Synthetic and Tautomeric Study on 5-Acylamino-3*H*-1,3,4-thiadiazolin-2-ones

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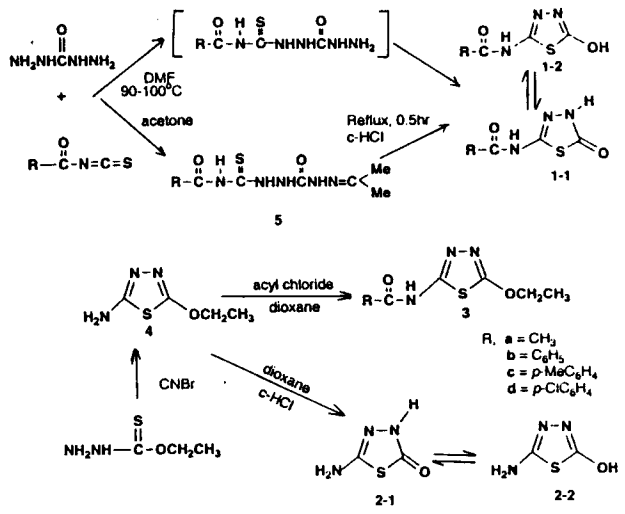
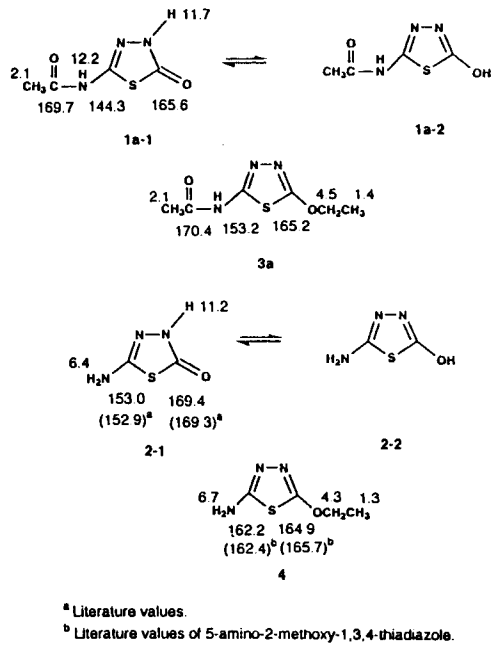
2-Acylamino-5-hydroxy-1,3,4-thiadiazoles (**1**) have been prepared through the addition and cyclization reactions of aroylisothiocyanates and carbonohydrazide *in situ*.[1] The yield of compound **1** was poor since triazole was competitively formed.[2] The compound **1** was named as a lactim[1,2] form without any evidence even though they can exist in two tautomeric forms; lactam form and lactim form like 5-amino-3*H*-1,3,4-thiadiazolin-2-one (**2**). Compound **2** was similarly named in two ways;[3~7] 2-amino-5-hydroxy-1,3,4-thiadiazole and 5-amino-3*H*-1,3,4-thiadiazolin-2-one before the identification of the stable tautomeic structure as a lactam form. The stable tautomer of **2** was identified as a lactam form by means of ^{13}C nmr spectroscopy.[8] The compound **2** was conformed to exist almost exclusively in the *oxo* tautomeric form with the aid of proton-coupled ^{15}N nmr spectra using the corresponding 3-methyl-1,3,4-thiadizolidin-2-one and 2-methoxy-1,3,4-thiadiazole as reference compounds.[9] The tautomeric equilibrium is influenced by the substituent at 5 position of 5-amino-3*H*-1,3,4-thiadiazolin-2-one.[8,9] Investigation of the relative stability of tautomers is important in biologically active compounds within the framework of structure-biological activity relationship studies. It is necessary to determine the stable tautomeric structures of these compounds not only in order to understand their reactivity but also to establish correct names for these compounds.

We thus promptly decided to synthesize compound **1** with good yield and to prove its stable tautomer by ^{13}C nmr. Analogy experiment of ^{13}C nmr was reviewed between 2-amino-5-ethoxy-1,3,4-thiadiazole (**4**)[11,12] and 5-amino-3*H*-1,3,4-thiadiazolin-2-one (**2**).[8~10] The synthesis of compound (**4**) was followed by the known method with ethyl thiocarbazate with cyanogen bromide.[11] The melting point of compound **4** is higher than the reported values in the literature (See Experimental).[11,12] However, the nmr spectra are nicely matched with the published ones in the literature.[8] Compound **2** was prepared *via* the cleavage of ethyl group in compound **4** by dioxane-hydrochloric acid.[8] The syntheses of 5-acylamino-3*H*-1,3,4-thiadiazolin-2-ones (**1**) have been carried out as shown in Scheme 1.

