

# Synthesis and styrene copolymerization of novel chloro and fluoro ring-disubstituted isopropyl cyanophenylacrylates

Christopher R. Savittieri, Atharva A. Shinde, Sara M Rocus, William S. Schjerven, and Gregory B. Kharas

DePaul University, Chemistry and Biochemistry Department, 1110 West Belden Avenue, Chicago, IL 60614-3214

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## Abstract

Novel chloro and fluoro ring-disubstituted isopropyl 3-phenyl-2-cyanoacrylates,  $RPhCH=C(CN)CO_2CH(CH_3)_2$  (where R is 2-chloro-4-fluoro, 2-chloro-6-fluoro, 3-chloro-2-fluoro, 3-chloro-4-fluoro, 4-chloro-3-fluoro) were prepared and copolymerized with styrene. The acrylates were synthesized by the piperidine catalyzed Knoevenagel condensation of ring-disubstituted benzaldehydes and isopropyl cyanoacetate and characterized by CHN elemental analysis, IR,  $^1H$ - and  $^{13}C$ -NMR. All the acrylates were copolymerized with styrene in solution with radical initiation (ABCN) at 70°C. The

composition of the copolymers was calculated from nitrogen analysis, and the structures were analyzed by IR,  $^1\text{H}$  and  $^{13}\text{C}$ -NMR, GPC, DSC, and TGA.

**Keywords:** Phenyl cyanoacrylates, Knoevenagel condensation, radical copolymerization, styrene copolymers

\* CONTACT: Gregory B. Kharas, Chemistry and Biochemistry Department, DePaul University, Chicago, IL 60614-3214. E-mail: gkharas@depaul.edu

## 1. Introduction

Ring-functionalized cyanoacrylates (PCA),  $\text{R}^1\text{PhCH}=\text{C}(\text{CN})\text{CO}_2\text{R}^2$  continue to attract attention as compounds with interesting properties, organic intermediates, and as comonomers for modification of polymers. Earlier we have prepared and copolymerized halogen ring-disubstituted PCA esters, methyl (1), ethyl (2), propyl (3, 4), and butyl (5) cyanoacrylates. Recently we have reported synthesis and styrene copolymerization of a number of novel halogen ring-substituted isopropyl esters of phenyl cyanoacrylates (6-8). With the objective to design novel structures, that could serve as a spring board for further development of novel materials with new properties and applications, we have prepared novel chloro and fluoro ring-disubstituted isopropyl phenylcyanoacrylates,  $\text{RPhCH}=\text{C}(\text{CN})\text{CO}_2\text{CH}(\text{CH}_3)_2$  where R is 2-chloro-4-fluoro, 2-chloro-6-fluoro, 3-chloro-2-fluoro, 3-chloro-4-fluoro, 4-chloro-3-fluoro, and explore the feasibility of their copolymerization with styrene. To the best of our knowledge (9), there have been no reports

on either synthesis of these isopropyl 3-phenyl-2-cyanoacrylates, nor their copolymerization with styrene.

## **2. Experimental**

### **2.1. Materials**

2-chloro-4-fluoro, 2-chloro-6-fluoro, 3-chloro-2-fluoro, 3-chloro-4-fluoro, 4-chloro-3-fluorobenzaldehydes, isopropyl cyanoacetate, piperidine, styrene, 1,1'-azobiscyclohexanecarbonitrile, (ABCN), and toluene supplied from Sigma-Aldrich Co., were used as received.

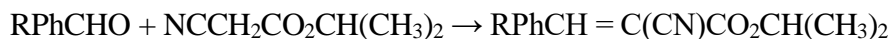
### **2.2. Instrumentation**

Infrared spectra of the TSE monomers and polymers (NaCl plates) were determined with an ABB FTLA 2000 FT-IR spectrometer. The melting points of the monomers, the glass transition temperatures ( $T_g$ ), of the copolymers were measured with TA (Thermal Analysis, Inc.) Model Q10 differential scanning calorimeter (DSC). The thermal scans were performed in a 25 to 200°C range at heating rate of 10°C/min.  $T_g$  was taken as a midpoint of a straight line between the inflection of the peak's onset and endpoint. The thermal stability of the copolymers was measured by thermogravimetric analyzer (TGA) TA Model Q50 from ambient temperature to 800°C at 20°C/min. The molecular weights of the polymers was determined relative to polystyrene standards in THF solutions with sample concentrations 0.8% (w/v) by gel permeation chromatography (GPC) using a Altech 426 HPLC pump at an elution rate of 1.0 mL/min; Phenogel 5 $\mu$  Linear column at 25°C and

