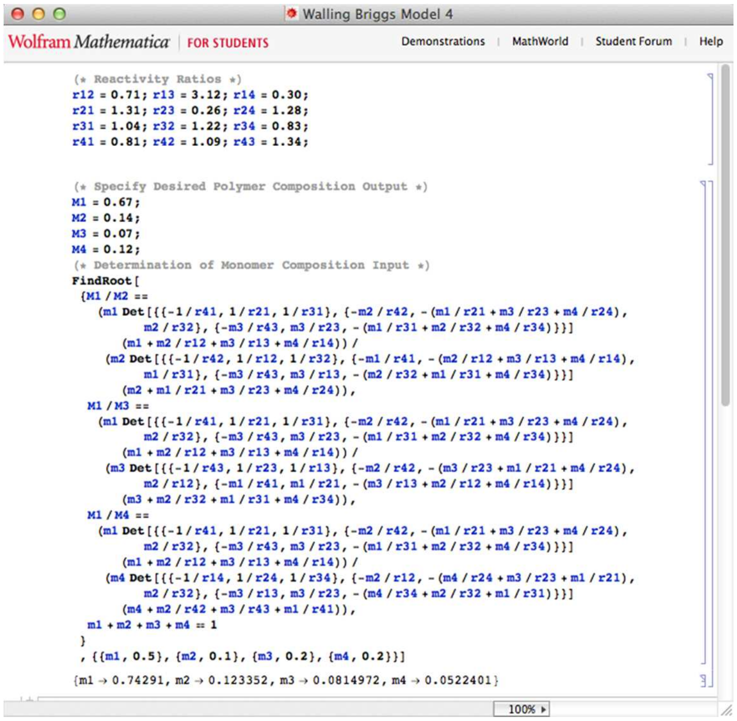


Figure S-15. SEC chromatogram of p(MA-*stat*-CEA-*stat*-HPA-*stat*-PAA) from Run 2 stopped at 44% conversion. The calculated M_n and Đ were 11.4 kg/mol and 1.09, respectively.

5 Walling-Briggs and Skeist Model Code

Figures S-16 and S-17 show an image of the Mathematica and Matlab codes used to solve the four-component Walling-Briggs and Skeist models, respectively. The files used for these calculations are available online. They can be easily extended to include additional monomeric components or reduced for simpler systems – if interested, please contact the authors for more information.

