Poly(amide-imide-esters) derived from asymmetric diacids and diphenols containing silicon or carbon as central atom. Synthesis, characterization and thermal studies

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ABSTRACT
Poly(amide-imide-esters) (PAIEs) were obtained from a series of unsymmetrical diacids containing an amide and an imide group in the structure and diphenols containing Si or C as central atoms. The unsymmetrical diacids were obtained from trimellitic anhydride chloride which reacted with \( p \)-aminobenzoic acid, followed by the reaction of the resulting amide–imide acid with an amino acid such as glycine, L-alanine, L-valine, and \( p \)-aminobenzoic acid. The obtained monomeric diacids were polymerized with bisphenol-A and with the analogous bisphenol containing silicon as central atom to give PAIEs. These polymers were characterized by spectroscopic methods and their main properties such as solubility, molecular weight, glass transition, and thermal stability were studied in correlation with the presence of C or Si atoms in the bisphenol segment and with the amount of aromatic units in the diacid segment.

1. Introduction
Poly(esters) are condensation polymers considered of interest due to their mechanical properties, chemical resistance, and thermal stability.[1–4] However, if polymers have rigid aromatic rings in the structure, the processability can be affected due mainly to the low solubility and high \( T_g \) values.[5–9]

Several structural changes have been proposed in order to improve the processability, increasing the solubility, decreasing the \( T_g \) values but maintaining the thermal stability. The introduction of flexible units in the main chain,[10,11] or bulky side groups,[12] has been proposed as a solution to improve the mentioned properties.

Mallakpour et al. has described several works in which amino acids residues have been included in the main chain as flexible units, due to the sp\(^3\) carbon atom and also to their side groups, which increases the separation between the polymeric chains and consequently decreases the \( T_g \) values.[13–18]

On the other hand, the inclusion of Si atoms in the main chain, bonded to four organic groups, has shown to be important and of technological interest due the potential applications in optoelectronic materials. The Si atom introduces \( \sigma-\pi \) conjugation which favors the electron transport in the polymeric chain.[19–21] Likewise, the difference of electronegativity of the C–Si bond slightly increases the ionic character of the chain, which can decrease the \( T_g \) values maintaining a good thermal stability and increasing the solubility of the samples.[22]

In our research group, we have described the synthesis and characterization of condensation polymers containing several functional groups and Si atoms in the main chain, showing that the incorporation of this heteroatom increases the solubility and maintains the thermal stability of the materials.[12,23–27]

In this work we describe the synthesis, characterization, and thermal studies of condensation polymers containing three organic functional groups in the repeating unit (amide, imide, and ester) and a Si atom provided by the diphenol moiety. The diacids are asymmetric in the sense that one acid group is of aliphatic nature provided by the amino acid, except when \( p \)-aminobenzoic acid was used, and the other is aromatic. As diphenols we used bisphenol-A and the silicon-containing analogous. Polymers were characterized by FT-IR and NMR and the thermal properties studied. The results were compared as function of the central atom of the diphenol moiety, C or Si, and also to the structure of the amino acid residue of the monomeric diacid.

2. Experimental part
2.1. Materials
Trimellitic anhydride chloride, glycine, L-alanine, L-valine, and \( p \)-amino-benzoic acid, were obtained from Aldrich
2.2. Instrumentation

The IR spectra (KBr pellets) were recorded on a Perkin-Elmer (Fremont CA) 1310 spectrophotometer over the range of 600–4000 cm⁻¹. ¹H, ¹³C, and ²⁹Si NMR spectra were carried out on a 400 MHz instrument (Bruker AC-200) using DMSO-d₆, CDCl₃, or acetone-d₆ as solvents and TMS as the internal standard. Viscosimetric measurements were made in a Desreux–Bischof-type dilution viscosimeter at 25 °C (c = 0.5 g·dl⁻¹). Tg values were obtained using a Mettler-Toledo (Greifensee, Switzerland) DSC 821 calorimetric system (20 °C·min⁻¹ under N₂ flow). Specific rotations were measured at 100 °C, and characterized by FT-IR and ¹H and ¹³C NMR spectroscopy.