2-Acylamino-5-ethoxy-1,3,4-thiadiazoles (**3**) were utilized as authentic lactim standard compounds. The selective cleavage of ethyl group of 2-acylamino-5-ethoxy-1,3,4-thiadiazoles (**3**) was nicely performed in the same manner of the cleavage of ethyl group of compound **4** without any side products. The overall yields of 1 were more than 40% from ethyl thiocarbazate. These purified yield are much higher than those from the addition and cyclization reactions of aroylisothiocyanates and carbonohydrazide *in situ* (Table 1). We attempted



Scheme 1. Synthesis of 5-Amino-3*H*-1,3,4-thiadiazolin-2-ones.



Scheme 2. ^{1}H and ^{13}C nmr of 5-amino-3*H*-1,3,4-thiadiazolines in DMSO-d_6.

to synthesize compound **1** through the method reported in the literature[1] and the cylization of the hydrazone (**5**). The compound **1b** could be obtained in a similar yield as reported.[1] The yield of **1d**[1] is a crude yield thus it can not be compared with that.

The ^{13}C nmr was reexamined for 2-amino-5-ethoxy-1,3,4-thiadiazole (**4**) and 5-amino-3*H*-1,3,4-thiadiazolin-2-one (**2**) whose stable tautomer is known as a lactam form.[8~10] The chemical shifts of 2 are almost identical with the reported values as shown in Scheme 2. The chemical shifts of compound **4** are same as those of 2-amino-5-methoxy-1,3,4-thiadiazole.[8] The chemical shift at C(2) of **2** is shown more 4.5 ppm down field than that of **4**.[8] If the **2** exists as a lactim form the C(2) should appear upfield compared with compound **4**.[8]

Table 1. Synthesized 5-Acylamino-3*H*-1,3,4-thiadiazolin-2-ones, **1** and 5-Acylamino-2-ethoxy-1,3,4-thiadiazoles, **3**

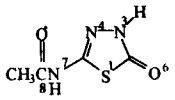
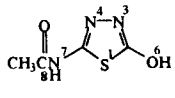
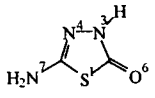
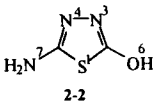
Comp. No.	R	Yield[a] (%)	Mp ℃	Molecular Formula (mol wt)	Elemental Analysis Calcd./Found % C	H	N	S
1a	CH_3		318-319	$C_4H_5N_3O_2S$	30.19	3.17	26.40	20.14
				(159.16)	30.01	3.21	26.17	20.32
1b	C_6H_5	50 (17,[b] 22[c] 20[d], 40 [e])	267-270	$C_9H_7N_3O_2S$	48.86	3.19	18.99	14.49
			(268-270)[d]	(221.23)	49.07	3.33	19.20	13.99
1c	*p*-MeC_6H_4	45 (5[b])	238-240	$C_{10}H_9N_3O_2S$	51.05	3.86	17.86	13.63
				(235.26)	51.14	3.78	17.72	13.07
1d	*p*-ClC_6H_4	41	257-260	$C_9H_6N_3O_2SCl$	HRMS[g]			
		(13[b], 42[e])	(268-271)[d]	(255.68)				
3a	CH_3	49	217-202	$C_6H_9N_3O_2S$	38.49	4.85	22.44	17.35
			(216.5-202)[f]	(187.22)	38.50	4.83	22.37	17.12
3b	C_6H_5	55	180	$C_{11}H_{11}N_3O_2S$	53.00	4.45	16.86	12.86
				(249.29)	53.07	4.46	16.83	13.29
3c	*p*-MeC_6H_4	50	178-180	$C_{12}H_{13}N_3O_2S$	54.73	4.98	15.96	12.18
				(263.32)	54.75	5.10	16.07	12.09
3d	*p*-ClC_6H_4	49	213	$C_{11}H_{10}N_3O_2S$	46.57	3.55	14.80	11.30
				(283.73)	46.60	3.65	14.84	11.66

[a] Yield of pure and isolated product from ethyl thiocarbazate. [b] Yield from the addition and cyclization reactions of aroylisothiocyanate and carbonohydrazide *in situ*. [c] Yield from the cyclization of 4-benzoyl-(1-isopropylidenamino)carbamoyl-3-thiosemicarbazide. [d] From ref. 1. [e] Crude yield from ref. 1. [f] From ref. 12. [g] m/z 256.9837 ($C_9H_6N_3O_2SCl$ requires 256.9840).