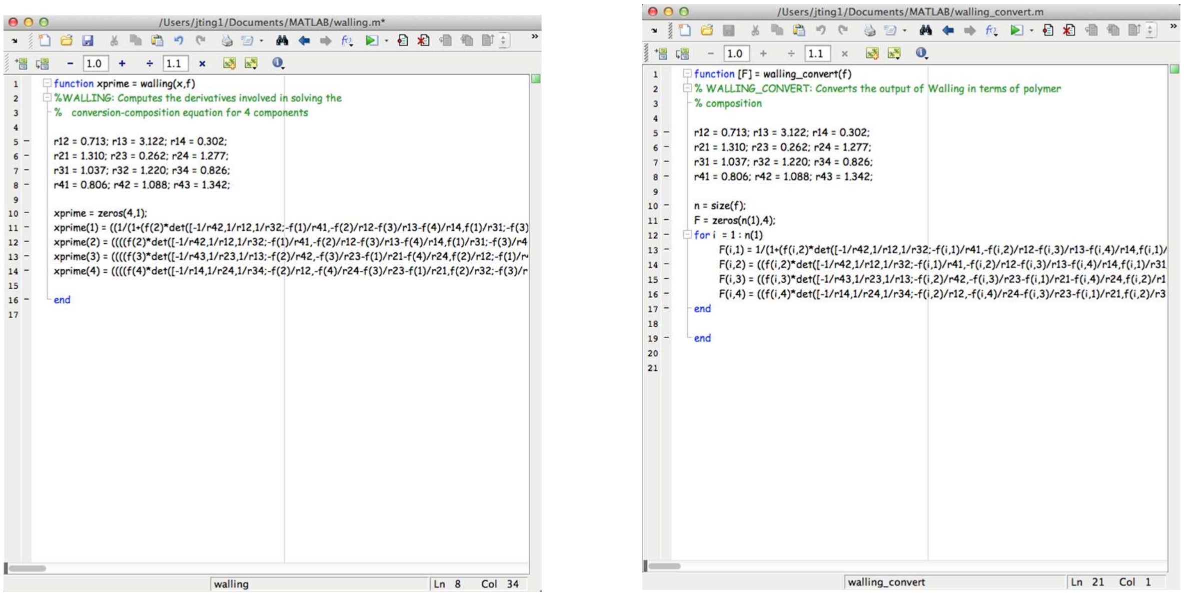


```
(* Reactivity Ratios *)
r12 = 0.71; r13 = 3.12; r14 = 0.30;
r21 = 1.31; r23 = 0.26; r24 = 1.28;
r31 = 1.04; r32 = 1.22; r34 = 0.83;
r41 = 0.81; r42 = 1.09; r43 = 1.34;

(* Specify Desired Polymer Composition Output *)
M1 = 0.67;
M2 = 0.14;
M3 = 0.07;
M4 = 0.12;
(* Determination of Monomer Composition Input *)
FindRoot[
 {M1 / M2 ==
    (m1 Det[{{-1 / r41, 1 / r21, 1 / r31}, {-m2 / r42, - (m1 / r21 + m3 / r23 + m4 / r24),
          m2 / r32}, {-m3 / r43, m3 / r23, - (m1 / r31 + m2 / r32 + m4 / r34)}}]
       (m1 + m2 / r12 + m3 / r13 + m4 / r14)) /
     (m2 Det[{{-1 / r42, 1 / r12, 1 / r32}, {-m1 / r41, - (m2 / r12 + m3 / r13 + m4 / r14),
          m1 / r31}, {-m3 / r43, m3 / r13, - (m2 / r32 + m1 / r31 + m4 / r34)}}]
       (m2 + m1 / r21 + m3 / r23 + m4 / r24)),
  M1 / M3 ==
    (m1 Det[{{-1 / r41, 1 / r21, 1 / r31}, {-m2 / r42, - (m1 / r21 + m3 / r23 + m4 / r24),
          m2 / r32}, {-m3 / r43, m3 / r23, - (m1 / r31 + m2 / r32 + m4 / r34)}}]
       (m1 + m2 / r12 + m3 / r13 + m4 / r14)) /
     (m3 Det[{{-1 / r43, 1 / r23, 1 / r13}, {-m2 / r42, - (m3 / r23 + m1 / r21 + m4 / r24),
          m2 / r12}, {-m1 / r41, m1 / r21, - (m3 / r13 + m2 / r12 + m4 / r14)}}]
       (m3 + m2 / r32 + m1 / r31 + m4 / r34)),
  M1 / M4 ==
    (m1 Det[{{-1 / r41, 1 / r21, 1 / r31}, {-m2 / r42, - (m1 / r21 + m3 / r23 + m4 / r24),
          m2 / r32}, {-m3 / r43, m3 / r23, - (m1 / r31 + m2 / r32 + m4 / r34)}}]
       (m1 + m2 / r12 + m3 / r13 + m4 / r14)) /
     (m4 Det[{{-1 / r14, 1 / r24, 1 / r34}, {-m2 / r12, - (m4 / r24 + m3 / r23 + m1 / r21),
          m2 / r32}, {-m3 / r13, m3 / r23, - (m4 / r34 + m2 / r32 + m1 / r31)}}]
       (m4 + m2 / r42 + m3 / r43 + m1 / r41)),
  m1 + m2 + m3 + m4 == 1
 }
 , {{m1, 0.5}, {m2, 0.1}, {m3, 0.2}, {m4, 0.2}}]

{m1 → 0.74291, m2 → 0.123352, m3 → 0.0814972, m4 → 0.0522401}
```