2.2.1. 2-(4-(N-(4-carboxyphenyl)aminocarbonyl)phthalimidyl)-acetic acid (II-a)

Yield: 92%. M.p.: 296 °C. FT-IR (KBr) (ν (cm⁻¹)): 3472 (OH), 3314 (NH), 3066 (CH arom.), 2942 (CH aliph.), 1771, 1709 (C=O), 1606, 1523 (C=C arom.), 1404 (CH aliph.), 853 (arom. 1,2,4-subst.), 841 (arom. p-subst.). ¹H NMR (DMSO-d₆) (δ (ppm)): 4.37 (s, 2H, CH₂), 7.92–7.94 (d, 2H, arom., J = 8.8 Hz), 7.96–7.98 (d, 2H, arom., J = 8.8 Hz), 8.08–8.10 (d, 1H, arom., J = 7.6 Hz), 8.42–8.43 (d, 1H, arom., J = 7.8 Hz), 8.50 (s, 1H, arom.), 10.82 (s, 1H, NH), 13.20 (s, 2H, OH). ¹³C NMR (DMSO-d₆) (δ (ppm)): 39.6 (CH₂), 120.2, 122.9, 124.1, 126.5, 130.7, 132.0, 134.2, 135.1, 140.6, 143.2 (C arom.), 164.2, 167.0, 167.1, 167.3, 169.2 (C=O).

2.2.2. 2-(4-(N-(4-carboxyphenyl)aminocarbonyl)phthalimidyl)-propionic acid (II-b)

Yield: 77%. M.p.: 300 °C. FT-IR (KBr) (ν (cm⁻¹)): 3489 (OH), 3329 (NH), 3063 (CH arom.), 1917 (CH aliph.), 1783, 1715, 1675 (C=O), 1607, 1593 (C=C arom.), 1455, 1383 (CH aliph.), 888 (arom. 1,2,4-subst.), 855 (arom. p-subst.). ¹H NMR (DMSO-d₆) (δ (ppm)): 1.59–1.60 (d, 3H, CH₃, J = 7.3 Hz), 4.91–4.96 (q, 1H, CH₂, J = 7.2 Hz), 7.93–7.90 (d, 2H, arom., J = 8.7 Hz), 7.96–7.99 (d, 2H, arom., J = 8.7 Hz), 8.06–8.08 (d, 1H, arom., J = 7.7 Hz), 4.81–4.83 (q, 1H, CH₂, J = 7.2 Hz), 8.09–8.11 (d, 2H, arom., J = 8.7 Hz), 8.48 (s, 1H, arom.), 10.82 (s, 1H, NH), 12.94 (s, 2H, OH). ¹³C NMR (DMSO-d₆) (δ (ppm)): 15.2 (CH₃), 47.8 (CH), 120.2, 122.8, 124.0, 126.5, 130.8, 132.0, 134.2, 134.3, 134.5, 140.6, 143.3 (C arom.), 164.5, 167.0, 167.1, 167.4, 171.4 (C=O).

2.2.3. 2-(4-(N-(4-carboxyphenyl)aminocarbonyl)phthalimidyl)-3-methyl-butanoic acid (II-c)

Yield: 74%. M.p.: 286 °C. FT-IR (KBr) (ν (cm⁻¹)): 3479 (OH), 3338 (NH), 3086 (CH arom.), 2970 (CH aliph.), 1779, 1722, 1681 (C=O), 1605, 1520 (C=C arom.), 1424, 1383 (CH aliph.), 877 (arom. 1,2,4-subst.), 854 (arom. p-subst.). ¹H NMR (DMSO-d₆) (δ (ppm)): 0.85–0.87 (d, 3H, CH₃, J = 6.8 Hz), 1.08–1.10 (d, 3H, CH₃, J = 6.6 Hz), 2.56–2.64 (m, 1H, CH-(CH₃)₂), 4.51–4.53 (d, 1H, CH-CH, J = 7.8 Hz), 7.93–7.95 (d, 2H, arom., J = 8.8 Hz), 7.97–7.99 (d, 2H, arom., J = 8.8 Hz), 124.6, 125.9, 126.6, 130.7, 132.0, 134.1, 136.2, 141.7, 143.1 (C arom.), 163.1, 163.2, 164.0, 167.3 (C=O).

2.3. Monomers

2.3.1. N-(4-carboxyphenyl)-4-aminocarbonyl-phthalic anhydride (I)

In a 250-mL flask, 3.1 g (0.016 mol) of trimellitic anhydride chloride were dissolved in 30 mL of DMAc and the mixture cooled at 0 °C. Then, 2.2 g (0.016 mol) of p-amino benzoic acid in 25 mL of DMAc were added dropwise at 0 °C and the mixture stirred until the appearance of a white solid. The solid was filtered, washed with methanol, dried at 100 °C, and characterized by FT-IR and ¹H and ¹³C NMR spectroscopy.

