Mass Spectra of Some 2-, 3-, and 4-Pyridinecarboxylic Acids. Further Evidence of a N-H Interaction for Loss of Carbon Dioxide

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Mass spectra of 3-acetamido-, 3-methoxy-, and 4-methoxy-2-pyridinecarboxylic acids, 2,6-pyridinedicarboxylic acid, 4-nitro-2-pyridinecarboxylic acid *N*-oxide, 2-chloro- and 2-nitro-x-pyridinecarboxylic acids (X = 3 and 5), 2-chloro- and 2-nitro-4-pyridinecarboxylic acids, and 4-pyridinecarboxylic acid are reported. The 2-pyridinecarboxylic acids lost carbon dioxide (M-44) as has been reported. The 3-pyridinecarboxylic acids showed no definite trend in fragmentation; however, the 4-pyridinecarboxylic acids lost OH (M-17) first. This change in fragmentation pattern is due to an interaction of the ring nitrogen and carboxyl group in the 2-pyridinecarboxylic acids which is not present in the 4-pyridinecarboxylic acids.

Several papers dealing with the mass spectra of aromatic carboxylic acids have recently been published which discuss the fragmentation pattern of the carboxyl group in benzoic acids (1,2) and 2-pyridinecarboxylic acids (3). The benzoic acids fragment by the initial loss of OH (M-17) or CO_2H (M-45) while the 2-pyridinecarboxylic acids lose CO_2 (M-44). This difference of fragmentation pattern was attributed to an interaction of the ring nitrogen and carboxyl group, in the case of the 2-pyridinecarboxylic acids, facilitating the loss of CO_2 (M-44) rather than loss of OH (M-17) or CO_2H (M-45).

Assuming that neutral gas molecules are bombarded in the direct inlet system and that no molecular collisions take place after ionization, it would be expected that if an N-H interaction is involved in the fragmentation of 2-pyridinecarboxylic acids that moving the carboxyl group to the 3- and 4-position would cause a change in fragmentation pattern, perhaps reverting to the patterns of the benzoic acids. To determine if this were the case, we have investigated the electron impact behavior of a series of pyridinecarboxylic acids in order to determine whether correlations exist between fragmentation patterns and position of the carboxyl group in these series of compounds.

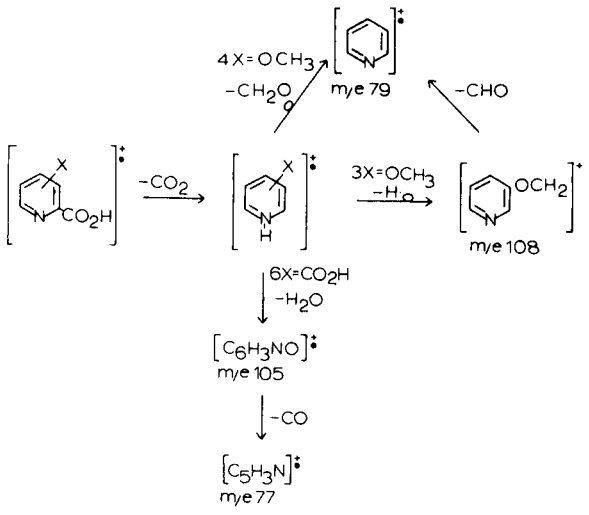

Figure 1

2-Pyridinecarboxylic Acids (4).

The mass spectral fragmentations are shown in Table I in fractional abundances. Figures 1 and 2 show the fragmentation patterns of 3-methoxy-2-pyridinecarboxylic acid (I), 4-methoxy-2-pyridinecarboxylic acid (II), 2,6-pyridinedicarboxylic acid (III), and 4-nitro-2-pyridinecarboxylic acid *N*-oxide (IV) and 3-acetamido-2-pyridinecarboxylic acid (V). All of these acids, except (V), had spectra similar to those reported previously for 2-pyridinecarboxylic acids (small molecular ion peaks and the loss of CO_2 generating a major peak) (3). These fragmentations are due primarily to electron bombardment because (a) two of the five acids show metastable ions which indicate that CO_2 is lost after ionization, (b) previously it was found that five of the ten 2-pyridinecarboxylic acids (3) reported showed metastable ions for loss of CO_2, and (c) the direct inlet temperature was well below the melting points of these compounds (all of these compounds decompose at or above their melting points).