Table 2. Spectral Data for 5-Acylamino-3*H*-1,3,4--thiadiazolin-2-ones **1** and 2-Acylamino-5-ethoxy-1,3,4-thiadiazoles **3**

Comp. No.	R	IR (cm^{-1}; KBr) ^1H nmr (ppm; DMSO-d_6) ^{13}C nmr (ppm; DMSO-d_6)
1a	CH_3	3200, 3180 (NH), 3070, 2850, 1650 (C=O), 1590 12.15 (1H, b, NH), 11.70 (1H, b, NH), 2.06 (3H, s, CH_3) 169.7 (C=O), 165.6 (amide C=O), 144.3 (C=N), 22.5 (CH_3)
1b	C_6H_5	3180 (NH), 3050, 2950, 2850 (CH), 1660 (C=O), 1640, 1580 (C=N) 12.3 (1H, b, NH), 12.2 (1H, b, NH), 8.0-7.5 (5H, m, Ph) 169.8 (C=O), 165.4 (amide C=O), 144.7 (C=N), 132.7, 131.6, 128.5, 128.1 (Ph)
1c	*p*-MeC_6H_4	3550, 3300, 3170 (NH), 3100, 3000, 2900 (CH), 1660 (C=O), 1630, 1580 (C=N), 1300, 12.2 (1H, b, NH), 12.3 (1H, b, NH), 8.0, 7.9, 7.4, 7.3 (4H, dd, Ph), 2.4 (3H, s, Me) 169.8 (C=O), 165.1 (amide C=O), 144.7 (C=N), 143.1, 129.1, 128.7, 128.2 (Ph), 21.0 (Me)
1d	*p*-ClC_6H_4	3200 (NH), 3140, 3090 (CH), 1660 (C=O), 1650, 1580 (C=N), 1520, 1500 12.36 (2H, b, 2NH), 8.04, 8.00, 7.64, 7.60 (4H, dd, Ph) 170.9 (C=O), 165.6 (amide C=O), 145.8 (C=N), 138.9, 131.6, 131.2, 129.8 (Ph)
3a	CH_3	3200, 3100 (NH), 3000 2710 (CH), 1700 (C=O), 1570 (C=N), 1500 12.2 (1H, b, NH), 4.5 (2H, q, CH_2) 2.1 (3H, s, $COCH_3$), 1.4 (3H, t, CH_3) 170.2 (C=O). 168.4 (amide C=O), 152.0 (C=N), 68.1 (OCH_2), 22.2 ($CO\underline{C}H_3$), 14.3 (CH_3)
3b	C_6H_5	3180, 3120 (NH), 3000, 2950, 2940 (CH), 1680 (C=O), 1600, 1580 (C=N), 1560, 1500 12.5 (1H, b, NH), 8.3-7.4 (5H, m, Ph), 4.4 (2H, q, CH_2), 1.4 (3H, t, CH_3) 170.6 (C=O), 165.2 (amide=O), 153.2 (C=N), 132.9, 131.6, 128.7, 128.4 (Ph), 68.2 (CH_2), 14.4(CH_3)
3c	*p*-MeC_6H_4	3160, 3050 (NH), 2980 (CH), 1650 (C=O), 1600, 1540 (C=N), 1490 12.7 (1H, b, NH), 8.0-7.4 (4H, dd, Ph), 4.5 (2H, q, CH_2), 2.4 (3H, s, $PhC\underline{H}_3$), 1.4 (3H, t, CH_3) 170.5 (C=O), 164.8 (amide CO), 152.9 (C=N), 143.2, 129.2, 128.6, 128.3 (Ph), 68.0 (CH_2), 21.0 ($PhCH_3$), 14.3 (CH_3)
3d	*p*-ClC_6H_4	3180, 3150 (NH), 3000, 2980 (CH), 1680 (C=O), 1600, 1560 (C=N), 1510, 13.1 (1H, b, NH), 8.4 7.6 (4H, dd, Ph), 4.5 (2H, q, CH_2), 1.4 (3H, t, CH_3), 170.4 (C=O), 164.4 (amide C=O), 153.2 (C=N), 137.8, 130.4, 130.2, 128.7 (Ph), 68.2 (CH_2), 14.3 (CH_3)