2.3.2. I

Yield: 75%. M.p.: 320 °C. FT-IR (KBr) (ν (cm⁻¹)): 3382 (NH), 3069 (CH arom.), 1853 (CH aliph.), 1853, 1770, 1676 (C=O), 1594, 1528 (C=C arom.), 891 (arom. 1,2,4-subst.), 867 (arom. p-subst.). ¹H NMR (DMSO-d₆) (δ (ppm)): 7.95–7.96 (m, 4H, arom.), 7.22–7.24 (d, 1H, arom., J = 7.6 Hz), 8.49–8.51 (d, 1H, arom., J = 7.6 Hz), 8.61 (s, 1H, arom.), 1.05 (s, 1H, NH), 12.49 (s, 1H, OH). ¹³C NMR (DMSO-d₆) (δ (ppm)): 120.2, 124.6, 125.9, 126.6, 130.7, 132.0, 134.1, 136.2, 141.7, 143.1 (C arom.), 163.1, 163.2, 164.0, 167.3 (C=O).
2.4. Poly(amide-imide-esters) (PAIES)

Poly(amide-imide-esters) (PAIES) were synthesized according to the following general procedure. In a typical polymerization process, 1.52 mmol of the diacid II were mixed with 2 mL of anhydrous pyridine under N₂ and stirred until total dissolution of the diacid. After that, a solution of 1.448 g of tosyl chloride, 0.82 mL of DMF, and 1.5 mL of anhydrous pyridine previously stirred for 30 min, was added and stirred for one hour. After this time, 1.52 mmol of the respective diphenol in 3.1 mL of anhydrous pyridine were added and the mixture was stirred at 80 °C for one hour, and then, at 100 °C for three hours. After this time the mixture was added to 600 mL of water and the precipitated PAIE was filtered, washed with water, dried until constant weight, and characterized.

2.4.1. PAIE-a-Si

FT-IR (KBr) (υ (cm⁻¹)): 3366 (NH), 3064 (CH arom.), 2931 (CH aliph.), 1780, 1723 (C=O), 1598, 1527 (C=C arom.), 1407, 1364 (CH aliph.), 1245 (C=O), 870 (arom. 1,2,4-subst.), 853 (arom. p-subst.). ¹H NMR (DMSO-d₆) (δ) (ppm): 0.23 (s, 6H, CH₃), 4.88 (s, 2H, CH₂), 6.80–8.36 (m, 15H, arom.), 10.65 (s, 1H, NH). ¹³C NMR (DMSO-d₆) (δ) (ppm): −1.8 (CH₃), 69.4 (CH₂), 114.9, 120.2, 124.4, 126.0, 128.1, 128.9, 130.8, 135.8, 136.7, 137.5, 143.3, 152.3 (C arom.), 159.7, 164.5, 167.4 (C=O). ²⁹Si NMR (DMSO-d₆) (δ) (ppm): −9.34 (Si-CH₃). Elem. anal. calcld for C₃₀H₂₀N₂O₇Si (576): C: 66.67%, H: 4.17%, N: 4.86%. Found: C: 67.21%, H: 4.05%, N: 4.78%.

2.4.2. PAIE-a-C

FT-IR (KBr) (υ (cm⁻¹)): 3319 (NH), 3059 (CH arom.), 2966 (CH aliph.), 1781, 1726 (C=O), 1579, 1511 (C=C arom.), 1407 (CH aliph.), 1205 (C=O), 862 (arom. 1,2,4-subst.), 833 (arom. p-subst.). ¹H NMR (DMSO-d₆) (δ) (ppm): 1.66 (s, 6H, CH₃), 4.8 (s, 2H, CH₂), 7.23–8.15 (m, 15H, arom.), 10.96 (s, 1H, NH). ¹³C NMR (DMSO-d₆) (δ) (ppm): 21.1 (CH₃), 31.1 (C=CH₂), 42.3 (CH₂), 115.2, 120.4, 121.6, 124.5, 125.9, 127.8, 128.0, 128.5, 131.1, 144.3, 148.1, 149.0, 155.6 (C arom.), 164.5, 164.6, 164.7 (C=O). Elem. anal. calcld for C₁₂₁H₁₀₂N₂O₇Si (560): C: 70.71%, H: 4.29%, N: 5.00%. Found: C: 70.43%, H: 4.22%, N: 4.89%.

