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A review

Thermal decomposition of salicylic acid and its salts

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ABSTRACT

A survey is given concerning studies of the thermal decomposition of salicylic acid and its alkaline, alkaline earth and other metal salts. The application of thermal analysis to the detection and quantitative determination of salicylic acid and its salts is discussed. Studies on the elucidation of the mechanism of commercial-scale manufacture of salicylic acid, by using thermal methods of analysis, have been reported.

INTRODUCTION

Salicylic acid (SA) is one of the most important aromatic hydroxy(carboxylic) acids. It was obtained in 1838 by oxidation of the glycoside occurring in the bark of willow (*Salix alba*). SA has been extensively used in the pharmaceutical industry for the manufacture of a variety of important antiseptics, disinfectants, antipyretics and antirheumatics. Moreover, it is used in the foodstuff industry and for the manufacture of dyestuffs[1].

An irritating and even corrosive action of SA on human tissue restricts its utilization in medicine, but its sodium salt (SA-Na) can be used. Of other SA salts, bismuth(III) subsalicylate [sub-SA-Bi(III)] and recently lithium (SA-Li) and mercuric salicylates have found use[2, 3].

Owing to the practical significance of SA and its salts, it has been decided, in this article, to characterize their thermal decomposition and rearrangement. The problem has not previously been the subject of a review article.

1. THERMAL DECOMPOSITION OF SALICYLIC ACID

SA forms colourless or white needles, m.p. 158 °C, which are sparingly soluble in water, especially in the cold. It is thermally unstable; on gentle heating, it undergoes decarboxylation to give phenol (PhOH). In the presence of 1 or 3 % potassium chloride, the m.p. of SA, determined in the Boetius' apparatus, shows no depression, except for being less sharp and having an extended range[4]. Similar results were obtained with specimens containing 5% of potassium chloride, potassium sulphate or potassium nitrate. A DTA endothermic peak due to the m.p. of SA was employed for the study of several factors influencing the DTA peak shape such as the location of the thermocouple for determination of the temperatures, the asymmetric location of the differential thermocouples, thermal asymmetry due to unequal loading of sample and reference materials, the effect of sample size on differential area using equal crucible loadings and constant sample concentration, and the effect of the heating rate on the peak height and area[5]. Crystalline SA diluted with 500 mesh carborundum (silicon carbide) was used in these studies. Silicon carbide was also used as a reference material. The results showed that the precision of the DTA using diluted samples overcomes some of the difficulties encountered in working with the pure sample, such as selection of a reference material with inadequate heat capacity, local cooling effects and major differences in particle size. Vold's equation, predicting a linear relationship between the enthalpy of reaction (ΔH) and the DTA peak area for undiluted samples, can be applied to diluted samples using the constant sample concentration, equal weight loadings in sample and reference crucibles and maintenance of detector symmetry in the centres of sample and reference materials. A marked deviation from linearity in the Vold equation occurs below a critical sample size which, in turn, depends on the percentage of active material in the sample, on the diameter of the sample crucible and the size of the thermocouple junction. By use of silver nitrate for estimation of the calibration curve, the specific heat of melting of SA (28.2 ± 0.5 cal g^{-1}) was calculated. The studies were continued to estimate the influence of the particle size, the heat capacity, and the thermal conductivity of the diluent on the DTA peak area[6]. Moreover, the effect of adsorption of gases on the diluent, the significance of liquid diluents and the masking effects of the diluents were also studied. It was shown that, in the case of a compound diluted with a material of high heat capacity, the differential thermal deflection was smaller in area than if the compound had been diluted with a material of a low heat capacity[6] (Table 1).

Pirisi and Mattu[7, 8] recorded endothermic peaks at 50–120°C (max. at 110°C), 150–185°C (max. at 157–160°C), 220–230°C (max. at 220°C) and 260–296°C (max. at 280°C) as well as an exothermic peak at 300–400°C on the DTA curve of SA. Peaks 2–5 (ref. 7) are due to the melting, formation of phenyl salicylate, formation of PhOH and probably the formation of xanthone, respectively. A DTA apparatus permitting almost continuous recording of the DTA curve with calcined china clay as a reference material was used for the study of SA mixed with calcined china clay in the proportion 1:4 by weight at a heating rate of 20°C min^{-1} (ref. 9). The curve showed only two endothermic peaks at 152 and 247°C due to melting and sublimation of SA. At about 400°C, the compound gave an additional small exothermic peak. It has been observed that the diluent sometimes reacts with active sample components to produce another thermally active material. This was observed when SA mixed with powdered iron was allowed to stand exposed to the atmosphere for five days[6]. The DTA curve recorded for ferric salicylate [SA-Fe(III)] diluted with silicon carbide

TABLE 1

AREA GENERATED BY 0.01 G OF SALICYLIC ACID DILUTED WITH VARIOUS MATERIALS[6]

Heating rate 7.9 °C min^{-1}, ΔT sensitivity 200 μV 3 $in.^{-1}$.