After the loss of CO_2 from compound I, (Figure 1) the ion at m/e 109 fragments as reported for 3-methoxy-

TABLE I (a)

Peak heights expressed in percent of total ionization
[Σ m/e 40 to m/e (P+2)]

3-Methoxy-2-pyridinecarboxylic Acid (I) (5). Mass spectrum (70 eV) m/e (fractional abundance)

153(1.99), 152(1.73), 149(1.30), 141(0.78), 135(2.17), 134(0.87), 123(1.21), 110(0.78), 109(5.03), 108(7.37), 107(1.73), 106(1.04), 105(1.99), 97(0.87), 95(0.87), 94(1.73), 93(1.56), 85(0.87), 84(0.61), 83(1.13), 82(0.78), 81(1.13), 80(1.99), 79(10.12), 78(5.20), 77(1.99), 76(1.13), 75(0.69), 73(0.87), 71(1.30), 70(0.87), 69(1.99), 68(0.87), 67(1.56), 66(2.69), 65(1.99), 64(1.73), 60(0.95), 57(2.43), 56(1.04), 55(2.34), 54(0.87), 53(1.56), 52(3.28), 51(1.99), 50(1.99), 45(1.73), 44(1.47), 43(2.77), 42(1.04), 41(2.77), 40(1.13).

4-Methoxy-2-pyridinecarboxylic Acid (II) (5). Mass spectrum (70 eV) m/e (fractional abundance)

153(2.29), 149(0.90), 141(0.90), 110(2.69), 109(31.82), 108(5.67), 105(0.80), 97(0.70), 94(1.99), 93(3.28), 89(0.70), 85(0.70), 82(1.29), 81(0.80), 80(1.69), 79(5.57), 78(2.29), 77(1.59), 76(1.89), 71(1.00), 69(1.19), 68(4.08), 67(2.89), 66(1.79), 65(1.39), 64(1.19), 57(1.19), 56(0.70), 55(1.19), 54(0.80), 53(2.29), 52(3.88), 51(2.99), 50(2.19), 45(0.90), 44(0.90), 43(0.80), 41(1.00), 40(0.80).

2-6-Pyridinedicarboxylic Acid (III). Mass spectrum (70 eV) m/e (fractional abundance)

167(0.09), 124(1.60), 123(18.02), 122(1.71), 106(1.32), 105(15.25), 94(1.56), 79(2.23), 78(4.50), 77(1.42), 76(2.60), 75(1.75), 66(1.00), 57(1.03), 53(1.49), 52(4.24), 51(6.96), 50(5.28), 49(1.28), 45(4.24), 44(1.49).

4-Nitro-2-pyridinecarboxylic Acid *N*-Oxide (IV) (5). Mass spectrum (70 eV) m/e (fractional abundance)

184(1.03), 154(0.77), 141(1.80), 140(19.26), 125(0.86), 124(7.87), 123(2.39), 111(0.86), 94(3.42), 85(0.77), 84(0.86), 82(0.86), 79(0.77), 78(4.62), 77(3.08), 76(1.71), 75(0.94), 67(1.03), 66(0.94), 64(3.93), 63(4.11), 62(1.54), 61(0.86), 53(1.03), 52(1.63), 51(4.02), 50(3.51), 49(0.94), 44(0.77).