Figure S-16. Four-component Walling-Briggs model code. The measured reactivity ratios are input at the top. For the polymer composition [MA/CEA/HPA/PAA] = [0.67/0.14/0.07/0.12], the system of equations is numerically solved using an input guess of [0.50/0.10/0.20/0.20]. The calculated monomer feed ratio is found to be [0.74/0.12/0.08/0.05] to target the desired polymer composition.



```matlab
function xprime = walling(x,f)
%WALLING: Computes the derivatives involved in solving the
%   conversion-composition equation for 4 components

r12 = 0.713; r13 = 3.122; r14 = 0.302;
r21 = 1.310; r23 = 0.262; r24 = 1.277;
r31 = 1.037; r32 = 1.220; r34 = 0.826;
r41 = 0.806; r42 = 1.088; r43 = 1.342;

xprime = zeros(4,1);
xprime(1) = ((1/(1+(f(2)*det([-1/r42,1/r12,1/r32;-f(1)/r41,-f(2)/r12-f(3)/r13-f(4)/r14,f(1)/r31;-f(3)
xprime(2) = ((((f(2)*det([-1/r42,1/r12,1/r32;-f(1)/r41,-f(2)/r12-f(3)/r13-f(4)/r14,f(1)/r31;-f(3)/r4
xprime(3) = ((((f(3)*det([-1/r43,1/r23,1/r13;-f(2)/r42,-f(3)/r23-f(1)/r21-f(4)/r24,f(2)/r12;-f(1)/r
xprime(4) = ((((f(4)*det([-1/r14,1/r24,1/r34;-f(2)/r12,-f(4)/r24-f(3)/r23-f(1)/r21,f(2)/r32;-f(3)/r

end
```

(a)

```matlab
function [F] = walling_convert(f)
% WALLING_CONVERT: Converts the output of Walling in terms of polymer
% composition

r12 = 0.713; r13 = 3.122; r14 = 0.302;
r21 = 1.310; r23 = 0.262; r24 = 1.277;
r31 = 1.037; r32 = 1.220; r34 = 0.826;
r41 = 0.806; r42 = 1.088; r43 = 1.342;

n = size(f);
F = zeros(n(1),4);
for i  = 1 : n(1)
        F(i,1) = 1/(1+(f(i,2)*det([-1/r42,1/r12,1/r32;-f(i,1)/r41,-f(i,2)/r12-f(i,3)/r13-f(i,4)/r14,f(i,1)/
        F(i,2) = ((f(i,2)*det([-1/r42,1/r12,1/r32;-f(i,1)/r41,-f(i,2)/r12-f(i,3)/r13-f(i,4)/r14,f(i,1)/r31
        F(i,3) = ((f(i,3)*det([-1/r43,1/r23,1/r13;-f(i,2)/r42,-f(i,3)/r23-f(i,1)/r21-f(i,4)/r24,f(i,2)/r1
        F(i,4) = ((f(i,4)*det([-1/r14,1/r24,1/r34;-f(i,2)/r12,-f(i,4)/r24-f(i,3)/r23-f(i,1)/r21,f(i,2)/r3
end

end
```

(b)

Figure S-17. Four-component Skeist model code. (a) The nonlinear system of coupled ordinary differential equations is stored in a script file in Matlab. (b) A script file to convert the monomer to polymer ratio using the Walling-Briggs model.

6 Supporting Skeist Model Plots

Figure S-18 contains the instantaneous and cumulative Skeist model plots for Run 1. Compared to Run 2, there is a significant depletion of HPA as the polymerization proceeds. From the instantaneous composition change as a function of total monomer conversion, the incorporation of HPA to active chain ends rapidly decreases in likelihood. Experimental results deviated from the theoretical curves potentially because of the pre-equilibration time associated with higher CEA content. This interesting behavior motivates us to continue exploring the mechanistic RAFT kinetics. Thus, with the inherent compositional drift in this system, to ensure chemical homogeneity, the reaction should be stopped at low conversions (~ 40%).