Diluting agent	*SA (%)*	*Specific heat of diluting agent ($cal\,g^{-1} \times 10^{-1}$)*	*Thermal conductivity of support*[a]	*Area/0.01 g SA (mm^2)*
Carborundum	6.87	1.1	5×10^{-4}	306
Iron metal	8.82	1.0	2×10^{-1}	710
Ferric oxide	3.40	1.8	3×10^{-4}	280
Glass beads, 0.029mm	4.57	1.9	2×10^{-3}	322
Glass beads, 0.29mm	5.58	1.9	2×10^{-3}	289
Alumina	8.60	1.9	2×10^{-3}	313
Nujol	20.00	4.7	4×10^{-4}	92

[a] Thermal conductivity is given in cal transmitted per sec through a plate 1 cm thick across an area of 1 cm^2 when the temperature difference is 1 °C at 100 °C.

was almost identical with that of the exposed mixture. Recording of the DTA, TG and DTG curves of mixtures containing SA and sodium bicarbonate, sodium carbonate or disodium salicylate (SA-Na_2) showed that in the each of the mixtures, SA-Na and appropriate gaseous products were formed quantitatively[30-32]. The occurrence of this reaction was confirmed by comparing the recorced curves with those of the products and starting reagents. An accurate analysis of ternary mixtures showed that, under the thermal analysis conditions, the ease of interaction with SA decreases in the sequence sodium carbonate > SA-Na_2 > sodium bicarbonate.

A study of a variety of binary mixtures obtained by the mechanical mixing of two organic compounds (physical mixture), the solidification of a fused physical mixture (fused mixture) or the evaporation to dryness of a solvent from a solution of the physical mixture and solidifing the residue by keeping at a temperature lower than the eutectic point but higher than the metastable eutectic point (evaporated mixture), has shown the possibility of using the DTA (DSC) for a detection of molecular compounds[10]. When the components do not form a molecular compound, the DTA (DSC) curves for the above three kinds of mixtures are very similar to each other. The evaporated mixture usually solidifies in a stable equilibrium state and the recorded DTA (DSC) curves become similar to that of the molecular compound or of its mixture with either of the components. The DTA curve of a physical mixture of SA and caffeine shows the consecutive appearance of endothermic and exothermic peaks due to the normal eutectic fusion of the mixture, formation of a molecular compound and its solidification. The results of these studies (Fig. 1) are important for the pharmaceutical industry because the knowledge of physical incompatibilities occurring in drug mixtures permits difficulties encountered in the manufacture of the solid dosage forms to be predicted. The heat evolved during mixing, sieving and compressing will sometimes raise the temperature above that of the metastable eutectic point. Even if the final product can be formed, its bio-

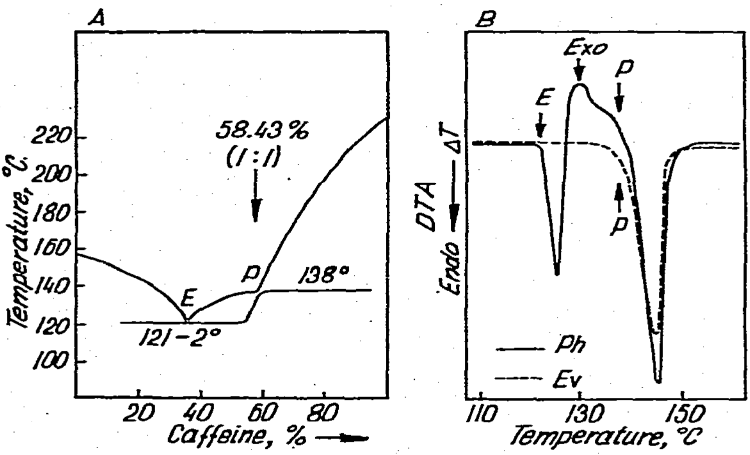


Fig. 1. Phase diagram (A) and DTA curves of a mixture containing 35% of salicylic acid and 65% of caffeine (B) (from ref. 10). Ph = Physical mixture, 43.5mg; Ev = evaporated mixture (from acetone solution), 42.2mg; E = eutectic point; P = peritectic point. Heating rate 1.5°C min^{-1}.