2.4.3. PAIE-b-Si

FT-IR (KBr) (υ (cm⁻¹)): 3390 (NH), 3066 (CH arom.), 2966 (CH aliph.), 1779, 1722 (C=O), 1600, 1512 (C=C arom.), 1407, 1374 (CH aliph.), 1249 (C=O), 853 (arom. 1,2,4-subst.), 811 (arom. p-subst.). Elem. anal. calcld for C₃₃H₂₄N₂O₇Si (590): C: 67.12%, H: 4.41%, N: 4.75%. Found: C: 67.73%, H: 4.37%, N: 4.88%.

2.4.4. PAIE-b-C

FT-IR (KBr) (υ (cm⁻¹)): 3376 (NH), 3061 (CH arom.), 2968 (CH aliph.), 1764, 1721 (C=O), 1599, 1505 (C=C arom.), 1459, 1429, 1380 (CH aliph.), 1206 (C=O), 878 (arom. 1,2,4-subst.), 840 (arom. p-subst.). ¹H NMR (DMSO-d₆) (δ) (ppm): 1.64 (m, 9H, CH₃), 5.33–5.39 (q, 1H, CH), 6.89–8.55 (m, 15H, arom.), 10.97 (s, 1H, NH). ¹³C NMR (DMSO-d₆) (δ) (ppm): 15.0 (CH₃–C), 30.6 (CH₃–CH), 42.2 (C–(CH₃)₂), 47.3 (CH₂), 120.6, 121.0, 121.5, 124.1, 125.6, 127.8, 131.0, 133.8, 137.7, 140.2, 143.9, 148.0, 148.6 (C arom.), 164.2, 166.4, 166.5, 166.8 (C=O). Elem. anal. calcld for C₃₃H₂₆N₂O₇ (574): C: 71.08%, H: 4.53%, N: 4.88%. Found: C: 70.82%, H: 4.75%, N: 4.97%.

2.4.5. PAIE-c-Si

FT-IR (KBr) (υ (cm⁻¹)): 3368 (NH), 3066 (CH arom.), 2971 (CH aliph.), 1780, 1721 (C=O), 1601, 1526 (C=C arom.), 1382 (CH aliph.), 1240 (C=O), 854 (arom. 1,2,4-subst.), 836 (arom. p-subst.). Elem. anal. calcld for C₃₃H₂₆N₂O₇Si (618): C: 67.96%, H: 4.84%, N: 4.53%. Found: C: 68.43%, H: 4.99%, N: 4.20%.

2.4.6. PAIE-c-C

FT-IR (KBr) (υ (cm⁻¹)): 3405 (NH), 3060 (CH arom.), 2967, 2933, 2874 (CH aliph.), 1780, 1722 (C=O), 1598, 1505 (C=C arom.), 1429, 1407, 1379 (CH aliph.), 1206 (C=O), 854 (arom. p-subst.). ¹H NMR (DMSO-d₆) (δ) (ppm): 0.97 (s, 3H, Ar–C–CH₂), 1.16 (s, 3H, Ar–C–CH₂), 1.67 (d, 6H, (CH₃)₂–C), 2.69 (m, 1H, CH(CH₃)₂), 5.05 (d, 1H, CH–CH–(CH₃)₂), 7.01 (m, 2H, arom.), 7.24–7.30 (m, 6H, arom.), 8.08–8.17 (m, 5H, arom.), 8.49–8.59 (m, 2H, arom.), 10.98 (s, 1H, NH). ¹³C NMR (DMSO-d₆) (δ) (ppm): 19.2 (CH₃–CH), 20.8 (CH₃–CH₃), 29.2 ((CH₃)₂–C), 30.9 (CH–(CH₃)₂), 42.5 (C–(CH₃)₂), 57.2 (CH–CH), 120.3, 121.7, 121.8, 123.2, 124.4, 128.0, 131.3, 131.5, 137.7, 135.4, 140.7, 144.2, 148.5, 149.0 (C arom.), 164.6, 167.3, 167.4, 167.6 (C=O). Elem. anal. calcld for C₃₆H₂₆N₂O₇Si (602):
3. Results and discussion

3.1. Monomer synthesis

Trimellitic anhydride chloride reacted with \( p \)-aminobenzoic acid in dimethylacetamide at 0 °C to obtain the corresponding amide I (Scheme 1) with high yield, and was characterized by spectroscopic methods. The results are summarized in the experimental part.