3-Acetamido-2-pyridinecarboxylic Acid (V) (11,13). Mass spectrum (70 eV) m/e (fractional abundance)

181(0.83), 180(6.00), 165 (1.24), 147(2.28), 138(6.10), 136(4.03), 135(3.52), 120(1.24), 119(3.00), 95(4.03), 94(15.81), 93(2.69), 92(2.90), 91(2.07), 69(1.24), 67(5.79), 66(2.69), 65(2.28), 64(2.07), 57(1.24), 55(1.45), 52(1.55), 51(1.24), 45(1.45), 43(8.69), 42(1.24), 41(2.38), 40(1.76).

2-Chloro-3-pyridinecarboxylic Acid (VII) (9,12). Mass spectrum (70 eV) m/e (fractional abundance)

159(6.96), 158(1.55), 157(21.94), 142(4.38), 141(1.03), 140(13.14), 122(0.77), 115(0.77), 114(2.06), 113(2.06), 112(6.44), 94(1.29), 85(1.29), 78(3.35), 77(3.35), 76(4.38), 75(1.29), 66(1.29), 47(2.06), 52(1.03), 51(4.12), 50(5.15), 49(1.29).

2-Chloro-5-pyridinecarboxylic Acid (VIII) (9,12). Mass spectrum (70 eV) m/e (fractional abundance)

159(7.75), 158(1.69), 157(23.00), 142(3.63), 141(3.39), 140(11.62), 137(9.20), 122(1.21), 114(1.69), 113(1.21), 112(6.30), 111(1.69). 85(1.69), 78(2.18), 77(1.21), 76(3.15), 75(1.21), 53(0.73), 52(0.97), 51(1.69), 50(3.15), 49(1.21), 45(1.69).

2-Nitro-3-pyridinecarboxylic Acid (IX) (11). Mass spectrum (70 eV) m/e (fractional abundance)

168(0.00), 160(1.72), 158(0.74), 157(1.23), 138(3.19), 124(1.23), 122(3.44), 120(0.98), 114(0.98), 112(2.46), 95(1.23), 94(5.41), 93(2.46), 92(1.72), 79(1.97), 78(30.71), 77(1.47), 76(2.21), 75(1.23), 67(1.23), 66(2.21), 65(0.98), 64(0.74), 52(2.95), 51(6.88), 50(3.69), 49(0.74), 44(0.98).

2-Nitro-5-pyridinecarboxylic Acid (X) (11). Mass spectrum (70 eV) m/e (fractional abundance)

168(0.62), 151(0.62), 149(0.62), 138(1.24), 123(3.73), 122(36.65), 121(0.62), 120(0.62), 110(0.62), 105(0.62), 104(0.62), 95(0.62), 94(3.11), 93(0.62), 82(0.62), 80(0.62), 79(0.62), 78(6.83), 77(3.73), 76(3.73), 75(1.86), 67(0.62), 66(3.11), 65(0.62), 64(0.62), 63(0.62), 55(0.62), 54(0.62), 53(1.24), 52(3.73), 51(8.07), 50(4.97), 49(1.24), 46(0.62), 45(4.97).

4-Pyridinecarboxylic Acid (XI). Mass spectrum (70 eV) m/e (fractional abundance)

124(1.58), 123(19.82), 107(0.79), 106(7.45), 105(2.54), 94(0.79), 79(1.58), 78(10.77), 77(1.58), 76(0.95), 75(0.79), 69(0.79), 68(0.63), 67(0.79), 57(1.11), 55(1.27), 53(1.58), 52(6.18), 51(12.04), 50(7.45), 59(1.74), 47(0.79), 45(2.38), 44(0.79), 43(1.27), 41(1.58).

2-Nitro-4-pyridinecarboxylic Acid (XII) (11). Mass spectrum (70 eV) m/e (fractional abundance)

168(0.36), 157(1.28), 151(0.73), 138(1.28), 123(2.00), 122(10.38), 105(5.65), 104(1.82), 94(2.73), 92(3.64), 80(0.73), 78(1.28), 77(2.37), 76(5.46), 75(1.28), 67(1.64), 66(9.11), 65(2.73), 57(4.55), 53(1.09), 52(1.64), 51(7.10), 50(6.01), 49(1.09), 45(5.10), 44(1.28), 43(1.82), 41(2.00).

