International Journal of Pharmaceutics, 45 (1988) 259–261
Elsevier

IJP 01496

Short Communications

Interactions in the ternary powder system microcrystalline cellulose, magnesium stearate and colloidal silica — a solubility parameter approach

R.C. Rowe

ICI Pharmaceuticals Division, Macclesfield (U.K.)

(Received 16 November 1987)
(Accepted 2 December 1987)

Key words: Interaction; Solubility parameter; Ternary powder mix

Summary

The intensity of the interactions between the components of the ternary powder system microcrystalline cellulose, magnesium stearate and colloidal silica have been predicted using literature and calculated values for their partial solubility parameters. These show that there is a greater interaction between magnesium stearate and colloidal silica than between magnesium stearate and microcrystalline cellulose, consistent with known literature data. With these results predictions can be made concerning the properties of tablets prepared from these ternary mixtures.

In a recent communication, Rowe (1988) proposed the concept of using partial solubility parameter data to predict the relative intensities of both the adhesive and cohesive interactions within a binary powder system thus allowing predictions to be made concerning the properties of the resultant tablet. It was shown that for the binary system of microcrystalline cellulose and magnesium stearate the adhesive interaction between the two powders was higher than the cohesive interaction within the lubricant thus resulting in the formation of a lubricant film over the microcrystalline cellulose and reduced tablet strength — a fact well known in practice. In this communication the concept has been extended to a ternary system of microcrystalline cellulose, magnesium stearate and colloidal silica. This system was chosen since it has been recently researched (Staniforth and Ahmed, 1986, 1987).

Implicit in the equations used to predict the relative intensities is a knowledge of the total solubility parameter (δ) and its dispersion or non-polar component (δ_d) for each material thus allowing the fractional polarity (x_p) to be calculated using the equation

$$x_p = 1 - \left(\frac{\delta_d}{\delta}\right)^2 \quad (1)$$

These data are readily available for microcrystalline cellulose and magnesium stearate (Table 1) but not for colloidal silica. However, it is possible to calculate the required data for silica from a consideration of liquid–solid chromatography data (Keller and Snyder, 1971). Silica is widely used as

Correspondence: R.C. Rowe, ICI Pharmaceuticals Division, Alderley Park, Macclesfield, Cheshire SK10 2NA, U.K.

TABLE 1

Molar volumes, solubility parameters and fractional polarities of materials used

Material	Molar volume cm^3/mol	δ $MPa^{1/2}$	δ_d $MPa^{1/2}$	x_p	Reference
Microcrystalline cellulose	216.0	39.3	19.4	0.76	Phuoc et al. (1987)
Magnesium stearate	542.0	18.2	15.7	0.26	Panzer (1973)
Silica	26.1	35.3	12.2	0.88	this work

a carrier and extensive work has been done to relate its liquid–solid solvent parameter, ϵ_0 — a measure of the adsorption energy of a solvent for the carrier — to the solubility parameter (expressed in units of $MPa^{1/2}$) of that solvent, i.e.:

$$\epsilon_0 = -0.519 + 0.0430\delta \quad (2)$$

Implicit in this equation is the fact that ϵ_0 will be zero when adsorption is due only to the presence of dispersive interactions and ϵ_0 will be unity when there is complete interaction. Using an argument analogous to that used by Hansen (1967) when determining the solubility parameters of pigments, it can be concluded that the values of the solubility parameters at these two extremes should closely correspond to δ_d and δ respectively for the silica itself (Table 1).

Applying the equations given previously (Rowe, 1988), it is possible to calculate the interaction parameter (ϕ) and the relative intensities of the cohesive and adhesive interactions in the ternary system (Table 2). These show that, firstly there is a greater interaction between magnesium stearate and silica than between magnesium stearate and microcrystalline cellulose although both interactions are greater than the cohesive interaction within the lubricant itself, and secondly, the interaction between silica and microcrystalline cellulose is high although less than the cohesive interactions within the silica itself.