Viscotek 302 detector.  $^1\text{H}$ - and  $^{13}\text{C}$ -NMR spectra were obtained on 10-25% (w/v) monomer or polymer solutions in  $\text{CDCl}_3$  at ambient temperature using Avance 300 MHz spectrometer. Elemental analyses were performed by Midwest Microlab, LLC (IN).

### ***2.3. Synthesis of chlorine and fluorine phenyl-disubstituted isopropyl phenylcyanoacrylates***

The chlorine and fluorine ring-disubstituted isopropyl phenylcyanoacrylates (IPCA) were synthesized by Knoevenagel condensation (10) of a ring-substituted benzaldehyde with isopropyl cyanoacetate, catalyzed by base, piperidine.



Where R is 2-chloro-4-fluoro, 2-chloro-6-fluoro, 3-chloro-2-fluoro, 3-chloro-4-fluoro, 4-chloro-3-fluoro. The preparation procedure was essentially the same for all the monomers. In a typical synthesis, equimolar amounts of isopropyl cyanoacetate and an appropriate dihalogen ring-substituted benzaldehyde were mixed in equimolar ratio in a 20 mL vial. A few drops of piperidine were added with stirring. The product of the reaction was isolated by filtration and purified by crystallization from 2-propanol. The condensation reaction proceeded smoothly, yielding products, which were purified by conventional techniques.

#### ***2.3.1. Isopropyl 3-(2-chloro-4-fluorophenyl)-2-cyanoacrylate***

Yield 84%; mp 91.4°C,  $^1\text{H-NMR}$   $\delta$  8.3 (s, 1H, CH=), 7.6-6.9 (m, 3H, Ph), 5.1 (m, 1H, OCH), 1.3 (d, 6H, CH<sub>3</sub>);  $^{13}\text{C-NMR}$   $\delta$  166 (C=O), 150 (HC=), 166, 135, 131, 117, 114 (Ph), 116 (CN), 132 (C=), 68 (OCH), 22 (CH<sub>3</sub>); IR (cm<sup>-1</sup>): 3102-2834 (m, C-H), 2236 (m, CN), 1725 (s, C=O), 1585 (s, C=C), 1278 (s, C-O-C), 892, 775 (s, C-H out of plane). Anal. Calcd. for C<sub>13</sub>H<sub>11</sub>ClFNO<sub>2</sub>: C, 58.33; H, 4.14; N, 5.23; Found: C, 58.14; H, 4.33; N, 5.27.

### **2.3.2. Isopropyl 3-(2-chloro-6-fluorophenyl)-2-cyanoacrylate**

Yield 92%; mp 121.2°C,  $^1\text{H-NMR}$   $\delta$  8.4 (s, 1H, CH=), 7.6-7.0 (m, 3H, Ph), 5.1 (m, 1H, OCH), 1.3 (d, 6H, CH<sub>3</sub>);  $^{13}\text{C-NMR}$   $\delta$  166 (C=O), 152 (HC=), 162, 135, 133, 126, 119, 116 (Ph), 115 (CN), 92 (C=), 68 (OCH), 22 (CH<sub>3</sub>); IR (cm<sup>-1</sup>): 3220-2805 (m, C-H), 2237 (m, CN), 1738 (s, C=O), 1577 (s, C=C), 1278 (s, C-O-C), 892, 752 (s, C-H out of plane). Anal. Calcd. for C<sub>13</sub>H<sub>11</sub>ClFNO<sub>2</sub>: C, 58.33; H, 4.14; N, 5.23; Found: C, 52.17; H, 4.39; N, 5.00.