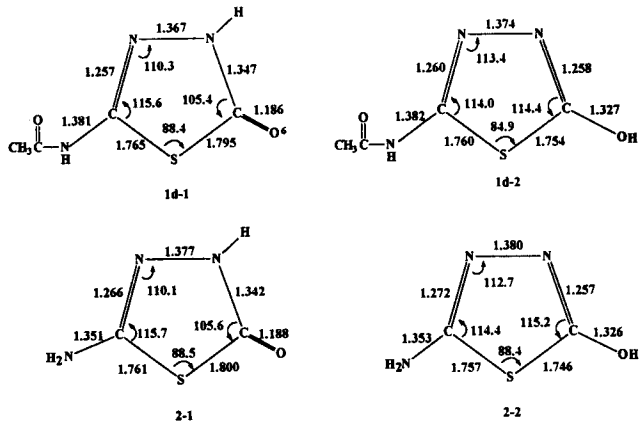
Table 3. The Relative Energies and the Atomic Charges of the Tautomers of 5-Amino-3*H*-1,3,4-thiadiazolin-2-ones

Tautomer	Basis set	Relative Energy (Kcal/mol)	Atomic Charge N(3)	N(4)	6(O)	7(N)
 1a-1	MP4/3-21G*	0.00 (−861.60856)[a]	−0.703	−0.345	−0.617	−1.008
	MP4/6-31G*	0.00 (−866.52529)	−0.568	−0.264	−0.577	−0.874
 1a-2	MP4/3-21G*	27.37 (−861.56494)	−0.396	−0.387	−0.698	−1.012
	MP4/6-31G*	22.26 (−666.48981)	−0.296	−0.299	−0.690	−0.883
 2-1	MP4/3-21G*	0.00 (−710.35724)	−0.703	−0.43	−0.625	−0.945
	MP4/6-31G*	0.00 (−714.28625)	−0.575	−0.342	−0.586	−0.928
 2-2	MP4/3-21G*	14.87 (−710.32682)	−0.443	−0.453	−0.717	−0.949
	MP4/6-31G*	19.08 (−714.26255)	−0.350	−0.378	−0.721	−0.936

[a] Parenthese values are absolute energies (Unit is Hatrees.).

A comparative experiment of ^{13}C nmr has been done between 5-acylamino-3*H*-1,3,4-thiadiazolin-2-ones (**1**) and 2-acylamino-5-ethoxy-1,3,4-thiadiazoles (**3**) as shown in Table 2. In the case of 5-acetylamino-3*H*-1,3,4-thiadiazolin-2-one (**1a**) and 2-acetylamino-5-ethoxy-1,3,4-thiadiazoles (**3a**), the chemical shifts at C(2) of **3a** and **1a** are almost the same. It offers the closest analogy with **2**. The difference of chemical shifts at C(5) between **1a** and **3a** (8.5 ppm) is closely similar to that of **2** and **4** (9.2 ppm). This is another evidence of analogy between **1** and **2**. Thus, it could be concluded that the stable tautomeric form of compound **1** is the lactam form on the basis of comparative study of ^{13}C nmr.

This result is also supported by theoretical calculations. The *ab initio* calculations were carried out on the tautomers of 5-amino-3*H*-1,3,4-thiadiazolin-2-ones. The relative energies and atomic charges of **1a** and **2** tautomers are summarized in Table 3. Both compound **1a-1** and **2-1**, lactam form, are much more stable form than **1a-2** and **2-2**, lactim form. The optimized geometries of the tautomers of compound **1a** (**1a-1** and **1a-2**) and **2** (**2-1** and **2-2**) at HF levels are summarized in Scheme 3. The C-S, C-N, and N-N distances and bond angles are comparable to those of the X-ray structure of 5-(1-hydroxycyclohexylthio)-1,3,4-thiadiazole-2-thione.[13] The significant features in the optimized geometries of tautomerism are changes in C-O and C-N bond distances. The C(2) =O(6) bond distance of 1.188 Å in **2-1** tautomer is increased by 0.138 Å to form the C-O single bond distance of 1.326 Å in **2-2** tautomer. The C(2)-N(3) single bond distance of 1.342 Å in lactam **2-1** tautomer is shortened by 0.085 Å to possess the double bond character of 1.257 Å in lactim **2-2** tautomer. This trend is also appearing in the optimized geometries of compound **1a**. These changes of C-O and C-N bond distances are in good agreement with other *ab initio* calculation results on the tautomerism of the pyrimidine bases.[14~16] The relative atomic charges are nicely matched with chemical shifts of ^1H and ^{13}C nmr.