Amide I reacted with the amino acids glycine, L-alanine, L-valine, and \( p \)-aminobenzoic acid in acetic acid, first at room temperature and then refluxed in order to obtain the cyclic imide.[29,30] The acetic acid was removed by distillation and the residue poured into an aqueous HCl solution in which the amide–imide diacid II precipitated as a white solid. Diacids were obtained in general with yields between 74 and 92%. These monomers were characterized by FT-IR and NMR and the results were in agreement with the proposed structures.
incorporation of the signals contributed by the aminoacidic residue. The 13C NMR spectra showed the signals for the aliphatic carbons atoms and five signals corresponding to the carbonyl groups, indicating the non-equivalence of the two acid groups and the imide carbonyl groups. Also, the spectra showed the signals corresponding to the aromatic carbon atoms. All the spectroscopic data of the diacids II-(a–d) were in agreement with the proposed structures in the Scheme 1. Figure 1 shows as an example the NMR spectra of the diacids II-a and Figure 2 those for diacid II-c (Scheme 1).

3.2. PAIEs synthesis and characterization

After the reaction was completed, the mixture was poured into water to precipitate the polymer.
The PAIEs were obtained according to the procedure described by Higashi [31,32] between the diacids II and the respective diphenol, which is based in the Vilsmeier adduct, formed by DMF, tosyl chloride, and pyridine. After the reaction was completed, the mixture was poured into water to precipitate the polymer.

The yields were for all the PAIEs almost quantitative, showing the effectiveness of the polymerization process, and are summarized in Table 1, which also shows the optical rotation values for those PAIEs containing a stereogenic C atom provided by the aminoacidic residue (L-alanine and L-valine).

Table 2 shows the results of the solubility test developed at room temperature to the PAIEs using 10 mg of sample in 1 mL of solvent. All polymers were soluble in aprotic polar solvents and in m-cresol, which is normal for this kind of materials, with the exception of PAIE-b-C, PAIE-c-Si, and PIAE-d-C, which were only partially soluble in DMSO. The solubility was analyzed in common organic solvents, and PAIEs were insoluble in acetone, two of them partially soluble in CHCl₃ and two partially soluble in THF. Probably the high aromatic content of the repeating units of these polymers does not permit an increase of the solubility in this kind of solvents.

In the experimental part are summarized the spectroscopic data corresponding to the PAIEs obtained according to Scheme 1. The FT-IR spectra show the disappearance of the band at about 3500 cm⁻¹ corresponding to the OH stretching of the acid groups and a new sharp band at about 1220 cm⁻¹ corresponding to the C–O bond of the
The 1H NMR spectra show an increase of the signals corresponding to the aromatic H atoms and the new signals of the methyl groups bonded to the central atom, C or Si, of the diphenol, which appeared as a singlet integrating for six hydrogen atoms. For the silicon-containing polymers, it was possible to verify a strong shift for these last signals. Thus, for PAIE-a-Si and PAIE-d-Si the CH₃ groups appear at 0.23 and 0.65 ppm; respectively, while the samples containing C as central atom show values at 1.7 ppm approximately. This phenomenon is due to the difference in the electronegativity of the Si and C atoms and it had already reported in other silylated polymers.

The 13C NMR spectra also show an increase of the aromatic C bands and new signals corresponding to the ester group was observed. The other bands were similar to those described for the monomeric diacids spectra.

The 1H NMR spectra show an increase of the signals corresponding to the aromatic H atoms and the new signals of the methyl groups bonded to the central atom, C or Si, of the diphenol, which appeared as a singlet integrating for six hydrogen atoms. For the silicon-containing polymers, it was possible to verify a strong shift for these last signals. Thus, for PAIE-a-Si and PAIE-d-Si the CH₃ groups appear at 0.23 and 0.65 ppm; respectively, while the samples containing C as central atom show values at 1.7 ppm approximately. This phenomenon is due to the difference in the electronegativity of the Si and C atoms and it had already reported in other silylated polymers.

The 13C NMR spectra also show an increase of the aromatic C bands and new signals corresponding to the
showed higher $\eta_{inh}$ values when compared with the analogous PAIEs derived from the diphenol with Si as central atom. This tendency does not apply for polymers derived from diacids II-b where the inherent viscosity values were very similar. The only difference between each pair of PAIE is the central atom of the diphenol, C or Si, and probably the growing polymeric chains derived from bisphenol A, were more soluble in the reaction media since they do not have the polarity of the C–Si bond of the other PAIEs.

