

---

# Contents

---

<b>Preface</b> . . . . .	xi
<b>Chapter 1. Stirring in a Vat: Homogenization of Pasty Products</b> . . . . .	1
1.1. Principles . . . . .	1
1.1.1. Types of stirrers . . . . .	1
1.1.2. Axial thrusters (circulating) . . . . .	2
1.1.3. Radial thrusters (shearing) . . . . .	3
1.1.4. Circulation in a stirred vat . . . . .	4
1.1.5. Maximum shear . . . . .	7
1.1.6. Discharge pressure of a turbine . . . . .	10
1.2. Power consumed and recirculation rate . . . . .	11
1.2.1. Dimensionless numbers . . . . .	11
1.2.2. Geometric coefficient $C_G$ . . . . .	13
1.2.3. Practical implementation of stirrers in a vat . . . . .	16
1.3. Homogenization of a solution . . . . .	16
1.3.1. Objective . . . . .	16
1.3.2. Viscous liquids . . . . .	18
1.3.3. Highly-viscous products . . . . .	18
1.4. Maintenance of a solid in suspension . . . . .	19
1.4.1. Distribution of a divided solid in a vat . . . . .	19
1.4.2. Homogeneity criteria . . . . .	20
1.4.3. Draft tube . . . . .	24
1.5. Dispersion of a gas in a liquid . . . . .	27
1.5.1. Preliminaries . . . . .	27
1.5.2. Engorgement . . . . .	28

1.5.3. Power at the shaft . . . . .	28
1.5.4. Diameter of the bubbles . . . . .	29
1.5.5. Limiting bubble ascension rate . . . . .	29
1.5.6. Volume interfacial area . . . . .	30
1.5.7. Gas retention. . . . .	30
1.6. Dispersion of a liquid insoluble in another liquid (emulsification) . . . . .	32
1.6.1. Liquid–liquid dispersion. . . . .	32
1.6.2. Mean drop diameter . . . . .	34
1.6.3. Material transfer coefficient on the side of the contiguous phase . . . . .	34
1.7. Mixers for pasty products . . . . .	35
1.7.1. Description and usage of mixers . . . . .	35
1.7.2. Scale of segregation . . . . .	35
1.7.3. Power, time and energy . . . . .	36
1.7.4. Extrapolation . . . . .	37
1.8. Ribbon mixer (pasty products) . . . . .	39
1.8.1. Usage . . . . .	39
1.8.2. Description. . . . .	39
1.8.3. Power consumed . . . . .	40
1.8.4. Mixing time . . . . .	41
1.8.5. Heat transfer at the wall . . . . .	41
<b>Chapter 2. Dispersion and Dissolution of Powders . . . . .</b>	<b>43</b>
2.1. General points about powders and crystals . . . . .	43
2.1.1. Properties of powders relative to dispersion/dissolution . . . . .	43
2.1.2. Concept of dispersibility. . . . .	45
2.1.3. Conditions for good dispersion. . . . .	45
2.2. Physics of wetting . . . . .	46
2.2.1. Surface energy and contact angle . . . . .	46
2.2.2. Helmholtz energy and enthalpy of immersion . . . . .	47
2.2.3. Energy of adherence. Dupré’s relation . . . . .	48
2.2.4. Energy of cohesion . . . . .	49
2.2.5. Wetting, spreading and Helmholtz energy . . . . .	49
2.2.6. Wettability (practical aspect) . . . . .	51
2.2.7. Measurement of the total surface energy of a liquid. . . . .	52
2.2.8. Measurement of the contact angle on a powder . . . . .	52
2.2.9. Wetting agents . . . . .	53