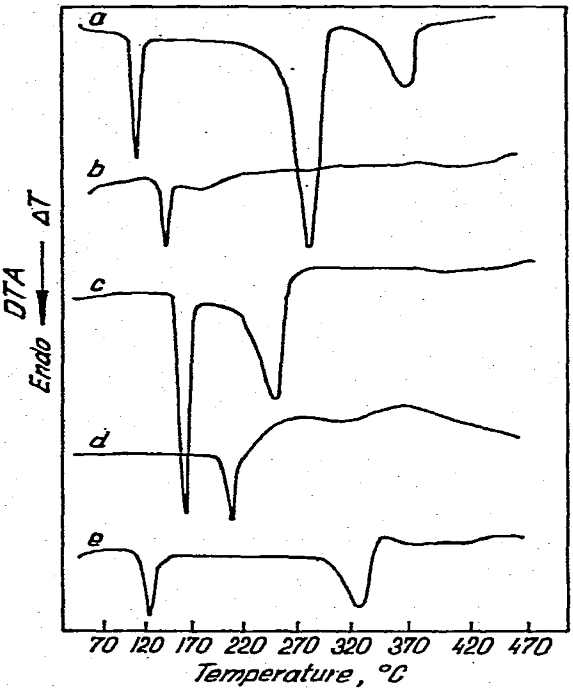


Fig. 2. DTA curves of some pharmaceuticals (from ref. 11). a, Meprobamate; b, acetylsalicylic acid; c, salicylic acid; d, papaverine hydrochloride; e, phenobarbital. Heating rate 12°C min^{-1}.

pharmaceutical properties will depend on the conditions of manufacture. The application of DTA to the detection of a solid state interaction between a variety of drugs has been described in many articles. An "Aminco" thermoanalyzer with alumina as a reference material was used for recording the DTA curves of a series of binary mixtures containing drugs[11] (Figs. 2 and 3). Of the mixtures studied, it has been shown that the mixture of SA and meprobamate suffered some variations which suggested that, in the solid state, a reaction occurred at 50°C between the

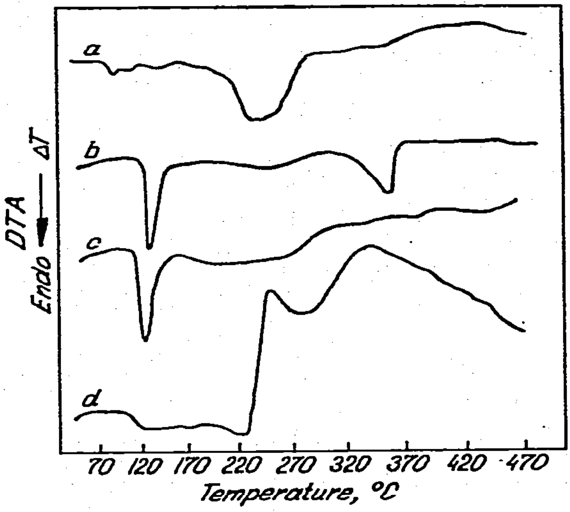


Fig. 3. DTA curves of mixtures of salicylic acid and some pharmaceuticals (from ref. 11). a, Salicylic acid and meprobamate; b, salicylic acid and phenobarbital; c, salicylic acid and acetylsalicylic acid; d, salicylic acid and papaverine hydrochloride. Heating rate 12°C min^{-1}.

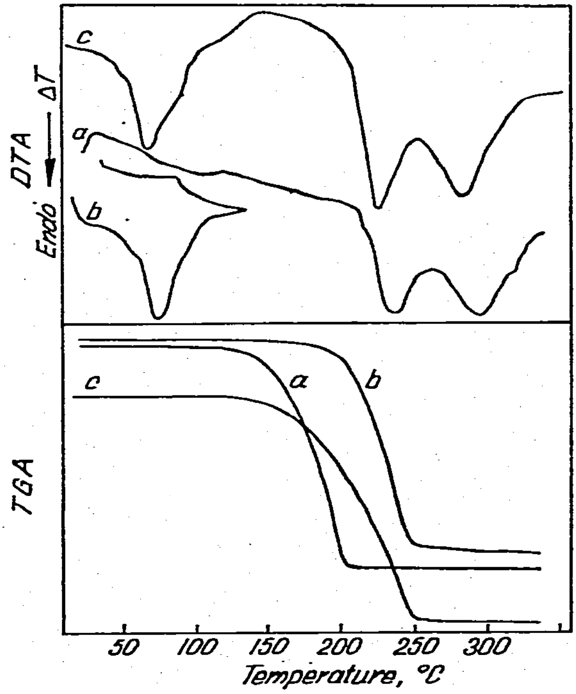


Fig. 4. DTA and TG curves recorded by Du-Pont 950 thermoanalyzer (from ref. 11). a, Salicylic acid; b, meprobamate; c, mixture of salicylic acid and meprobamate (1 : 1 by weight). Heating rate 12°C min^{-1}.

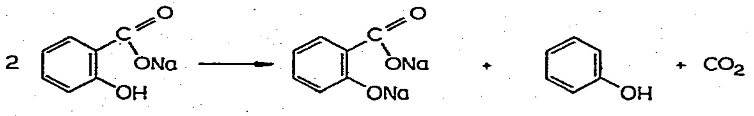
–COOH group of one of them and the –NH_2 groups of the other with the approximate mole stoichiometric ratio of the reagents of 1 : 2 (Fig. 4).