### **2.3.3. Isopropyl 3-(3-chloro-2-fluorophenyl)-2-cyanoacrylate**

Yield 90%; mp 102.5°C,  $^1\text{H-NMR}$   $\delta$  8.3 (s, 1H, CH=), 7.8-7.1 (m, 3H, Ph), 5.1 (m, 1H, OCH), 1.3 (d, 6H, CH<sub>3</sub>);  $^{13}\text{C-NMR}$   $\delta$  166 (C=O), 146 (HC=), 162, 129, 121, 120 (Ph), 116 (CN), 105 (C=), 68 (OCH), 22 (CH<sub>3</sub>); IR (cm<sup>-1</sup>): 3212-2826 (m, C-H), 2232 (m, CN), 1718 (s, C=O), 1587 (s, C=C), 1272 (s, C-O-C), 898, 781 (s, C-H out of plane). Anal. Calcd. for C<sub>13</sub>H<sub>11</sub>ClFNO<sub>2</sub>: C, 58.33; H, 4.14; N, 5.23; Found: C, 57.75; H, 4.20; N, 5.19.

### **2.3.4. Isopropyl 3-(3-chloro-4-fluorophenyl)-2-cyanoacrylate**

Yield 71%; mp 82.8°C,  $^1\text{H-NMR}$   $\delta$  8.5 (s, 1H, CH=), 8.1-7.2 (m, 3H, Ph), 5.1 (m, 1H, OCH), 1.3 (d, 6H, CH<sub>3</sub>);  $^{13}\text{C-NMR}$   $\delta$  166 (C=O), 152 (HC=), 160, 132, 130, 129, 129, 116 (Ph), 115 (CN), 103 (C=), 68 (OCH), 22 (CH<sub>3</sub>); IR (cm<sup>-1</sup>): 3232-2822 (m, C-H), 2233 (m, CN), 1720 (s, C=O), 1592 (s, C=C), 1262 (s, C-O-C), 891, 779 (s, C-H out of plane). Anal. Calcd. for C<sub>13</sub>H<sub>11</sub>ClFNO<sub>2</sub>: C, 58.33; H, 4.14; N, 5.23; Found: C, 55.96; H, 4.13; N, 5.16.

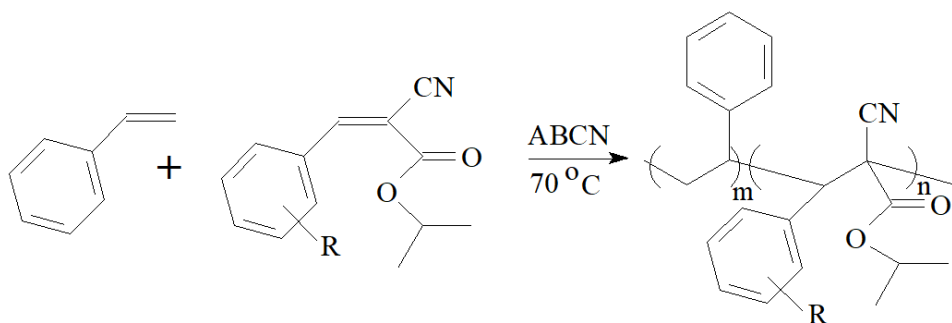
### **2.3.5. Isopropyl 3-(4-chloro-3-fluorophenyl)-2-cyanoacrylate**

Yield 87%; mp 101.2°C,  $^1\text{H-NMR}$   $\delta$  8.6 (s, 1H, CH=), 7.9-7.2 (m, 3H, Ph), 5.1 (m, 1H, OCH), 1.3 (d, 6H, CH<sub>3</sub>);  $^{13}\text{C-NMR}$   $\delta$  166 (C=O), 153 (HC=), 159, 133, 130 (Ph), 116 (CN), 104 (C=), 68 (OCH), 22 (CH<sub>3</sub>); IR (cm<sup>-1</sup>): 3301-2845 (m, C-H), 2232 (m, CN), 1737 (s, C=O), 1581 (s, C=C), 1266 (s, C-O-C), 987, 843 (s, C-H out of plane). Anal. Calcd. for C<sub>13</sub>H<sub>11</sub>ClFNO<sub>2</sub>: C, 58.33; H, 4.14; N, 5.23; Found: C, 58.47; H, 4.29; N, 5.9.

## **2.4. Copolymerization**

Copolymers of the ST and the IPCA monomers were prepared in 25-mL glass screw cap vials at ST/ IPCA = 3 (mol) the monomer feed using 0.12 mol/L of ABCN at an overall monomer concentration 2.44 mol/L in 10 mL of toluene. The copolymerization was conducted at 70°C. After a predetermined time, the mixture was cooled to room temperature, and precipitated dropwise in methanol. The composition of the copolymers

was determined based on the nitrogen content. The copolymers' yield was kept low to minimize copolymer compositional drift at given conversion.