---

2.2.10. Dispersive energy and polarization energy . . . . .	54
2.2.11. Practical measurements . . . . .	55
2.3. Practice of dispersion – equipment . . . . .	56
2.3.1. Dispersion procedures (food industry) . . . . .	56
2.3.2. Destruction of aggregates . . . . .	57
2.3.3. Dispersion in the pharmaceutical industry . . . . .	60
2.3.4. Principles of action of devices for mechanical dispersion . . . . .	61
2.3.5. Choice of devices . . . . .	61
2.3.6. Paint and plastic material industries . . . . .	62
2.3.7. Other industrial dispersion processes . . . . .	64
2.4. Dissolution of a small crystal and dissolution of a powder . . . . .	64
2.4.1. Affinity for water (hygroscopicity) . . . . .	64
2.4.2. Description of the dissolution of a crystal . . . . .	66
2.4.3. Rate of attack of the surface and oversaturation of crystallization . . . . .	67
2.4.4. Theory of the diffusion layer . . . . .	68
2.4.5. Time for dissolution of a single crystal in an infinite volume of liquid . . . . .	70
2.4.6. Dissolution of a crystal in a limited volume of liquid . . . . .	71
2.5. Continuous-flow dissolution of a suspension . . . . .	73
2.5.1. Continuous-flow dissolver (Figure 2.5). . . . .	73
2.6. Specific cases. . . . .	74
2.6.1. Dissolution of capsules, tablets and pills . . . . .	74
2.6.2. Theory of penetration of a liquid into a porous medium (tablet or granulated powder). . . . .	75
2.6.3. Influence of pressing on the dissolution of a tablet . . . . .	77
<b>Chapter 3. Mixture of Divided Solids: Choice of Mixing Devices . . . . .</b>	<b>79</b>
3.1. Criteria for evaluating the homogeneity of a mixture . . . . .	79
3.1.1. Introduction . . . . .	79
3.1.2. Mean, variance and variation coefficient . . . . .	79
3.1.3. Binary mixtures, noteworthy identities . . . . .	81
3.1.4. Variance of a totally separated (unmixed) binary system. Intensity of segregation . . . . .	81
3.1.5. Reference variances . . . . .	82

3.1.6. Reference sample too large for the counting of the particles . . . . .	83
3.1.7. Measuring the variance . . . . .	84
3.1.8. Influence on the variance of the number and size of samples. . . . .	85
3.1.9. Variance reduction ratio . . . . .	87
3.1.10. Angle of repose . . . . .	87
3.1.11. Diameter distribution desirable for the active ingredient . . . . .	88
3.2. Autocorrelation function . . . . .	88
3.2.1. Definition . . . . .	88
3.3. Acceptance of the quality of a mixture. . . . .	90
3.3.1. Probability of an event and probability density . . . . .	90
3.3.2. Central limit theorem. . . . .	91
3.3.3. Estimation by confidence interval . . . . .	92
3.3.4. Acceptability criteria for the mixture . . . . .	94
3.4. Evolution of the DS over the course of mixing. . . . .	97
3.4.1. Mechanisms of mixing. . . . .	97
3.4.2. Motions in a DS. . . . .	98
3.4.3. Evolution of a mixture and variance. . . . .	99
3.4.4. Evolution of variance according to [ROS 59] . . . . .	100
3.4.5. Cohesion and particle diameter. . . . .	101
3.4.6. Analytical attempts to express a mixing operation . . . . .	102
3.4.7. Duration of the operation of mixing . . . . .	104
3.5. Mixers (practical data): choice of device . . . . .	106
3.5.1. The operation of homogenization (mixing). . . . .	106
3.5.2. Devices employing dropping (or pouring) and raising . . . . .	106
3.5.3. Mixing in a screw transporter. . . . .	107
3.5.4. Rotary cylinder . . . . .	108
3.5.5. Devices with moderate internal stirring (convection/shearing) . . . . .	108
3.5.6. Violent internal stirring devices (mills) . . . . .	109
3.5.7. Energy consumed. . . . .	110
3.5.8. Choice of mixers . . . . .	110
3.6. Segregation . . . . .	111
3.6.1. Principle . . . . .	111
3.6.2. Influence of a vertical vibration . . . . .	112
3.6.3. Spilling (pouring) of a loose DS onto a pile . . . . .	112

---

3.6.4. Dropping under the influence of gravity . . . . .	113
3.6.5. Gravity-based flow on an inclined plane . . . . .	113
3.6.6. Effect of convection/shearing. . . . .	114
3.6.7. Mathematical synthesis . . . . .	115
3.6.8. Ways of combatting segregation . . . . .	116
3.6.9. Conclusions on segregation . . . . .	117
<b>Appendices . . . . .</b>	<b>119</b>
<b>Appendix 1. Mohs Scale . . . . .</b>	<b>121</b>
<b>Appendix 2. Apparent Density of Loose Divided Solids (kg.m<sup>-3</sup>). . . . .</b>	<b>125</b>
<b>Bibliography . . . . .</b>	<b>127</b>
<b>Index . . . . .</b>	<b>135</b>