DTA was used for the quantitative determination of SA. A method has been developed for the determination of SA diluted with silicon carbide in the concentration range 0.1–10% based on the fact that when total sample and reference material sizes as well as the heating rate are constant, the DTA peak area varies linearly with the concentration of SA in a sample[5]. Similarly, the peak height varying in a defined but not linear manner can be used in the quantitative determination of 1–10 mg of SA. The standard deviation of the peak height measurement was 0.07 mg and that of the area was 0.15 mg. Also, the possibility was demonstrated of a semi-quantitative determination of SA in binary, ternary and quaternary mixtures containing sodium bicarbonate, sodium carbonate, SA-Na or SA-Na$_2$[30–32].

Of other thermoanalytical methods used for the study of SA, it is worthwhile to name the reaction thermal analysis (RTA) method. This method is based on the reaction of a test substance with a suitable reagent under programmed temperature conditions[12]. The gaseous reaction products are detected by the gas chromatography detector. This method seems to be applicable to the identification of chemical groups and their location in certain types of molecules. Analysis of SA by RTA, based on a reaction with alkaline cupric carbonate in quinoline solution, was performed at 40–500 °C[13]. Attention was mainly directed to the moment when carbon dioxide was split off. A simple TAS method (T = thermomicro and transfer, A = application, S = substance) is also used for the study of SA. It is based on a simple technique for the separation of many substances the solid materials. A material to be analysed is placed in a glass cartridge with a conical tip and heated rapidly for a short time to a pre-determined temperature with the direct transfer of the decomposition products to the starting line of a thin-layer chromatography plate[14]. The plate is then chromatographed in the usual way. The method was applied for the rapid detection of SA used as a preservative in the commercial foodstuffs manufactured in the German Federal Republic[15].

2. THERMAL DECOMPOSITION OF SALICYLIC ACID SALTS

Mattu and Pirisi[8, 16] observed several endothermic peaks on the DTA curve of SA-Na over the ranges 40–70 °C, 70–140 °C, 275–325 °C (max. at 310 °C) and 440–455 °C as well as an exothermic peak at 455–480 °C (max. at 470 °C). On the basis of the TG curve recorded at a heating rate of 300 °C h^{-1}, Duval[17] showed that SA-Na undergoes vigorous decomposition at 260–320 °C to form sodium carbonate which melted above 858 °C to undergo partly dissociation. The decomposition of SA-Na studied by Radecki et al.[18, 19] using a thermobalance, without automatically programmed temperature, and the recorded TG curve show that SA-Na remained undecomposed up to 300 °C. The extensive decomposition with the formation of sodium carbonate was observed over the range 300–440 °C. A somewhat lower theoretical loss in weight was explained as being due to incomplete breakdown of the salt. The DTA and TG curves as well as X-ray analysis showed that both SA-Na and potassium salicylate (SA-K) decomposed according to the equation



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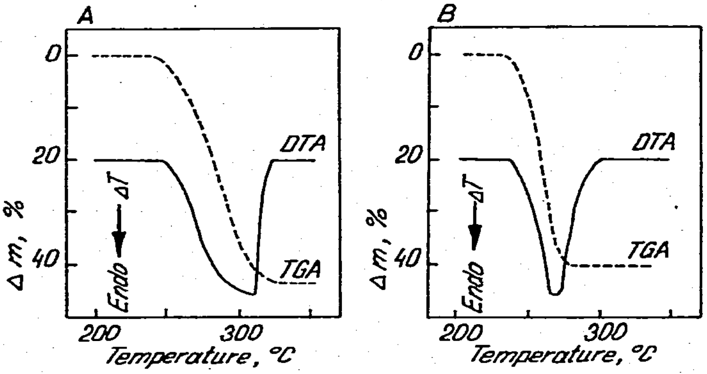


Fig. 5. DTA and TG curves of sodium salicylate (A) and potassium salicylate (B) (from ref. 20). Heating rate 10°C min^{-1}; sample weight 100 mg.

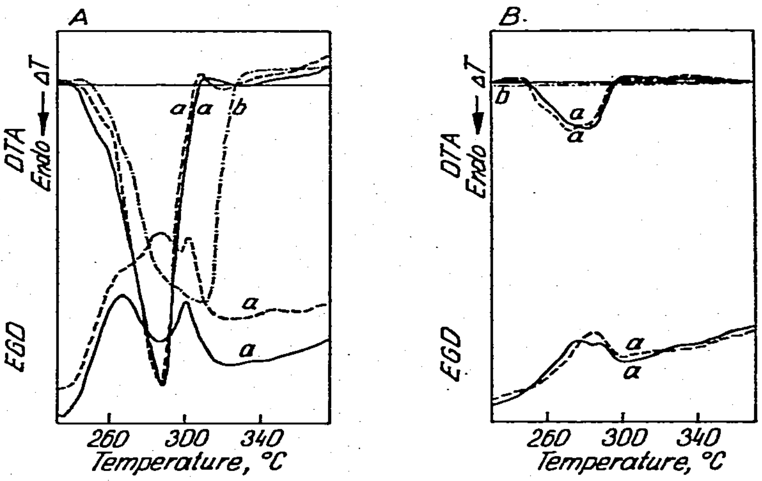
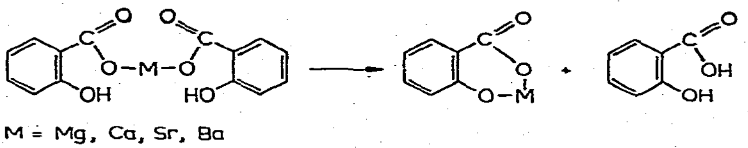


Fig. 6. DTA and EGD curves of sodium salicylate (A) and disodium salicylate (B) in an atmosphere of nitrogen (from ref. 54). a, Microanalysis ——, under a pressure of 3.85 atm of nitrogen ----; b, macroanalysis –.–.–.