**Scheme 1.** ST-IPCA copolymer synthesis, R = 2-chloro-4-fluoro, 2-chloro-6-fluoro, 3-chloro-2-fluoro, 3-chloro-4-fluoro, 4-chloro-3-fluoro.

#### 2.4.1. *ST- Isopropyl 3-(2-chloro-4-fluorophenyl)-2-cyanoacrylate Copolymer*

Yield 13.6%;  $^1\text{H-NMR}$   $\delta$  7.6-6.7 (Ph), 5.4-4.8 (OCH), 3.7-2.8 (CHPh), 2.5-2.1 (CH, IPCA), 1.8-1.4 ( $\text{CH}_2$ ), 1.2-1.0 ( $\text{CH}_3$ );  $^{13}\text{C-NMR}$   $\delta$  166-160 (C=O), 159-124 (Ph), 117-116 (CN), 78-73 (OCH), 48-33 ( $\text{CH}_2$ ), 45-38 (CHPh, ST), 35-30 (CH, IPCA), 23-21 ( $\text{CH}_3$ ); IR ( $\text{cm}^{-1}$ ): 3823-2809 (m, C-H), 2244 (m, CN), 1738 (s, C=O), 1134 (s, C-O-C), 813, 747 (s, C-H out of plane). Anal. for N (wt%) 2.73.

#### 2.4.2. *ST- Isopropyl 3-(2-chloro-6-fluorophenyl)-2-cyanoacrylate Copolymer*

Yield 11.2%;  $^1\text{H-NMR}$   $\delta$  7.7-6.4 (Ph), 5.1-4.7 (OCH), 3.8-2.6 (CHPh), 2.4-2.1 (CH, IPCA), 1.7-1.3 ( $\text{CH}_2$ ), 1.2-1.0 ( $\text{CH}_3$ );  $^{13}\text{C-NMR}$   $\delta$  167-162 (C=O), 159-122 (Ph), 117-116 (CN), 75-71 (OCH), 46-33 ( $\text{CH}_2$ ), 43-37 (CHPh, ST), 34-31 (CH, IPCA), 25-22 ( $\text{CH}_3$ ); IR ( $\text{cm}^{-1}$ ): 3500-2800 (m, C-H), 2241 (m, CN), 1739 (s, C=O), 1249 (s, C-O-C), 832, 777 (s, C-H out of plane). Anal. for N (wt%) 2.68.

**2.4.3. ST- Isopropyl 3-(3-chloro-2-fluorophenyl)-2-cyanoacrylate Copolymer**

Yield 13.4%;  $^1\text{H-NMR}$   $\delta$  7.9-6.6 (Ph), 5.1-4.8 (OCH), 3.8-2.6 (CHPh), 2.6-2.3 (CH, IPCA), 1.7-1.2 ( $\text{CH}_2$ ), 1.5-1.2 ( $\text{CH}_3$ );  $^{13}\text{C-NMR}$   $\delta$  165-161 (C=O), 159-119 (Ph), 117-116 (CN), 76-72 (OCH), 47-35 ( $\text{CH}_2$ ), 42-37 (CHPh, ST), 36-30 (CH, IPCA), 25-21 ( $\text{CH}_3$ ); IR ( $\text{cm}^{-1}$ ): 3843-2825 (m, C-H), 2245 (m, CN), 1747 (s, C=O), 1249 (s, C-O-C), 832, 749 (s, C-H out of plane). Anal. for N (wt%) 2.82.

**2.4.4. ST- Isopropyl 3-(3-chloro-fluorophenyl)-2-cyanoacrylate Copolymer**

Yield 11.6%;  $^1\text{H-NMR}$   $\delta$  7.9-6.3 (Ph), 5.3-4.8 (OCH), 3.7-2.7 (CHPh), 2.5-2.1 (CH, IPCA), 1.6-1.3 ( $\text{CH}_2$ ), 1.3-1.1 ( $\text{CH}_3$ );  $^{13}\text{C-NMR}$   $\delta$  168-163 (C=O), 157-124 (Ph), 118-116 (CN), 76-71 (OCH), 47-36 ( $\text{CH}_2$ ), 43-36 (CHPh, ST), 36-32 (CH, IPCA), 25-20 ( $\text{CH}_3$ ); IR ( $\text{cm}^{-1}$ ): 3834-2808 (m, C-H), 2243 (m, CN), 1743 (s, C=O), 1248 (s, C-O-C), 828, 748 (s, C-H out of plane). Anal. for N (wt%) 2.69.