Since it is the relative intensities of the interactions rather than the values themselves that are important, it can be concluded that when microcrystalline cellulose is mixed with minor amounts of either magnesium stearate or silica (assuming both to be much smaller in size than the microcrystalline cellulose) both materials will adhere to the microcrystalline cellulose particles. Shearing each binary mixture will result in film formation in the case of the lubricant but fracture at the interface in the case of the silica. Binary mixtures of silica and magnesium stearate will result either in enrobement of the lubricant by the silica in the case where the silica has a particle size much smaller than the magnesium stearate or coverage of the silica in the case where the magnesium stearate is much smaller than the silica. Shearing in this case will result in shearing of the magnesium stearate particles.

If these ideas are transferred to the practical situation studied by Stanniforth and Ahmed (1986, 1987) for mixtures of microcrystalline cellulose (mean particle size ≈ 50 μm) with 0.5% w/w magnesium stearate (mean particle size ≈ 5 μm) and 2% w/w colloidal silica (mean particle size ≈ 0.2 μm) then it can be predicted that in the ternary system the microcystalline cellulose will be

TABLE 2

Interaction parameters (ϕ), adhesive and cohesive interactions in ternary systems

	Interaction parameter (ϕ)	Strength of interaction (MPa)
Adhesive		
MCC–MS	0.48	85.8
CS–MS	0.58	93.2
MCC–CS	0.68	236.2
Cohesive		
MCC–MCC	–	386.1
CS–CS	–	311.5
MS–MS	–	82.8

MCC, microcrystalline cellulose; MS, magnesium stearate; CS, colloidal silica.

preferentially coated by the colloidal silica, although some will be partially coated by magnesium stearate, and that the majority of the magnesium stearate will be enrobed by the colloidal silica. On compaction at high shear forces shearing of the enrobed magnesium stearate will occur first followed by shearing at the microcrystalline cellulose–silica interface. This will result in a tablet with a slightly lower strength than one prepared from microcrystalline cellulose alone but with a higher strength than one prepared from a binary mixture of microcrystalline cellulose and magnesium stearate. The shearing of the enrobed magnesium stearate should provide enough lubrication at the die wall to decrease the ejection force over that required for a tablet prepared from a binary mixture of microcrystalline cellulose and silica. All the predictions are consistent with the results reported by Staniforth and Ahmed (1986, 1987).

As stated previously (Rowe, 1988), it must be realised that the model used in this approach is somewhat crude and oversimplified and hence the equations can do nothing more than predict trends. However, as can be seen from the results presented here, the predictions are consistent with known facts.

References

Hansen, C.M., The three dimensional solubility parameter — key to paint component affinities. II Dyes, emulsifiers, mutual solubility and compatibility and pigments. *J. Paint Technol.*, 39 (1967) 505–510.

Keller, R.A. and Synder, L.R., Relation between the solubility parameter and the liquid-solvent strength parameter. *J. Chromatogr. Sci.*, 9 (1971) 346–349.

Panzer, J., Components of solid surface free energy from wetting measurements. *J. Colloid Interface Sci.*, 1973 (44) 142–161.

Phuoc, N.H., Hô Nam Tran, Buchmann, M. and Kesselring, U.W., Experimentally optimised determination of the partial and total cohesion parameters of an insoluble polymer (microcrystalline cellulose) by gas-solid chromatography. *Int. J. Pharm.*, 34 (1987) 217–223.

Rowe, R.C., The interaction of lubricants with microcrystalline cellulose and anhydrous lactose — a solubility parameter approach. *Int. J. Pharm.*, 41 (1988) 223–226.

Staniforth, J.N. and Ahmed, H.A., Influence of ternary components on compressibility of microcrystalline cellulose following blending with magnesium stearate. *J. Pharm. Pharmacol.*, 38 (1986) Suppl. 50P.

Staniforth, J.N. and Ahmed, H.A., Influence of ternary components on lubrication of microcrystalline cellulose following blending with magnesium stearate. *J. Pharm. Pharmacol.*, 39 (1987) Suppl. 68P.