The only of difference was that, in the case of SA-K, dipotassium *p*-hydroxybenzoate (PHBA-K_2) was formed[20] (Fig. 5). These reactions were accompanied by single endothermic DTA peaks. Thermal decomposition of SA-Na_2 and dipotassium salicylate (SA-K_2) were also studied by the same authors[21]. The rearrangement of SA-K_2 into PHBA-K_2 involves both endothermic and exothermic peaks and is accelerated by the presence of carbon dioxide. The activation energy determined by the Kissinger's method is 21 kcal mole^{-1} over the carbon dioxide pressure range of 500–800 mm of Hg. The course of the thermal decomposition of SA-Na according to reaction (1) is also described in refs. 22 and 30. The DTA curve of SA-Na recorded simultaneously with the EGD curve (determination of the sum of PhOH and carbon dioxide) using a Shimadzu EGD-20 apparatus and a DT–GC system, exhibited a sharp and clear endothermic peak due to the rearrangement of SA-Na into SA-Na_2 and liberation of gaseous products[54] (Fig. 6). The DTA curve indicated that SA-Na_2 remained unchanged over the temperature range studied.

The DTA, TG and DTG curves showed that the thermal decomposition of alkaline earth metal salicylates occurs in four stages: evolution of crystalline water, formation of an internal salt according to



(2)

decomposition of these salts a form appropriate carbonates and their dissociation to oxides[23]. The thermal stability of the metal carbonates increased as the ionic radius of the metal increased. Further evidence supporting this view has been provided by the failure of an attempt to isolate magnesium carbonate in the case of magnesium salicylate on the one hand and the ease of isolation of the carbonates of the remaining metals on the other. It has also been observed that the DTA peak areas decreased with increasing ionic radius and specific gravity of the metal. The DTA curve of calcium salicylate was also described by Tanabe and Okamoto[24].

Endothermic peaks were found on the DTA curve of sub-SA-Bi(III) at 40–70 °C (a small max. at 66 °C), 170–185 °C (max. at 175 °C) and 280–310 °C (max. at 295 °C) as well as exothermic peaks at 310–340 °C (max. at 320 °C) and over the range 340–500 °C. The last-named peak was poorly reproducible due to a variety of decomposition reactions taking place[8, 25]. Based on the DTA, TG and DTG curves of SA-Bi(III) and of sub-SA-Bi(III), the thermal decomposition of both compounds was shown to be characterized by evolution of water of crystallization and water of constitution, respectively, and then by decomposition to form bismuth trioxide as the final product[26]. The decomposition was indicated by an extensive exothermic DTA peak. Further heating of bismuth trioxide up to 950 °C resulted in the occurrence of characteristic endothermic DTA peaks which were probably due to a polymorphic transformation of bismuth trioxide. Wendlandt[27] pointed to the possibility of using the TG and DTA (DSC) curves to identify various solid antacids. Of a variety of the solid pharmaceuticals, Pepto-Bismol® containing sub-SA-Bi(III), calcium carbonate and glycine was studied. The author showed that it was impossible to comment on the origin of each endothermic or shoulder peak in the DTA curves due either to the complexity of the antacid mixture or, in some cases, to its unknown composition. This information is of potential usefulness in forensic analysis. The DTA curve was also recorded for SA-Fe(III) diluted with silicon carbide[6], similar to the TG curves for aluminium subsalicylate and lead salicylate[28].

Duval[28] and Guichard[56] found that a knowledge of the thermal decomposition of particular components makes it possible for them to be assayed quantitatively in the binary and multicomponent mixtures. Studies based on the TG curves of the mixtures containing SA-Na, sodium acetate or sodium benzoate confirmed this finding because a linear relationship was found between the weight losses up to the appearance of a horizontal and the percentage of components in a mixture[29] (Fig. 7). The DTA, TG and DTG curves of mixtures containing SA and sodium bicarbonate,