Scheme 3. The optimized bond distances and angles for the tautomers of 5-amino-3*H*-1,3,4-thidiazolin-2-ones at 6-31G* level. The bond distances are in angstroms and the angles in degrees.

Experimental

All melting points were determined on an electrically heated Thomas-Hoover capillary melting point apparatus but uncorrected. The ir spectra were measured on a Jasco Report-100 spectrophotometer. The ^1H and ^{13}C nmr spectra were recorded on either a 80 MHz Bruker AC-80 or a 300 MHz Bruker AM-300 using tetramethylsilane as the internal standard. Elemental analyses were carried out on a Perkin-Elmer apparatus, model 240, at the Korea Research Institute of Chemical Technology, Taejon, Korea. Low resolution and exact mass spectra were obtained on a Varian MAT 212

mass spectrometer using perfluorokerosene as the interanl standard, coupled with SS MAT 300 data system.

The progress of the reaction and the purity of all compounds were checked by thin layer chromatography on precoated glass plates with silica gel 60 F-254 as the absorbent (purchased from Whatman cat. No. 4861110). The eluent for tlc was used a mixture of n-hexane, ethyl acetate, and acetic acid (4 : 8 : 1, v/v). Most of the commercially available starting materials and solvents were purchased from Aldrich Chemical Company, Milwaukee, WI.

***Ab initio* calculations.** Gaussian 92 and 94 packages[17] were used on Cray Y-MP C916 and Indigo 2 workstation. Molecular geometries were optimized at 3-21G* and 6-31G* basis sets.[18] Fourth order Moller-Plesset perturbation (MP4) calculations were carried out at the RHF optimized geometries to obtain improved energy comparisons.

Potassium ethylxanthate was prepared with the yield of more than 80% by the procedure described in the literature.[19] The synthesis of ethyl thiocarbazate was also followed the Ruffenacht's method.[20]

2-Amino-5-ethoxy-1,3,4-thiadiazole (4). Ethyl thiocarbazate (4.8 g, 0.04 mol) was dissolved in 24 mL of 2 N NaOH at 0-10 ℃. Cyanogen bromide 4.2 g dissolved in 20 mL of ethanol was added to the above solution keeping the temperature below 10 ℃ during 45 minutes. The solid product (4.1 g, 71%) was collected by filtration. To obtain the analytical sample the product was recrystallized from ethanol. mp 200-202 ℃ (lit.[12] 182.5-185 ℃, lit.[11] 190-202 ℃); ir (KBr, cm^{-1}) 3300 (NH), 3150 (NH), 3000 (CH), 2950 (CH), 1620 (C=O), 1580 (C=N), 1520; ^{1}H nmr (DMSO-d_6) δ 6.65 (2H, b, NH_2), 4.25 (2H, q, CH_2), 1.29 (3H, t, CH_3); ^{13}C nmr (DMSO-d_6) δ 164.85 (C=N), 162.18 (C-O), 67.46 (CH_2), 14.35 (CH_3); Anal. Calcd. for $C_4H_7N_3OS$: C, 33.09; H, 4.86; N, 28.94. Found; C, 33.71; H, 4.94; N, 28.50.

5-Amino-3*H*-1,3,4-thiadiazolin-3-one (2). 5-Amino-2-ethoxy-1,3,4-thiadiazole (**4**) (5 g, 34.5 mmol) was dissolved in 50 mL of dioxane and 3.3 mL of c-HCl was added. The reaction mixture was refluxed for 4.5 hours. The solvent was distilled off under reduced pressure. The residue product was washed with ether (3.7 g, 92.5 %). To obtain the analytical sample the product was recrystallized from water. mp 176-178 ℃ (lit.[8] 170-172 ℃); ir (KBr, cm^{-1}) 3450 (NH), 3150 (NH), 3100, 3000 (CH), 2900 (CH), 1700 (C=O), 1610, 1500 (C=N); ^{1}H nmr (DMSO-d_6) δ 11.3 (1H, b, NH), 6.4 (2H, b, NH_2); ^{13}C nmr (DMSO-d_6) δ 169.4 (C=N), 153.0 (C=O); Anal. Calcd. for $C_2H_3N_3OS$: C, 20.51; H, 2.58; N, 35.88; S, 27.37. Found; C, 20.19; H, 2.65; N, 34.28; S, 27.22.