**2.4.5. ST- Isopropyl 3-(4-chloro-3-fluorophenyl)-2-cyanoacrylate Copolymer**

Yield 17.6%;  $^1\text{H-NMR}$   $\delta$  7.9-6.6 (Ph), 5.5-4.9 (OCH), 3.9-2.7 (CHPh), 2.8-2.3 (CH, IPCA), 1.8-1.3 ( $\text{CH}_2$ ), 1.4-1.0 ( $\text{CH}_3$ );  $^{13}\text{C-NMR}$   $\delta$  169-165 (C=O), 148-120 (Ph), 118-116 (CN), 76-73 (OCH), 47-35 ( $\text{CH}_2$ ), 42-32 (CHPh, ST), 37-33 (CH, IPCA), 24-22 ( $\text{CH}_3$ ); IR ( $\text{cm}^{-1}$ ): 3832-2848 (m, C-H), 2241 (m, CN), 1742 (s, C=O), 1276 (s, C-O-C), 821, 781 (s, C-H out of plane). Anal. for N (wt%) 2.76.

Copolymerization (Sch. 1) of chloro and fluoro ring-disubstituted IPCA with ST resulted in formation of copolymers (Table 1) with weight-average molecular masses 62.4 to 73.7



kD. According to elemental analysis, between 29.0 and 31.3 mol% of IPCA monomer is present in the copolymers prepared at ST/ IPCA = 3 (mol), which is indicative of relatively high reactivity of the monomers towards ST. The copolymers prepared in the present work are all soluble in ethyl acetate, THF, DMF and CHCl<sub>3</sub> and insoluble in methanol, ethyl ether, and petroleum ether.

**Table 1.** Copolymerization of chloro and fluoro ring-disubstituted isopropyl phenylcyanoacrylates with styrene.

						<i>TGA</i>			
R	Yield <sup>a</sup> (wt%)	N (wt%)	m <sub>2</sub> in copol. (mol%)	M <sub>w</sub> (kD)	T <sub>g</sub> (°C)	Onset of decomp. (°C)	10 wt% loss (°C)	50 wt% loss (°C)	Residue wt%
2-Chloro-4-fluoro	13.6	2.73	29.8	62.4	123	158	283	349	5.2
2-Chloro-6-fluoro	11.2	2.68	29.0	73.7	132	172	288	342	6.1
3-Chloro-2-fluoro	13.4	2.82	31.3	67.9	115	174	288	346	5.7
3-Chloro-4-fluoro	11.6	2.69	29.2	72.4	127	162	278	349	4.9
4-Chloro-3-fluoro	17.6	2.76	30.3	68.5	119	168	286	339	5.7

<sup>a</sup>Polymerization time was 8 h.

The ST- IPCA copolymers are amorphous and show no crystalline DSC endotherm. Results of thermal analysis of ST- IPCA copolymers are presented in Table 1. Information on the

degradation of the copolymers was obtained from thermogravimetric analysis.

Decomposition of the copolymers in nitrogen occurred in two steps, first in the 200-500°C range with residue (4.9-6.1% wt.), which then decomposed in the 500-800°C range.

#### **4. Conclusions**

Novel isopropyl chloro and fluoro ring-substituted cyanophenylacrylates were prepared and copolymerized with styrene. The compositions of novel copolymers were calculated from nitrogen analysis and the structures were analyzed by IR, H<sup>1</sup> and <sup>13</sup>C-NMR. The thermal gravimetric analysis indicated that the copolymers decompose in two steps, first in the 200-500°C range with a residue, which then decomposed in the 500-800°C range.

