

Condensation of Nitriles with Thiamides II. Acetonitrile with Thiobenzamide; and Benzonitrile with Thioacetamide

By

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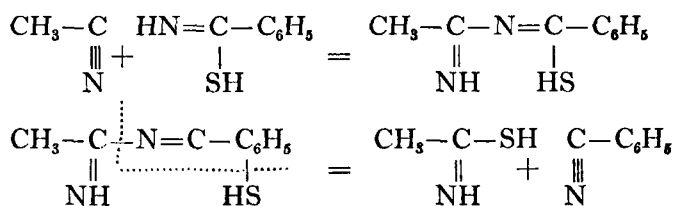
(Received July 11, 1923)

In the previous communication¹ it was reported that benzonitrile and thiobenzamide combine together to form benziminoisothiobenzamide, when their ethereal solution is saturated with dry hydrogen chloride. Now in extending the study to the condensation of acetonitrile with thiobenzamide a quite unexpected result was found. The condensation product then obtained was not acetiminoisothiobenzamide as was expected but benziminoisothiobenzamide, the very substance which was reported previously as the condensation-product of benzonitrile with thiobenzamide. At first I suspected that this unexpected result was brought about by benzonitrile, with which the ethereal solution had become admixed by some mistake. So that the experiment was repeated once more all the materials used being strictly examined and carefully purified. But the experiment always resulted in the production of the same substance, leaving no room to doubt that what is produced by passing dry hydrogen chloride into an ethereal solution of acetonitrile and thiobenzamide is nothing but benziminoisothiobenzamide. The only substance conceivable as the source of benzonitrile which entered into the condensation, is thiobenzamide from which it might be considered to have been produced either by simple decomposition or by an interaction with acetonitrile. To decide which

¹ These Memoirs, V, 179 (1921).

was really the case, dry hydrogen chloride was saturated in a cooled ethereal solution of thiobenzamide as is described in experiment II. The yellow colour of the solution remained unchanged; no hydrogen sulphide was evolved; no sign of the decomposition of the thiamide into benzonitrile and hydrogen sulphide could be observed. When, however, acetonitrile was added to it the colour of the solution began to change gradually from yellow to reddish yellow, showing that condensation between benzonitrile and thiobenzamide had now set in.

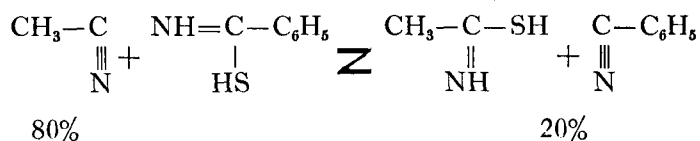
As to the mechanism of the reaction by which benzonitrile is produced from acetonitrile and thiobenzamide the author ventures to explain it on the assumption, that acetonitrile and thiobenzamide first condense with each other in the same manner as in the condensation of benzonitrile and thiobenzamide, and this condensation-product because of its instability decomposes into benzonitrile and thio-acetamide as is seen in the following equation :



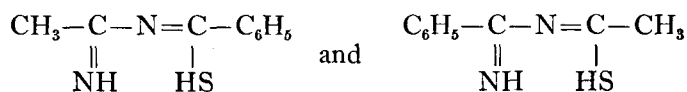
If this explanation is correct thio-acetamide must be found in the solution, in which the condensation took place. So the solution was examined by treating it in the manner described in experiment III, and thio-acetamide was really isolated.

While in the condensation of benzonitrile with thiobenzamide the yield of benziminoisothiobenzamide is nearly quantitative, the quantity of the same condensation-product formed by the interaction of acetonitrile and thiobenzamide is so small, that only about 14% of the thiobenzamide originally used can be regarded as having taken part in the condensation. The doubt as to what causes such a discrepancy between the two condensations was made clear on studying the condensation of benzonitrile with thio-acetamide. When the ethereal solution of benzonitrile and

thioacetamide was saturated with dry hydrogen chloride as usual, benziminoisothiobenzamide was also formed as the condensation-product, and at the same time a lot of thiobenzamide was produced. From the quantities of the condensation-product and thiobenzamide it was roughly calculated that about 71% of the benzonitrile used had changed into thiobenzamide (Experiment IV). On considering the above two relations together it may be concluded that the reaction between acetonitrile and thiobenzamide is a reversible one which attains an equilibrium when about 20% of them changes into benzonitrile and thioacetamide thus :



All efforts to isolate the intermediate condensation-products



were found fruitless.

EXPERIMENTAL PART

EXPERIMENT I.

2.0 grams of acetonitrile and 6.64 grams of thiobenzamide (molecular proportion) were dissolved in 200 c.c. of ether, and into this solution dry hydrogen chloride was conducted when the solution gradually acquired a reddish tint which became the deeper the more hydrogen chloride was passed. As the ethereal solution thus saturated with hydrogen chloride produced no crystalline substance even after 12 hours an equal volume of ether was added, whereupon orange-coloured crystals separated out. The crystals were gathered, washed with ether and treated with a soda solution; the substance thus liberated was extracted with benzene and crystallized from it by addition of petroleum ether. About 0.2 gram of red prismatic crystals melting at 75° was thus

¹ These Memoirs, V, 179(1921).

obtained. Their physical and chemical properties were all found to be quite identical with those of benziminoisothiobenzamide¹ formerly reported as formed by the condensation of benzonitrile with thiobenzamide. The result of the experiment was quite unexpected, but it was confirmed by repeating the experiment with the utmost care. The condensation-product was analysed with the following results :