2-Acylamino-5-ethoxy-1,3,4-thiadiazoles (3). 5-Amino-2-ethoxy-1,3,4-thiadiazole (**1**) (1 g, 7.4 mmol) was dissolved in anhydrous dioxane (20 mL) at 80 ℃. Triethylamine (1.5 mL, 11.1mmol) and acyl chloride (1 mL, 8.9 mmol) was added respectively to the above solution. The reaction solution was stirred at 80 ℃ for 40 minutes. The thin layer chromatography was used to determine the completion of the reaction. The reaction mixture was then cooled to room temperature and the triethylamine hydrochloride was filtered. After the filterate was distilled off the white solide product was remained. The solide was washed with ethanol and recrystallized from ethanol. The yields, melting points, elemental analysis, and spectral data of the products are shown in Tables 1 and 2.

5-Acylamino-3*H*-1,3,4-thiadiazoline-2-ones (1). 5-Acylamino-3*H*-1,3,4-thiadiazoline-2-ones (**1**) were synthesized from acylisothiocyanate and carbonohydrazide through the addition and cyclization reaction described in the literature [3]. The yields, melting points, elemental analysis, and spectral data of the products are shown in Tables 1 and 2.

4-Benzoyl-(1-isopropylidenamino)carbamoyl-3-thiosemicarbazide (5). KSCN (13.3 g, 0.137 mol) was dissolved in 100 mL of acetone while stirring. Benzoyl chloride (9.3 mL, 0.08 mol) was added to the above solution and the reaction mixture was refluxed for one hour. After the reaction mixture was cooled to room temperature in ice bath, byproduct KCl and unreacted KSCN were filter off. The filterate was condensed to half of it. Carbonohydrazide (7.2 g, 0.08 mol) solution in 50 mL acetone was added to it while stirring. The reaction mixture was refluxed for one hour. The solid product was collected and washed with water (10.1 g, 43%) and recrystallized from ethanol : acetone (1 : 1) to afford the analytical sample. mp 194-196 ℃; ir (KBr, cm^{-1}) 3300 (NH), 3200 (NH), 3100 (CH), 1690 (C=O), 1670 (C=O), 1600, 1590 (C=N), 1520; ^{1}H nmr (DMSO-d_6) δ 12.8, 11.6, 9.8, 9.4 (4H, b, 4NH), 8.0-7.5 (5H, m, Ph), 1.93 (3H, s, CH_3), 1.85 (3H, s, CH_3); ^{13}C nmr (DMSO-d_6) δ 173.99 (C=S), 168.25 (C=O), 153.45 (C=O), 150.40 (C=N), 133.85, 131.13, 128.68, 128.46 (Ph), 25.06 (CH_3), 17.17 (CH_3); Anal. Calcd. for $C_{11}H_{15}N_5O_2S$: C, 49.13; H, 5.15; N, 23.87; S, 10.91. Found; C, 50.74; H, 5.51; N, 24.32; S, 11.50.

5-Benzoylamino-3*H*-1,3,4-thiadiazolin-2-one (1a). 4-Benzoyl-(1-isopropylidenamino)carbamoyl-3-thiosemicarbazide (1 g, 3.4 mmol) was dissolved in 7 mL of c-HCl while stirring. The reaction mixture was refluxed for 30 minutes and then cooled to 20 ℃. The solid product was collected (0.38 g, 51%) and recrystallized from ethanol to obtain the analytical sample. mp 265-270 ℃; ir (KBr, cm^{-1}) 3180 (NH), 3050 (NH), 2950 (CH), 2850, 1660 (C=O), 1640 (C=O), 1580 (C=N); ^{1}H nmr (DMSO-d_6) δ 12.3 (1H, b, NH), 12.2 (1H, b, NH), 8.0-7.5 (5H, m, Ph); ^{13}C nmr (DMSO-d_6) δ 169.8 (C=N), 165.4 (amide C=O), 144.7 (C=O), 132.7, 131.6, 128.5, 128.1 (Ph); Anal. Calcd. for $C_9H_7N_3O_2S$: C, 49.07; H, 3.33; N, 19.20; S, 13.99. Found; C, 48.86; H, 3.19; N, 19.99; S, 14.49.

