

Contents

1 Introduction and Overview	1
1.1 Introduction	1
1.2 Generation of x-rays	3
1.3 Scattering by a single electron	7
1.4 Scattering of a plane wave	8
1.5 Absorption of x-rays	9
1.6 Reflection and refraction of x-rays	11
1.7 Coherent properties of x-rays	13
1.8 X-ray, neutron, and light scattering	15
2 Basic Scattering by Particles	18
2.1 Scattering by complex systems	18
2.1.1 Atoms, molecules, and crystal lattices	18
2.1.2 Scattering geometry and Ewald sphere	20
2.1.3 Scattering and Fourier transformation	21
2.2 Diffraction of model scattering distributions	23
2.2.1 Diffraction of a ‘top-hat’ distribution	23
2.2.2 Diffraction from spherical objects	25
2.3 Atoms and molecules—Solutions	26
2.3.1 Particles at low resolution—Form factor	27
2.3.2 Guinier regime	29
2.3.3 Porod regime	30
2.4 Case study: Modelling SAXS of non-interacting particles	32
2.5 Extension to simple liquids—Structure factor	35
3 Order/Disorder in Soft Matter	39
3.1 Short-range order	39
3.2 Long-range order	41
3.3 Orientational and positional order in liquid crystals	42
3.3.1 The nematic phase	42
3.3.2 The smectic-A phase	43
3.4 Order and dimensionality	47
3.4.1 Fluctuations at low dimensions	47
3.4.2 Two-stage melting in two dimensions	49
3.5 Case study: Order in smectic membranes	51
4 Diffraction Physics: Scattering by Crystals	54
4.1 Elements of crystallography	54
4.1.1 Different types of lattice	54
4.1.2 Lattice planes and Miller indices	56

4.2	Diffraction by a crystal lattice	59
4.2.1	Bragg law	59
4.2.2	Introducing reciprocal space	60
4.2.3	Lattice sum and scattering conditions	63
4.3	Miscellaneous properties of crystal scattering	66
4.3.1	Debye–Waller factor	66
4.3.2	Mosaic spread	67
4.3.3	Line width and average domain size	68
4.3.4	Polycrystalline diffraction	69
4.4	Case study: Polymer crystallization	71
4.4.1	Example 1: Polyethylene (PE)	72
4.4.2	Example 2: Isotactic polypropylene (iPP)	73
4.4.3	Degree of crystallization	74
4.4.4	The onset of crystallization	75
5	Applications to Soft Matter	77
5.1	Instrumentation, SAXS, and WAXS	77
5.2	Examples	79
5.2.1	Liquid crystal phases	79
5.2.2	Colloids	83
5.2.3	Amphiphilic compounds	85
5.2.4	Biomembranes	89
5.2.5	Block copolymers	92
5.3	Case study: Bridging length scales—Order and frustration	96
5.3.1	Confined crystallization in block copolymers	97
5.3.2	Liquid crystalline block copolymers	98
5.3.3	Liquid crystalline dendrimers	100
6	Soft Matter Films and Surfaces	103
6.1	Reflectivity at a single interface	103
6.1.1	Fresnel theory	103
6.1.2	Practical aspects: Scanning, footprint, and roughness	106
6.1.3	Examples of soft interfaces	108
6.2	Multiple interfaces: Soft matter films	110
6.2.1	Uniform films	110
6.2.2	Multilayers: Recursive formalism	112
6.2.3	Example 1: Monolayers of fluorinated alkanes	114
6.2.4	Example 2: Lamellar diblock copolymer films	116
6.3	Grazing incidence diffraction	119
6.3.1	Surface freezing of alkyl monolayers	120
6.3.2	Controlled orientations in a smectic block copolymer film	122
6.4	Case study: Monolayer structure of substituted thiophenes	123
	Bibliography	129
	Index	133