2-Chloro-4-pyridinecarboxylic Acid (XIII) (9,12). Mass spectrum (70 eV) m/e (fractional abundance)

159(9.93), 158(2.21), 157(30.15), 142(1.84), 140(5.51), 139(0.74), 123(0.74), 122(7.35), 114(1.47), 112(4.04), 109(0.74), 94(0.74), 87(1.10), 86(0.74), 85(2.94), 79(2.21), 77(1.10), 76(2.21), 75(1.47), 66(2.57), 62(0.74), 51(3.68), 50(5.51), 49(1.47), 45(2.21).

(a) All peaks between m/e 40 and P+2 of significance are reported.

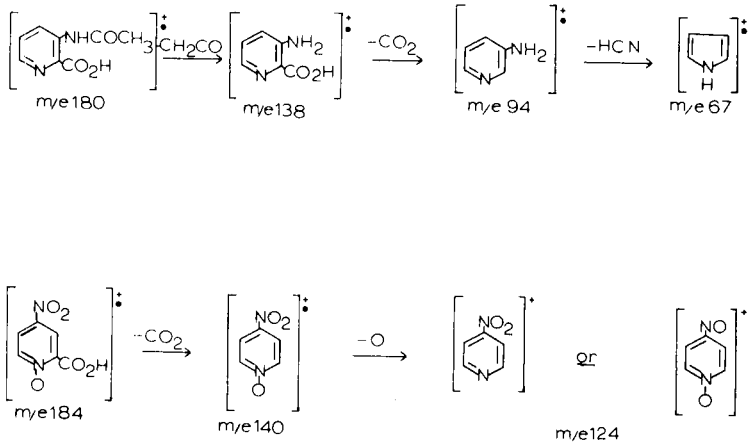

Figure 2

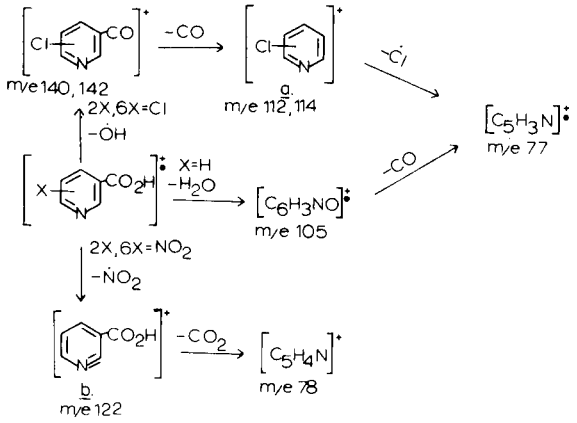

Figure 3

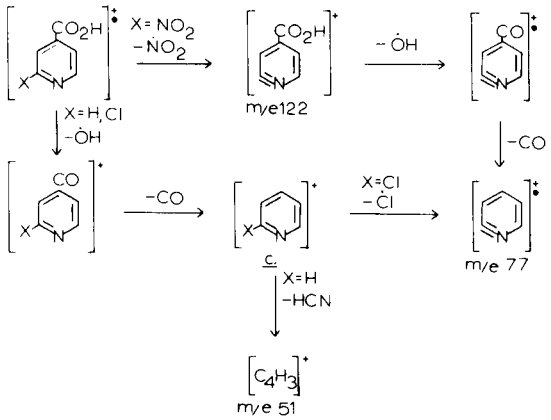

Figure 4

pyridine (loss of H followed by CHO) (5). Although the reported fragmentation pattern of 3-methoxypyridine is only tentative, our data supported this pattern. Compound II, (Figure 1) lost CO_2* to yield an ion at m/e 109. Compound III, (Figure 1) lost CO_2 to yield an ion at m/e 123. This ion was not believed to be the 2-pyridinecarboxylic acid ion since it lost H_2O* followed by CO* instead of CO_2 as expected for a 2-pyridinecarboxylic acid ion. Compound IV, (Figure 2) lost CO_2 in its first fragmentation. Since the postulated mechanism for the loss of CO_2 involved and N-H interaction (3), the *N*-oxide could also have an O-H interaction to facilitate the loss of CO_2. The ion, m/e 140, loses oxygen to yield either 4-nitropyridine ion or 4-nitrosopyridine *N*-oxide ion. We presently favor the 4-nitropyridine ion since with substituted quinoline and isoquinoline *N*-oxides the abundance of the M-16 ion amounts to 15-40% of the base peak while the corresponding parent *N*-oxides lost an oxygen atom to the extent of less than 12% even in the presence of a nitro group (7,8). Compound V, (Figure 2) loses ketene to yield an ion at m/e 138. This ion is believed to be the 3-amino-2-pyridinecarboxylic acid ion which then loses CO_2* to yield the 3-aminopyridine ion at m/e 94. This ion then fragments as expected (loss of HCN) (9). The loss of ketene from V could be explained by a McLafferty type rearrangement. The loss of CH_2CO* was also reported from the 6-acetamido-2-pyridinecarboxylic acid ion (3).

3-Pyridinecarboxylic Acids.

Figure 3 shows the fragmentation patterns of 3-pyridinecarboxylic acid (VI) (3), 2-chloro-3-pyridinecarboxylic acid (VII), 2-chloro-5-pyridinecarboxylic acid (VIII), 2-nitro-3-pyridinecarboxylic acid (IX), and 2-nitro-5-pyridinecarboxylic acid (X). These acids did not show any one similar fragmentation pathway. Compound VI lost H_2O* followed by CO* to yield a peak at m/e 77. After the loss of OH* and CO* compounds VII and VIII yielded at m/e 112 and 114. This ion was identified by its subsequent