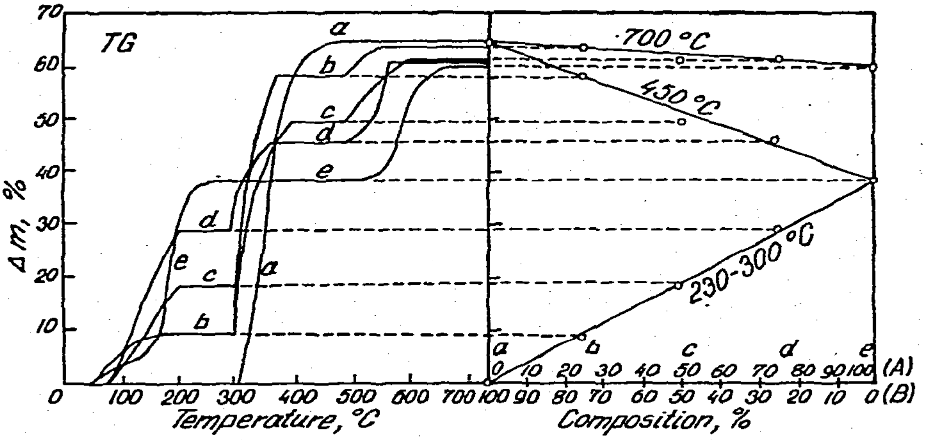


Fig. 7. Thermal decomposition of mixtures of sodium acetate (A) and sodium salicylate (B) (from ref. 29). Weight losses as a function of temperature and composition. Heating rate 5 °C min^{-1}; sample weights 100–400 mg.

sodium carbonate or SA-Na_2 offer the possibility of analysing mixtures of components which are able to react with each other during the course of the thermal decomposition. SA-Na, formed in the reaction between SA and sodium bicarbonate or sodium carbonate, increases the percentage of salt already present in the mixture, forming a mixture of non-reacting components[30, 31]. The DTA curves reflect well the thermal effects of reactions occurring in the mixtures considered on heating. A correlation was found between the percentage of individual components in a mixture and the area of the DTA peaks, but the character of this correlation could not be established. The presence of four components in the mixture studied reduces their percentage in the samples taken, and consequently results in a reduction of the DTA peak areas. The results obtained suggest that there is the possibility of employing the mixtures for the control of the course and degree of conversion in the commercial manufacture of SA-Na and for checking the declared compositions, degrees of

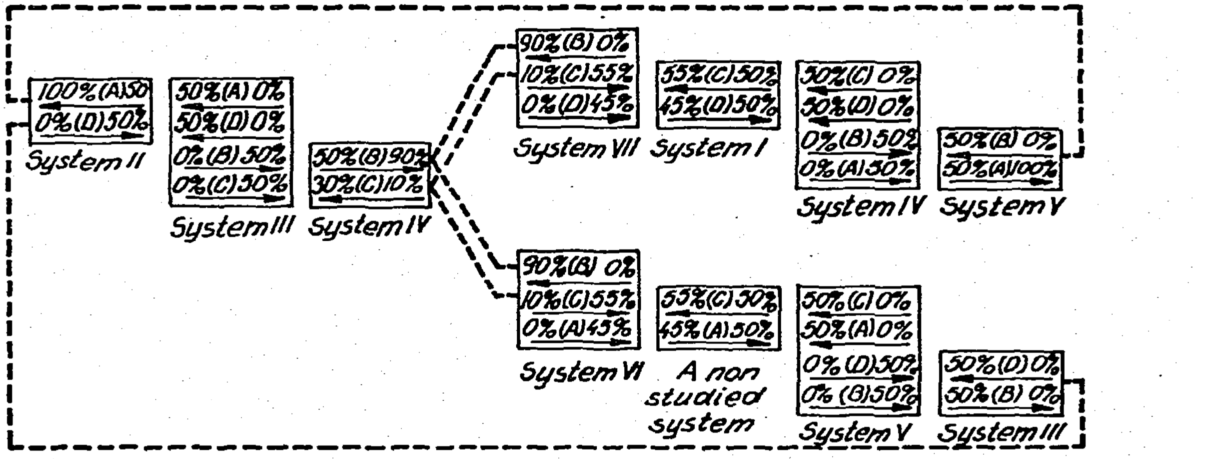


Fig. 8. Schematic diagram of binary, ternary and quaternary mixtures (from ref. 32). A, Sodium bicarbonate; B, salicylic acid; C, sodium carbonate; D, disodium salicylate sesquihydrate.

hydration and contamination of mixtures comprising salicylates. Each of the studied mixtures can be employed in the chemical analysis alone or in combination with any other binary, ternary and quaternary mixture[32] (Fig. 8).

3. THERMAL REARRANGEMENTS OF ALKALI METAL SALICYLATES

The first method for the manufacture of SA, developed by Kolbe in 1874, was based on heating sodium phenolate (PhONa) in a stream of carbon dioxide. In this method, SA-Na interacts with partly unreacted PhONa to form SA-Na_2. Schmidt proposed heating PhONa under carbon dioxide pressure at about 150 °C, thus making possible quantitative conversion of PhONa to SA-Na. It is interesting to note that potassium *p*-hydroxybenzoate (PHBA-K) was formed as the main product when potassium phenolate (PhOK) was used[33].