1. 0.3464	gram. hydrochloride	gave	0.1803	gram. AgCl
2. 0.2354	gram. ,, ,,	gave	0.1188	gram. ,,
				Calc. (C ₁₄ H ₁₂ N ₂ S.HCl)
	Found			
	(1)	(2)		
Cl	12.88	12.49		12.84 %
3. 0.2400	gram. the substance required 20.9 c.c. $\frac{1}{10}$ N-I for			
	oxidation and gave 0.2336 gram. dibenzylazosulphime.			
	Found		Calc. (C ₁₄ H ₁₂ N ₂ S)	
$\frac{1}{10}$ N-I	20.9		20.0 c.c.	
C ₁₄ H ₁₀ N ₂ S	0.2336		0.2380 gram.	

The molecular weight of the condensation-product was determined by the cryoscopic method, using its benzene solution.

Benzene 17.6826 gram., the substance 0.3435 gram., freezing point depression 0.417°

	Found	Calc. (C ₁₄ H ₁₂ N ₂ S)
Mol. Weight	247	240

EXPERIMENT II.

To see whether benzonitrile could be produced from thiobenzamide by the action of hydrogen chloride, 0.83 gram of thiobenzamide was dissolved in 50 c.c. of ether, and into this ethereal solution dry hydrogen chloride was passed. The solution became turbid after about an hour but again clear on further saturation with hydrogen chloride, and no colour-change was observed. This clearly points out that no benzonitrile was liberated in the solution. For, if some benzonitrile were liberated, it would condense with thiobenzamide so as to yield benziminoisothiobenzamide, which must impart a reddish colour to the solution.

When the solution after standing over-night was mixed with the calculated quantity of acetonitrile, the colour of the solution began to change into reddish yellow, showing that the condensation-reaction between benzonitrile and thiobenzamide had now set in. It is, therefore, evident that benzonitrile is the product of the reaction between thiobenzamide and acetonitrile, but not that of the decomposition of thiobenzamide itself.

EXPERIMENT III.

If the reaction between acetonitrile and thiobenzamide actually proceeds in such a manner as the author assumes it to be, thioacetamide must be detected as one of the reaction-products. To confirm this, the following experiment was conducted. 10.0 grams of thiobenzamide and 2.99 grams of acetonitrile (molecular proportion) were together dissolved in ether and the solution was treated with dry hydrogen chloride as described before. By this treatment about 0.42 gram of benziminoisothiobenzamide was produced leaving 8.38 grams of thiobenzamide unchanged. To isolate thioacetamide from the ethereal solution in which the above condensation-reaction took place ether and hydrogen chloride were driven out by passing carefully dried air into the solution. Ether was then added to the residue and again driven out, and this process was repeated several times. The residue, still acidic, was digested with water, and the aqueous solution obtained was extracted with ether. Ether was then driven out from the ether extract, and the residue was again digested with water. On evaporating the aqueous extract a colourless crystalline substance mixed with thiobenzamide was obtained. It was washed with a small quantity of ether and recrystallized from ether. It was found to crystallize in plates, to melt at 107–108° and to precipitate silver sulphide from a silver nitrate solution. These properties and others all agree well with those of thioacetamide.

In this experiment 0.42 gram of benziminoisothiobenzamide and 8.38 grams of thiobenzamide were obtained from 10.0 grams of thioben-

zamide. It is, therefore, calculated that 14% of the thiobenzamide originally used changed into benzonitrile. This percentage could not be much increased by using twice as much thiobenzamide.

EXPERIMENT IV.

7.5 grams of thio-acetamide and 10.31 grams benzonitrile (molecular proportion) were dissolved in 100 c.c. of ether, and into this solution, cooled with ice, dry hydrochloric acid gas was passed. Some white crystalline substance was observed to crystallize out, but it gradually disappeared as the solution became saturated with hydrogen chloride, and at the same time the solution was coloured reddish yellow. On keeping the solution in a cooled chamber for 24 hours, its colour changed entirely to red. The ether was now driven out from the solution by passing dry air into it, and the residue (I) was repeatedly washed with ether and then treated with a soda solution. The free condensation-product liberated was extracted with ether and recrystallized from a mixture of benzene and petroleum ether. The ethereal solution obtained by washing the residue (I) with ether was evaporated, and the residue was treated with a small quantity of cold water to remove thio-acetamide and finally was dissolved in hot water from which thiobenzamide was obtained as needle crystals on cooling. By this process about 0.62 gram of the condensation-product and 9.104 grams of thiobenzamide were obtained. They were each analysed with the following results :

0.1851	gram.	hydrochloride of the condensation-product gave
0.0954	gram.	AgCl
		Found Calc. (C ₁₄ H ₁₂ N ₂ S.HCl)
Cl		12.75 12.84%
0.5013	gram.	thiobenzamide (m. p. 114—115°) gave 0.8210
	gram.	BaSO ₄ when oxidized with KMnO ₄ .
		Found Calc. (C ₇ H ₇ NS)
S		22.47 23.31 %

The value of sulphur was found a little lower than the theoretical, as a part of the thiobenzamide was transformed into dibenzylazo-sulphime which resisted further oxidation.

The author wishes to express his sincere thanks to Prof M. Matsui at whose suggestion the work was carried out.