BULLETIN OF THE CHEMICAL SOCIETY OF JAPAN, VOL. 46, 3294—3295 (1973)

On Liquefaction Caused by the Trituration of Pairs of Solid Compounds. II

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(Received May 25, 1973)

In a previous paper a report was given on pairs of solid compounds which give rise to liquefaction on trituration.[1] Urea was found to cause liquefaction with most of the inorganic compounds examined. Tests, not rigorous but practical, were prescribed to find pairs for liquefaction. We have since extended our search for new pairs utilizing the tests and have been able to find some. We are still far from grasping the principle for the selection of the pairs, but a systematic representation of the data will suffice for the present (Table 1).

The experimental procedure and the mode of representation are the same as before. A pair consists of (a) an inorganic compound with water of crystallization and (b) an organic compound. The former is considered to liberate water for liquefaction as a result of interaction with the latter. For (a), sulfates were chosen because of their small hygroscopicity, while for (b) we chose salts of organic acids and bases with a fairly large solubility in water. Some inorganic and organic compounds were also chosen for the sake of

TABLE 1. MODES OF LIQUEFACTION

(a)	(b)						
	NH_4NCS	NaNCS	KNCS	HCOONa	CH_3COONH_4	CH_3COONa	CH_3COOK
$Na_2B_4O_7\cdot 10H_2O$	++	−	++	−	++	−	−
$Na_3PO_4\cdot 12H_2O$	++	−	−	−	+	−	+
$Na_2HPO_4\cdot 12H_2O$	+++	+	++	+	+++	+	+++
$NaH_2PO_4\cdot 2H_2O$	++	−	+	++	++	+	+
$Na_2SO_4\cdot 10H_2O$	+++	+++	+++	+++	+++	+++	+++
$MgSO_4\cdot 7H_2O$	−	+	++	++	+++	+++	+++
$Al_2(SO_4)_3(NH_4)_2SO_4\cdot 24H_2O$	++	++	+	++	++	−	−
$Al_2(SO_4)_3Na_2SO_4\cdot 24H_2O$	−	+++	+++	+++	+++	+	+++
$Al_2(SO_4)_3K_2SO_4\cdot 24H_2O$	−	++	−	+++	++	−	−
$FeSO_4(NH_4)_2SO_4\cdot 6H_2O$	−	+	++	+	+	++	−
$Fe_2(SO_4)_3(NH_4)_2SO_4\cdot 24H_2O$	++	++	++	+++	+++	++	++
$CuSO_4\cdot 5H_2O$	+	+	++	+++	+++	++	+
$ZnSO_4\cdot 7H_2O$	++	−	++	+	+++	++	+
$CCl_3CH(OH)_2$	++	+	++	+++	+	++	−

1) T. Katsurai, S. Matsuo, and K. Sone, This Bulletin, **44**, 2276 (1971); this article, with the same title as the present one, is referred to as I.

(a)	(b)					
	$COONa$ | $COONa$	$NH_2(CH_2)_3$-$COOH$	$NH_2(CH_2)_5$-$COOH$	$HOOC$-$\underset{NH_2}{\overset{H}{C}}$-$(CH_2)_2COONa$	$(NH_2)_2CO$	$C_2H_5NH_2$ $\cdot HCl$
$Na_2B_4O_7\cdot 10H_2O$	−	−	−	−	−	+
$Na_3PO_4\cdot 12H_2O$	−	++	−	−	−	++
$Na_2HPO_4\cdot 12H_2O$	−	+++	−	−	+	+++
$NaH_2PO_4\cdot 2H_2O$	−	++	−	−	−	−
$Na_2SO_4\cdot 10H_2O$	−	+++	−	+	+++	+++
$MgSO_4\cdot 7H_2O$	−	−	−	−	+	+
$Al_2(SO_4)_3(NH_4)_2SO_4\cdot 24H_2O$	−	+	−	−	+	+
$Al_2(SO_4)_3Na_2SO_4\cdot 24H_2O$	−	++	++	+	+++	+++
$Al_2(SO_4)_3K_2SO_4\cdot 24H_2O$	−	+	−	−	+	−
$FeSO_4(NH_4)_2SO_4\cdot 6H_2O$	−	−	−	−	−	−
$Fe_2(SO_4)_3(NH_4)_2SO_4\cdot 24H_2O$	++	++	++	−	+++	+++
$CuSO_4\cdot 5H_2O$	−	−	−	+	+	++
$ZnSO_4\cdot 7H_2O$	−	++	−	−	+++	+++
$CCl_3CH(OH)_2$	−	++	++	−	+++	+++

(a)	(b)						
	NH_2OH $\cdot HCl$	$(NH_2OH)_2$ $\cdot H_2SO_4$	$NH_2NHCONH_2$ $\cdot HCl$	$NH{=}C(NH_2)_2$ $\cdot HCl$	CCl_3CH-$(OH)_2$	$C_6H_{12}O_6$ D-levulose	$C_{12}H_{22}O_{11}$ sucrose
$Na_2B_4O_7\cdot 10H_2O$	+++	+	+++	++	+	−	−
$Na_3PO_4\cdot 12H_2O$	++	+	+++	++	+++	−	−
$Na_2HPO_4\cdot 12H_2O$	+++	+++	+++	+++	+++	++	+
$NaH_2PO_4\cdot 2H_2O$	+++	−	−	++	−	−	−
$Na_2SO_4\cdot 10H_2O$	+++	+++	+++	+++	+++	+++	+++
$MgSO_4\cdot 7H_2O$	−	−	−	+	−	−	−
$Al_2(SO_4)_3(NH_4)_2SO_4\cdot 24H_2O$	−	−	−	−	−	−	−
$Al_2(SO_4)_3Na_2SO_4\cdot 24H_2O$	+	+	−	++	++	++	+
$Al_2(SO_4)_3K_2SO_4\cdot 24H_2O$	−	−	−	−	−	−	−
$FeSO_4(NH_4)_2SO_4\cdot 6H_2O$	−	−	−	−	−	−	−
$Fe_2(SO_4)_3(NH_4)_2SO_4\cdot 24H_2O$	+++	+++	++	+++	+	++	++
$CuSO_4\cdot 5H_2O$	++	−	++	++	−	−	−
$ZnSO_4\cdot 7H_2O$	+++	+	+++	+++	+	−	−
$CCl_3CH(OH)_2$	+	−	−	++		−	−

(a): Water liberating compound, (b): Compound making (a) liberate water
+++ denotes rapid, ++ moderately fast, + slow, and − no liquefaction

comparison.

We see that many of the pairs found consist of combinations of reagents with which weare familiar. They would have been found much earlier if liquefaction had attracted attention. It is expected that more pairs will be found by future attempts.

A few remarks should be added. Of (a), $Na_2SO_4\cdot 10H_2O$ and $Al_2(SO_4)_3\cdot Na_2SO_4\cdot 10H_2O$ undergo liquefaction to a great extent. Among the sodium phosphates, $Na_2HPO_4\cdot 12H_2O$ undergoes liquefaction most easily. Besides urea, several organic compounds as well as alkali thiocyanates were found to cause liquefaction with inorganic compounds.

The following combinations are suitable for the demonstration of liquefaction:

$$Na_3PO_4\cdot 12H_2O + NH_2NHCONH_2\cdot HCl$$

$$Na_2HPO_4\cdot 12H_2O + CH_3COONH_4$$

$$ZnSO_4\cdot 7H_2O + C_2H_5NH_2\cdot HCl$$

$$ZnSO_4\cdot 7H_2O + NH{=}C(NH_2)_2\cdot HCl$$