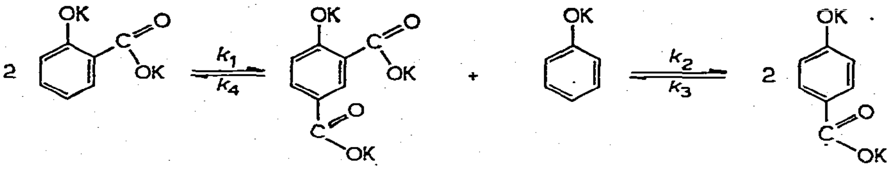
In order to elucidate the mechanism of the Kolbe–Schmidt reaction, studies of thermal rearrangements of alkali metal salicylates under isothermal conditions were undertaken[34]. The results showed that the thermal rearrangements run according to reaction (1) in the case of SA-Li and SA-Na only. However, SA-K, rubidium and caesium salicylates yield, in addition to dialkali salts of PHBA, a small amount of SA, 4-hydroxyisophthalic acid (4HIPA) and 6-hydroxytrimesic acid. The reaction is catalyzed by traces of moisture and PhOH. Moreover, it is facilitated by electron-releasing substituents in the benzene ring and is probably not proton-catalyzed. It was postulated that the smaller e^2r^{-1} values of the Li and Na ions than those of the K, Rb and Cs ions give rise to internal chelate formation which does not rearrange. Studies of the thermal rearrangements of SA-K and SA-K_2, as well as their mixtures, on heating between 207–240 °C in sealed containers evacuated to low pressure showed that the decomposition of SA followed a logarithmic curve, whilst the formation of PHBA followed a sigmoidal curve[35, 36] (Table 2, Fig. 9). The authors suggest

TABLE 2

RESULTS OF THERMAL REARRANGEMENTS OF SODIUM SALICYLATE, DISODIUM SALICYLATE, POTASSIUM SALICYLATE AND DIPOTASSIUM SALICYLATE IN SEALED TUBES[35]

Salt	*Temp. (°C)*	*Time (min)*	*Products (mole %)*				
			4HIPA	*2HIPA*	*SA*	*PHBA*	*PhOH*
SA-Na	220	5	0.0	0.0	99.4	0.0	0.06
	220	180	0.0	0.0	96.2	0.0	3.2
	220	324	0.2	0.2	85.3	0.4	13.4
SA-Na_2	220	240	0.0	0.0	99.5	0.0	1.4
	237	5.5	0.0	0.0	96.5	0.0	2.4
SA-K	220	60	0.05	0.03	92.6	3.2	3.5
	220	180	0.1	0.03	79.9	11.2	6.4
	220	420	2.2	0.04	76.2	13.4	7.3
SA-K_2	220	4	0.8	0.5	90.3	3.1	2.5
	220	31	8.4	1.4	7.1	64.2	12.6
	220	186	0.1	0.1	0.3	92.8	2.2

that the reaction is an intermolecular one and proceeds via tripotassium salts of 2- and 4-HIPA according to



(3)

It is supposed that, under these conditions, some of the SA-K undergoes decarboxylation to give SA-K_2, PhOH and carbon dioxide. This is confirmed by an excess of PhOH to that equivalent to 2- and 4-HIPA. The rearrangement occurs more readily under an increased pressure of carbon dioxide or nitrogen.

The studies were continued to obtain PHBA-K_2 by the Kolbe–Schmidt reaction. The analytical results showed that the reaction starts from PhOK, proceeds successively through intermediate compounds, SA-K and SA-K_2, to PHBA-K_2[37, 38]. Similarly, PHBA-K_2 was obtained in 90% yield when SA-K_2 was heated 1 h at 250 °C[39]. Addition of PhOH had little effect on the yield of the reaction. The results showed[40–43] that there is a possibility of the formation of PHBA-K_2 in the reaction of PhOK and carbon dioxide, as well as by thermal rearrangement of SA-K_2 to PHBA-K_2.

The DTA and UV methods employed for the elucidation of the Kolbe–Schmidt reaction showed that the reaction of PhOK with carbon dioxide proceeds faster than that of PhONa[44–46]. In the case of PhOK, PHBA and SA are formed below 240 °C. Above 240 °C, rearrangement of SA-K_2 into PHBA-K_2 takes place via 4HIPA as an intermediate compound. Reinvestigation of this reaction under carbon dioxide or nitrogen at ambient or higher pressures confirmed the existence of 4HIPA[47]. On the DTA curve of SA-K_2 recorded under nitrogen, two endothermic peaks and an exothermic peak are observed[48] at 250, 280 and 320 °C. These peaks are due to volatilization of gaseous decomposition products, PhOH and carbon dioxide, and the rearrangement of SA-K_2 into PHBA-K_2 via 4HIPA. Under carbon dioxide, the reaction proceeds vigorously at a lower temperature. Two partly overlapping endo-

