

Remington's Pharmaceutical Sciences

Eighteenth Edition

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Table of Contents

Part 1 Orientation

1	Scope	3
2	Evolution of Pharmacy	8
3	Ethics	20
4	The Practice of Community Pharmacy	28
5	Opportunities for Pharmacists in the Pharmaceutical Industry	33
6	Pharmacists in Government	38
7	Drug Information	49
8	Research	60

Part 2 Pharmaceutics

9	Metrology and Calculation	69
10	Statistics	104
11	Computer Science	138
12	Calculus	145
13	Molecular Structure, Properties and States of Matter	158
14	Complex Formation	182
15	Thermodynamics	197
16	Solutions and Phase Equilibria	207
17	Ionic Solutions and Electrolytic Equilibria	228
18	Reaction Kinetics	247
19	Disperse Systems	257
20	Rheology	310

Part 3 Pharmaceutical Chemistry

21	Inorganic Pharmaceutical Chemistry	329
22	Organic Pharmaceutical Chemistry	356
23	Natural Products	380
24	Drug Nomenclature—United States Adopted Names	412
25	Structure-Activity Relationship and Drug Design	422

Part 4 Testing and Analysis

26	Analysis of Medicinals	435
27	Biological Testing	484
28	Clinical Analysis	495
29	Chromatography	529
30	Instrumental Methods of Analysis	555
31	Dissolution	589

Part 5 Radioisotopes in Pharmacy and Medicine

32	Fundamentals of Radioisotopes	605
33	Medical Applications of Radioisotopes	624

Part 6 Pharmaceutical and Medicinal Agents

34	Diseases: Manifestations and Pathophysiology	655
35	Drug Absorption, Action and Disposition	697
36	Basic Pharmacokinetics	725
37	Clinical Pharmacokinetics	746
38	Topical Drugs	757
39	Gastrointestinal Drugs	774
40	Blood, Fluids, Electrolytes and Hematologic Drugs	800
41	Cardiovascular Drugs	831
42	Respiratory Drugs	860
43	Sympathomimetic Drugs	870

44	Cholinomimetic Drugs	889
45	Adrenergic and Adrenergic Neuron Blocking Drugs	898
46	Antimuscarinic and Antispasmodic Drugs	907
47	Skeletal Muscle Relaxants	916
48	Diuretic Drugs	929
49	Uterine and Antimigraine Drugs	943
50	Hormones	948
51	Vitamins and Other Nutrients	1002
52	Enzymes	1035
53	General Anesthetics	1039
54	Local Anesthetics	1048
55	Sedatives and Hypnotics	1057
56	Antiepileptics	1072
57	Psychopharmacologic Agents	1082
58	Analgesics and Antipyretics	1097
59	Histamine and Antihistamines	1123
60	Central Nervous System Stimulants	1132
61	Antineoplastic and Immunosuppressive Drugs ...	1138
62	Antimicrobial Drugs	1163
63	Parasitocides	1242
64	Pesticides	1249
65	Diagnostic Drugs	1272
66	Pharmaceutical Necessities	1286
67	Adverse Drug Reactions	1330
68	Pharmacogenetics	1344
69	Pharmacological Aspects of Drug Abuse	1349
70	Introduction of New Drugs	1365

Part 7 Biological Products

71	Principles of Immunology	1379
72	Immunizing Agents and Diagnostic Skin Antigens	1389
73	Allergenic Extracts	1405
74	Biotechnology and Drugs	1416

Part 8 Pharmaceutical Preparations and Their Manufacture

75	Preformulation	1435
76	Bioavailability and Bioequivalency Testing	1451
77	Separation	1459
78	Sterilization	1470
79	Tonicity, Osmoticity, Osmolality and Osmolarity ..	1481
80	Plastic Packaging Materials	1499
81	Stability of Pharmaceutical Products	1504
82	Quality Assurance and Control	1513
83	Solutions, Emulsions, Suspensions and Extractives	1519
84	Parenteral Preparations	1545
85	Intravenous Admixtures	1570
86	Ophthalmic Preparations	1581
87	Medicated Applications	1596
88	Powders	1615
89	Oral Solid Dosage Forms	1633
90	Coating of Pharmaceutical Dosage Forms	1666
91	Sustained-Release Drug Delivery Systems	1676
92	Aerosols	1694