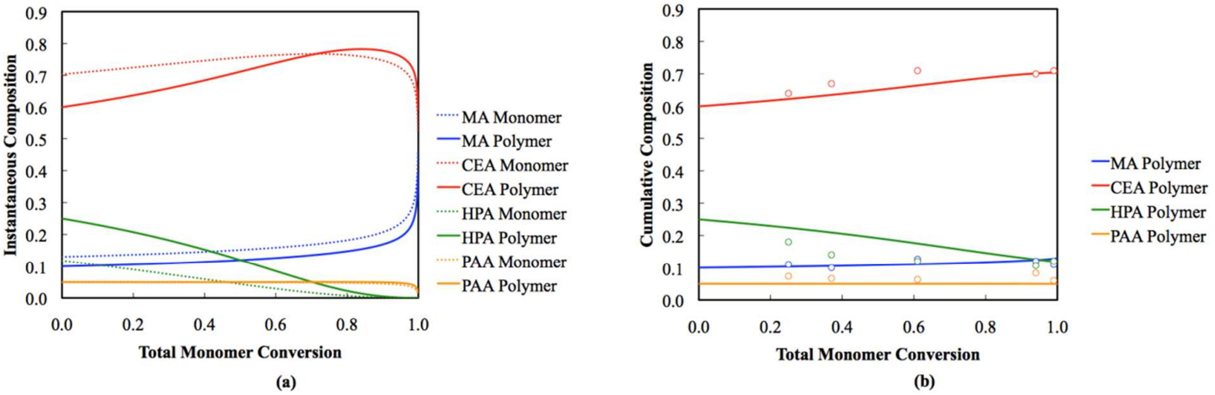


Figure S-18. Comparison of (a) instantaneous and (b) cumulative chemical composition versus conversion for a targeted [MA / CEA / HPA / PAA] = [0.10 / 0.60 / 0.25 / 0.05] polymer composition. Dotted and solid lines represent the predicted monomer and polymer compositions, respectively. Open circles describe experimental data points of the average polymer composition, determined by ^{1}H NMR.

7 Homopolymerization of Acrylate Monomers

Figure S-19 shows the initial RAFT homopolymerization kinetic study of MA, CEA, HPA, and PAA. These studies were carried out in accordance to the quarterpolymer synthesis procedure above. The slow inhibition time of MA is well documented in literature.[2] Further study of how RAFT pre-equilibration affects chemical composition is currently underway.

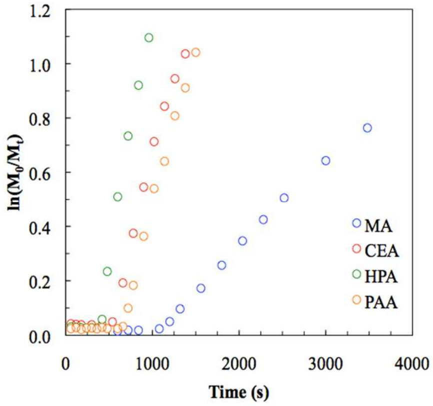


Figure S-19. RAFT homopolymerization kinetics of MA, CEA, HPA, and PAA ($[M]_0$:[CPP]:[AIBN] = 200:10:1) at 70 °C in DMF-d_7 with a 3 M monomer concentration. M_0/M_t denotes the ratio between the monomer concentrations initially and at time *t*. Open circles describe experimental data points, determined by ^{1}H NMR.

(2) McLeary, J. B.; McKenzie, J. M.; Tonge, M. P.; Sanderson, R. D.; Klumperman, B. *Chem. Commun.* **2004**, *17*, 1950-1951.