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#### **References**

1. Novel Copolymers of Styrene. 16. Halogen Ring-Disubstituted Methyl 2-Cyano-3-Phenyl-2-Propenoates. G.B. Kharas, S.E. Chavez, H. Browning, J. Sepe, M.E. Romanelli, M. Susnis, G. Choquegonzales, K. Fuentes, R. Treneva, and C. Murphy. *J. Macromol. Sci.* A51(10) 751-755 (2014)
2. Novel Copolymers of Styrene. 3. Halogen Ring-substituted Ethyl 2-Cyano-3-phenyl-2-propenoates. G.B. Kharas, E.S. Molina, K.E. Abma, R.A. Ali, K.D. Bairaktaris, F.P. Biasiello, E.A. Cygan, J. Gibson, S. Haq, D.E. Hoag, K. Johnson, S.I. Jordan,

- M.B. Mathews, C.A. Shaddock, N. Tuzik. *J. Macromol. Sci. A*50 (2) 139-143 (2013).
3. Synthesis and Radical Copolymerization of Novel Phenyl-Disubstituted Cyanoacrylates. C.R. Savittieri, S.M. Tinsley, A.J. Diehn, F. Hai, K.E. Humanski, E.J. Kempke, B.Y. Killam, J. Kozeny, E.W. Makhoul, M.C. Obert, A.C. Parisi, V.C. Parrilli, and G.B. Kharas. *Acad. J Polym Sci.* 2019; 2(5): 555597.  
DOI:10.19080/AJOP.2019.02.555597
  4. Synthesis and styrene copolymerization of novel trisubstituted ethylenes: 11. Halogen ring-substituted propyl 2-cyano-3-phenyl-2-propenoates. K.E. Humanski, S.D. Patterson, P.J. Pecorin, M.M. Perfitt, J. Romero, W.R. Sassack, S.M. Sweeney, C.O. Talwar, D.A. Tolentino, M.E. Wilson, W.S. Schjerven & G.B. Kharas. *J. Macromol. Sci. A*55:10, 709-717, DOI: 10.1080/10601325.2018.1526639 (2018).
  5. Novel Copolymers of Styrene. 12. Halogen Ring-Disubstituted Butyl 2-Cyano-3-Phenyl-2-Propenoates. G.B. Kharas, S.M. Rocus, H.E. Aynessazian, Z.L. Christy-Aronson, I.C. Chaoui-Boudrane, R.M. Lange, J.C. Richardson, B.S. Sukhera, S.T. Tamrakar, and C.A. Vanjo. *J. Macromol. Sci. A*53 (6) 335-339 (2016).
  6. Synthesis and styrene copolymerization of halogen ring-substituted isopropyl cyanophenyl propenoates. B.Y. Killam, T.S. Bullock, J. Carmichael, S.J. Carvalho, A.A. Dominguez, T. Faith, J. Garcia, A.D. Gould, E.E. Jacobs, K. Kochan, C.M. Rubert Pérez, S.M. Rocus, G.B. Kharas. *Int. J. Chemistry Studies.* 3 (4) 17-21 (2019).

7. A.R. Krause, H.E. Aynessazian, M.C. Gonzalez, A.M. Khan, L.R. Lieberman, M.H. McNicholas, N.M. Pelsi, Z.S. Pierard, S.M. Rocus, W.S. Schjerven, G.B. Kharas. Synthesis and Styrene Copolymerization of Novel Fluoro and Oxy Ring-Disubstituted Isopropyl Phenylcyanoacrylates. ChemRxiv. Preprint. <https://doi.org/10.26434/chemrxiv.10279751.v1>
8. Synthesis and styrene copolymerization of novel halogen, alkoxy, and alkyl ring-disubstituted isopropyl 2-cyano-3-phenyl-2-propenoates. K.M. Hussain, R.M. Breault, N.J. Caporusso, C.J. Cu, K.J. Decker, T.K. Gill, E.K. Gray, C.J. Homs, M.F. Kanji, R.M. Stone, J.L. Zepeda, S.M. Rocus, W.S. Schjerven, G.B. Kharas. ChemRxiv, Preprint. <https://doi.org/10.26434/chemrxiv.9932393>.
9. SciFinder: Chemical Structure Search (accessed December 12, 2019).
10. Smith, M. B., March, J. (2001) Addition to Carbon-Hetero Multiple Bonds, In March's Advanced Organic Chemistry; J. Wiley & Sons: New York, Ch.16, 1225.