Part 9 Pharmaceutical Practice

93	Ambulatory Patient Care	1715
94	Institutional Patient Care	1737
95	Long-Term Care Facilities	1758
96	The Pharmacist and Public Health	1773

Disperse Systems

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Interfacial Phenomena

Very often it is desirable or necessary in the development of pharmaceutical dosage forms to produce multiphase dispersions by mixing together two or more ingredients which are not mutually miscible and capable of forming homogeneous solutions. Examples of such dispersions include suspensions (solid in liquid), emulsions (liquid in liquid) and foams (vapor in liquids). Because these systems are not homogeneous and thermodynamically stable, over time they will show some tendency to separate on standing to produce the minimum possible surface area of contact between phases. Thus, suspended particles agglomerate and sediment, emulsified droplets cream and coalesce and the bubbles dispersed in foams collapse, to produce unstable and nonuniform dosage forms. In this chapter the fundamental physical chemical properties of dispersed systems will be discussed, along with the principles of interfacial and colloidal physics and chemistry which underly these properties.

Interfacial Forces and Energetics

In the bulk portion of each phase, molecules are attracted to each other equally in all directions, such that no resultant forces are acting on any one molecule. The strength of these forces determines whether a substance exists as a vapor, liquid or solid at a particular temperature and pressure.

At the boundary between phases, however, molecules are acted upon unequally since they are in contact with other molecules exhibiting different forces of attraction. For example, the primary intermolecular forces in water are due to hydrogen bonds, whereas those responsible for intermolecular bonding in hydrocarbon liquids, such as mineral oil, are due to London dispersion forces.

Because of this, molecules situated at the interface contain potential forces of interaction which are not satisfied relative to the situation in each bulk phase. In liquid systems such unbalanced forces can be satisfied by spontaneous movement of molecules from the interface into the bulk phase. This leaves fewer molecules per unit area at the interface (greater intermolecular distance) and reduces the actual contact area between dissimilar molecules.

Any attempt to reverse this process by increasing the area of contact between phases, ie, bringing more molecules into the interface, causes the interface to resist expansion and to

behave as though it is under a tension everywhere in a tangential direction. The force of this tension per unit length of interface generally is called the interfacial tension, except when dealing with the air-liquid interface, where the terms surface and surface tension are used.

To illustrate the presence of a tension in the interface, consider an experiment where a circular metal frame, with a looped piece of thread loosely tied to it, is dipped into a liquid. When removed and exposed to the air, a film of liquid will be stretched entirely across the circular frame, as when one uses such a frame to blow soap bubbles. Under these conditions (Fig 19-1A), the thread will remain collapsed. If now a heated needle is used to puncture and remove the liquid film from within the loop (Fig 19-1B), the loop will stretch spontaneously into a circular shape.

The result of this experiment demonstrates the spontaneous reduction of interfacial contact between air and the liquid remaining and, indeed, that a tension causing the loop to remain extended exists parallel to the interface. The circular shape of the loop indicates that the tension in the plane of the interface exists at right angles or normal to every part of the looped thread. The total force on the entire loop divided by the circumference of the circle, therefore, represents the tension per unit distance of surface, or the surface tension.

Just as work is required to extend a spring under tension, work should be required to reverse the process seen in Figs 19-1A and B, thus bringing more molecules to the interface. This may be seen quantitatively by considering an experiment where tension and work may be measured directly. Assume that we have a rectangular wire with one movable side (Fig 19-2). Assume further that by dipping this wire into a liquid, a film of liquid will form within the frame when it is removed and exposed to the air. As seen earlier in Fig 19-1, since it comes in contact with air, the liquid surface will tend to contract with a force, F , as molecules leave the surface for the bulk. To keep the movable side in equilibrium, an equal force must be applied to oppose this tension in the surface. We then may define the surface tension, γ , of the liquid as $F/2l$, where $2l$ is the distance of surface over which F is operating ($2l$ since there are two surfaces, top and bottom). If the surface is expanded by a very small distance, Δx , one can then estimate that the work done is

$$W = F\Delta x \quad (1)$$

and therefore

Dr Zografi authored the section on *Interfacial Phenomena*. Dr Schott authored the section on *Colloidal Dispersions*. Dr Swarbrick

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