5-Acylamino-3*H*-1,3,4-thiadiazolin-2-one (1) from 2-acylamino-5-ethoxy-1,3,4-thiadiazole (3). 2-Acylamino-5-ethoxy-1,3,4-thiadiazole (1.7 mmol) was dissolved in dioxane (15 mL) and c-HCl (0.2 mL, 2.1 mmol). The reaction mixture was refluxed for 90 minutes, cooled down to room temperature and condensed under the reduced pressure to collect yellowish solid product. To obtain the analytical sample the solid was recrystallized from ethanol. The yield was varied from the substituents however those are more than 80%. Physical properties and spectroscopic data are identical with those shown in Table 2.

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One-Step Construction of Tricyclic Benzene Derivatives *via* Palladium Catalyzed Cyclization of Acyclic Triynes

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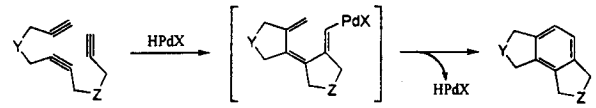
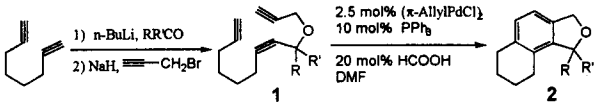
Construction of polycyclic compounds has been a major challenge in modern synthetic organic chemistry due to the large appearance of biologically active natural products possessing polycyclic rings.[1] Structurally well-oriented triynes have been cyclized to the corresponding benzene derivatives with an aid of transition metal catalysts such as cobalt,[2] nickel,[3] and rhodium[4] in good to excellent yields. Limited utility of these reactions mostly stems from the problem of selectivities in intermolecular cyclizations. Such problems could be resolved by tethering three acetylene units. Recently, it was reported that tetrakis(triphenylphosphine)palladium(0) could cyclize appropriately structured triynes, haloendiynes, or haloeneyne-alkyne mixture to the corresponding benzene derivatives.[5] Continuing our interest in palladium catalyzed polycyclizations,[6] we have envisioned these [2+2+2] polycyclizations of triynes and wish to report a general and mild method to provide the tricyclic benzene derivatives *via* palladium(II) catalyzed triyne cyclizations (Scheme 1).

Initially, the terminal acetylene unit reacts with HPdX species, *in situ* formed from commercial palladium compound plus additive formic acid, to give vinylpalladium species which could easily undergo consecutive carbapalladation to generate the triene palladium species. The intermediate then could cyclize and cleave to the benzene derivative and HPdX species which react with an acetylene unit of other triynes to repeat this process. We have found a good condition: π-allylpalladium chloride dimer as a catalyst, triphenylphosphine as a ligand, and formic acid as a hydrogen source.[7] Thus we have applied this condition to triynes **1a-d** which could be easily prepared in a two-step operation (Scheme 2).

When a dimethylformamide solution of substrate **1a**, 2.5 mol% of π-allylpalladium chloride dimer,[8] 10 mol% of triphenylphosphine, and 20 mol% of formic acid was stirred for 1 h at 110 ℃, the reaction solution turned black within 10 min and the corresponding cyclic product **2a** was isolated as an only isolable product. Lowing the reaction temperature down to 90 ℃ under the similar condition proceeded the cyclization smoothly to the corresponding benzene derivatives in 69% yield as a sole product. Further lowering the reaction temperature down to 70 ℃ and 50 ℃ retarded this cyclization to the product **2a** in lower yields. The similar condition was applied to triyne **1b** and **1c**. Both **1b** and **1c**



Scheme 1.



R, R'=	Substrate	Conditions	Product	Yield (%)
H, $CH_2CH_2CH_3$	**1a**	110 ℃, 1 h	**2a**	50
		90 ℃, 3 h		69
		70 ℃, 2 h		60
		50 ℃, 4 h		19
H, $CH(CH_3)_2$	**1b**	90 ℃, 3 h	**2b**	77
H, C_6H_5	**1c**	60 ℃, 2 h	**2c**	54
CH_3, CH_3	**1d**	60 ℃, 2 h	**2d**	68

Scheme 2.