### 3.3. Thermal properties of the PAIEs

Table 1 shows the $T_g$ values obtained for each PAIE according to the procedure described in the experimental part, in which the samples were heated twice in order to have the same thermal history. For those PAIEs containing Si as central atom of the diphenol, the PAIE-a-Si containing glycine as aminocacidic residue, without aliphatic side chain, showed a $T_g = 37 \degree C$, but for PAIE-b-Si and PAIE-c-Si, with an aliphatic side chain, $-\text{CH}_3$ and $-\text{CH(}\text{CH}_3)_2$, respectively, the values of $T_g$ decrease. This phenomenon would be associated to the increasing of the size of the side aliphatic chain. Thus, a free volume between chains is obtained due to the higher distance between them, affecting their internal mobility.

For the PAIEs containing a C atom as central atom of the diphenol moiety, the tendency was the opposite, there was an increase of the $T_g$ values when the volume of the aminocacidic residue in the main chain increases. One possible explanation to this result is that the polymeric chain does not have the polarity that would give the presence of the heteroatom, and also that the (C–X) bond distance in PAIEs derived from bisphenol-A (X=C) is shorter than the analogous derived from silylated diphenol (X=Si). Both effects can make the polymeric chain more rigid and, consequently, the $T_g$ values higher, and predominant respect to the side chain of the amino acids.

If both polymer series are compared, Si and C as central atom of the diphenol moiety, the silicon-containing PAIEs showed lower values relative to those with C atom. It is

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**Table 1.** Yields, $[\alpha]_D$, $\eta_{inh}$, $T_g$, and TDT of the PAIEs.

|          | Yield (%) | $[\alpha]_D$ (deg cm$^2$ dm$^{-1}$ g$^{-1}$) | $\eta_{inh}$ (dL g$^{-1}$) | $T_g$ (°C) | TDT (°C) | $R^d$ (%) |
|----------|-----------|---------------------------------------------|----------------------------|-------------|---------|-----------|
| PAIE-a-Si| 98        | –                                           | 0.24                       | 37          | 259     | 25        |
| PAIE-a-C | 89        | –                                           | 0.33                       | 161         | 363     | 36        |
| PAIE-b-Si| 95        | 20                                          | 0.25                       | −14         | 329     | 40        |
| PAIE-b-C | 97        | 30                                          | 0.29                       | 164         | 347     | 17        |
| PAIE-c-Si| 99        | 40                                          | 0.29                       | −22         | 297     | 25        |
| PAIE-c-C | 99        | 30                                          | 0.35                       | 196         | 377     | 35        |
| PAIE-c-dSi| 99       | 30                                          | 0.43                       | 116         | 423     | 34        |
| PAIE-c-dC | 99       | –                                           | 0.57                       | 200         | 451     | 42        |

*In DMF at 25 °C.

$^b$Inherent viscosity, in NMP at 25 °C (c = 0.5 g dL$^{-1}$).

$^d$10% of weight loss.

$^e$Residue chart.
of both series due to the increase of the aromatic content in the main chain, which normally increases the thermal stability.

Finally, the residues obtained at 850 °C are ranked between 17 and 42%, which is a normal result in the thermal analysis of silylated polymers. No volatile silicon-containing derivatives are probably obtained at this temperature.

4. Conclusions

Unsymmetrical PAIEs including aminoacidic residues were obtained with good yields and moderate $\eta_{inh}$ values. The $T_g$ values were dependent on the central atom of the diphenol, Si or C: those with Si showed lower $T_g$ values due to the longer distance and to the polarity of the C–Si bond. The PAIEs, which include $p$-aminobenzoic acid, showed the higher $T_g$ values due to the rigidity of the $p$-aromatic ring incorporated to the polymeric chain. With the exception of the PAIEs including $p$-aminobenzoic acid, the synthesized polymers cannot be considered as thermostable, and those derived from the diphenol with Si, showed lower TDT values relative to those derived from bisphenol-A due to the longer distance of the C–Si bond. The PAIEs, which include $p$-aminobenzoic acid, showed the higher $T_g$ values due to the rigidity of the $p$-aromatic ring incorporated to the polymeric chain. With the exception of the PAIEs including $p$-aminobenzoic acid, the synthesized polymers cannot be considered as thermostable, and those derived from the diphenol with Si, showed lower TDT values relative to those derived from bisphenol-A due to the longer distance of the C–Si bond. Also the TDT values were influenced by the nature of the aminoacidic residue: when the aliphatic side chain was increased, the TDT values also increased, due probably to the longer separation of the polymeric chains and the consequent weakness in their interaction.

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