loss of a chlorine atom. The loss of a chlorine atom was also supported by the appropriate metastable ion in VII. Both compounds IX and X lost NO_2 first to yield b at m/e 122. This peak then lost CO_2.

4-Pyridinecarboxylic Acids.

The fragmentation patterns of 4-pyridinecarboxylic acid (XI), 2-nitro-4-pyridinecarboxylic acid (XII), and 2-chloro-4-pyridinecarboxylic acid (XIII) are shown in Figure 4. These acids show a regular fragmentation pattern similar to the benzoic acids. All of these compounds lose OH followed by CO. After the loss of OH*, compound XI yielded an ion at m/e 106 which then lost CO. The ion at m/e 78 was tentatively identified as c by the subsequent loss of 27 mass units to yield an ion at m/e 51 (10). Compound XII lost NO_2* first. This was expected since it has been reported that a nitro group at the 2-position is very easily lost (3,10). The ion at m/e 122 then lost OH followed by CO* to yield the ion at m/e 77. Compound XIII lost OH* followed by CO* to yield c. This ion was tentatively identified by a comparison of the spectra of compounds XII and VIII. Ion c then lost a chlorine atom to yield a peak at m/e 77. These results are interpreted as further evidence that the irregular loss of CO_2 (M-44) as previously reported for the 2-pyridinecarboxylic acids (3) is due to a ring nitrogen-carboxyl group interaction which is not possible for the 4-pyridinecarboxylic acids. A similar interaction (*N*-oxide-carboxyl group) may take place with 2-pyridinecarboxylic acid *N*-oxides.

EXPERIMENTAL

The 70 eV mass spectra of these compounds were obtained with a Hitachi Perkin-Elmer RMU-6E mass spectrometer using the direct inlet method at temperatures (up to 270°) high enough to obtain sufficient sample for a determination. These acids were prepared according to the literature (5,11,12,13) or purchased. They were all analytically pure.

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(4) A star (*) following a fragment ion indicates that this process is supported by the presence of the appropriate metastable ion in the mass spectrum.

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