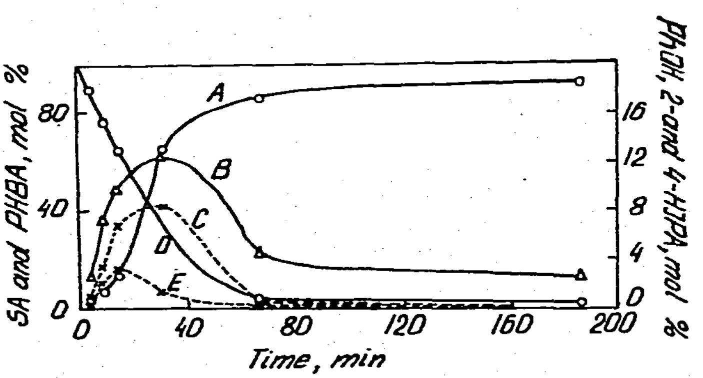


Fig. 9. Thermal rearrangement of dipotassium salicylate at 220 °C under reduced pressure (from ref. 35). A, *p*-Hydroxybenzoic acid; B, phenol; C, 4-hydroxyisophthalic acid; D, salicylic acid; E, 2-hydroxyisophthalic acid.

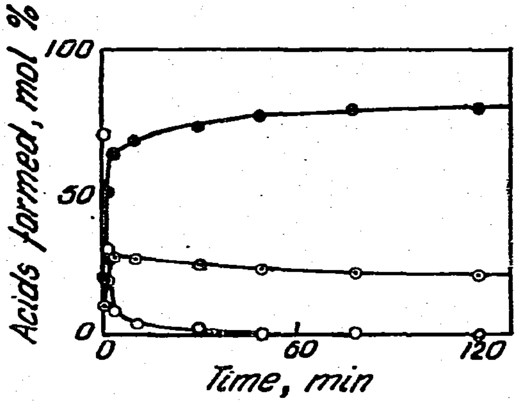
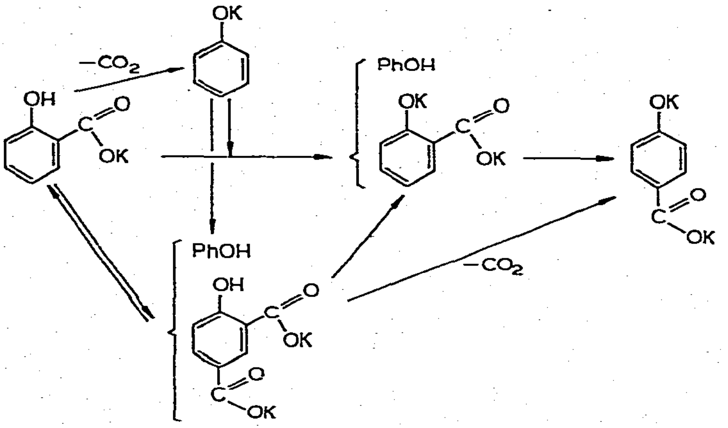


Fig. 10. Thermal rearrangement of potassium salicylate at 250°C in an atmosphere of nitrogen (from ref. 51). ○, Salicylic acid; ●, *p*-hydroxybenzoic acid; ⊙, 4-hydoxyisophthalic acid.

thermic peaks are observed at 240°C with an exothermic peak at 260°C. An excess of carbon dioxide enhances the formation of 4HIPA and PHBA and also facilitates the recarboxylation of PHBA to 4HIPA. The disodium salt of PHBA (PHBA-Na_2) rearranges to SA-Na_2 via 4HIPA above 300°C under carbon dioxide[49]. Under nitrogen, the reaction occurs at still higher temperature. Based on the series of experiments, it has been suggested that the difference in the substitution ratio of the *o*- and *p*-positions in the Kolbe–Schmidt reaction in the case of PhONa and PhOK is due to the difference in the thermal behaviour of the sodium and potassium salts of 4HIPA[50]. The DTA curve of SA-K taken in a stream of nitrogen had three endothermic peaks[51]. The DTA, TG and EGD curves indicate that the decarboxylation of SA takes place together with the rearrangement of SA into PHBA. The quantity of 4HIPA formed at the beginning of the reaction drops with increasing amount of PHBA[51] (Fig. 10). This agrees with the result where the acids formed contain 13–19% of 4HIPA. These results were utilized for advancing the following thermal rearrangement scheme of SA-K into PHBA-K_2.



(4)

The rearrangement occurring in a mixture of the tripotassium salt of 4HIPA and PhOH or PhOK on raising the temperature at the rate of 10°C min^{-1} from 30 to 300°C under nitrogen gives both SA and PHBA and the rate of the conversion decreases in the order $k_2 > k_4$ as was shown in reaction (3)[52]. The conversion is affected more remarkably by the presence of PhOH than by the presence of PhOK. A similar effect was observed in the case of the dipotassium salt of 4HIPA. However, mixtures containing the disodium or trisodium salts of 4HIPA and PhOH or PhONa at 340°C under nitrogen or carbon dioxide were converted mainly to SA. These results were also confirmed in other articles[53, 54] and were utilized for the development of a thermal method for preparing aromatic hydroxy(carboxylic) acids[55].

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