Contents

Preface xi
This book, and how to use it xv

Part I 1

1 Unit analysis: the neglected key to confidence 3
   1.1 Calculating with units 3
   1.2 Ways of writing composite units 5
   1.3 How unit analysis can guide thinking and help solve problems 5
   1.4 When to specify substances along with units 6
   1.5 The need to use appropriate and compatible units in formulae 7
   1.6 Checking and deriving formulae 8
   1.7 When unit analysis raises questions about formulae 10
   1.8 Dimensional analysis 10

Part II 13

2 Units: length, area, volume, mass, moles and equivalents 15
   2.1 The Système International and unit prefixes 15
   2.2 Length and distance 16
   2.3 Area 17
   2.4 Volume 17
   2.5 Mass 17
   2.6 Moles 18
   2.7 Equivalents 19
   2.8 Conversion between units 20
       Problems 22
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Percentages</td>
<td>23</td>
</tr>
<tr>
<td>3.1 When percentages mislead: human body fat and fat in milk</td>
<td>24</td>
</tr>
<tr>
<td>3.2 Heat loss from the body: further questionable percentages</td>
<td>27</td>
</tr>
<tr>
<td>Problems</td>
<td>28</td>
</tr>
<tr>
<td>4 Composite units I – density</td>
<td>29</td>
</tr>
<tr>
<td>4.1 Specific gravity</td>
<td>30</td>
</tr>
<tr>
<td>4.2 Specific volume</td>
<td>30</td>
</tr>
<tr>
<td>4.3 Two definitions of body density</td>
<td>31</td>
</tr>
<tr>
<td>4.4 Thinking about a formula</td>
<td>33</td>
</tr>
<tr>
<td>Problems</td>
<td>33</td>
</tr>
<tr>
<td>5 Composite units II – concentration</td>
<td>35</td>
</tr>
<tr>
<td>5.1 Concentrations: kilograms of water vs litres of solution</td>
<td>36</td>
</tr>
<tr>
<td>5.2 Simple protein-free salt solutions</td>
<td>37</td>
</tr>
<tr>
<td>5.3 Millimolar and millimolal concentrations in blood plasma</td>
<td>38</td>
</tr>
<tr>
<td>5.4 Some quite different uses for Eq. (5.1)</td>
<td>39</td>
</tr>
<tr>
<td>Problems</td>
<td>39</td>
</tr>
<tr>
<td>6 Aspects of problem solving</td>
<td>41</td>
</tr>
<tr>
<td>6.1 Letting unit analysis solve the problem</td>
<td>41</td>
</tr>
<tr>
<td>6.2 ‘Let x be the unknown’</td>
<td>44</td>
</tr>
<tr>
<td>Problems</td>
<td>49</td>
</tr>
<tr>
<td>7 Making up and diluting solutions</td>
<td>51</td>
</tr>
<tr>
<td>7.1 Preparing 250 mL of 150 mM NaCl from the dry salt</td>
<td>51</td>
</tr>
<tr>
<td>7.2 Preparing dilutions from stock solutions</td>
<td>53</td>
</tr>
<tr>
<td>Problems</td>
<td>56</td>
</tr>
<tr>
<td>8 Calculating drug doses</td>
<td>57</td>
</tr>
<tr>
<td>Problems</td>
<td>59</td>
</tr>
<tr>
<td>9 More about solutions – electroneutrality, osmotic pressure and activity</td>
<td>61</td>
</tr>
<tr>
<td>9.1 The principle of electroneutrality</td>
<td>61</td>
</tr>
<tr>
<td>9.2 But what about membrane potentials and short-circuit currents?</td>
<td>64</td>
</tr>
<tr>
<td>9.3 Anion gap</td>
<td>64</td>
</tr>
<tr>
<td>9.4 Osmoles and osmolality</td>
<td>66</td>
</tr>
<tr>
<td>9.5 Osmolar gap</td>
<td>68</td>
</tr>
<tr>
<td>9.6 Osmosy</td>
<td>70</td>
</tr>
<tr>
<td>9.7 Cell contents</td>
<td>70</td>
</tr>
<tr>
<td>9.8 Effective osmolality, effective osmotic pressure</td>
<td>72</td>
</tr>
<tr>
<td>9.9 Osmotic shifts of water between cells and extracellular fluid</td>
<td>73</td>
</tr>
<tr>
<td>9.10 Free and bound concentrations, activities</td>
<td>76</td>
</tr>
</tbody>
</table>
CONTENTS

Part III 79

10 Graphs, straight lines and equations 81
  10.1 Graphs: some terminology 81
  10.2 Advice on drawing graphs 81
  10.3 The equation of a straight line 82
  10.4 Finding the equation of a line that passes through two specified points 83
  10.5 Drawing a line that is defined by a specified equation 85
  10.6 Finding the equation of a line from its gradient and the coordinates of a single point on it 86
  10.7 Finding the line that best fits a number of points when these lie only roughly in a straight line 86
  10.8 ‘Proportional’ and ‘inversely proportional’ 87
  10.9 Gradients of curves 87
  10.10 A note on units 87
  10.11 On the different kinds of formulae and equations 88
    Problems 90

11 On shapes and sizes 93
  11.1 Areas and volumes of simple shapes 93
  11.2 Erythrocytes, cylinders and spheres 94
  11.3 The swelling of erythrocytes in hypo-osmotic solutions 96
  11.4 Distortion of erythrocytes in passing along narrow blood vessels 97
  11.5 An exercise in rearranging equations to eliminate an unwanted term 98
  11.6 Easy and general ways to check algebraic working 100
  11.7 Solving the equation by trial and error in a spreadsheet 101
  11.8 Why do we not have naturally spherical erythrocytes? 101
  11.9 General properties of simple geometrical shapes 102
  11.10 Replacing volumes with masses in these equations 105
  11.11 A digression on graphs 105
  11.12 Calculating surface area from volume and height: another exercise in re-arranging equations and eliminating unwanted terms 106
  11.13 Another digression to check algebraic working 107
  11.14 Generalizing the formula to include the human body 108
  11.15 Surface/volume and surface/mass ratios 110
  11.16 The surface area of the human body 112
  11.17 Standard formulae for body surface area 113
  11.18 An exercise in comparing formulae containing exponents 116
    Problems 118

12 Body size, body build, fatness and muscularity: unit analysis as an aid to discovery 121
  12.1 Variations in fat-free mass with height and age 122
  12.2 The Rohrer index, or ‘height–weight index of build’ 125
  12.3 The body mass index: estimating body fat from body mass and height 126
## CONTENTS

12.4 Upper arm muscle: how its cross-sectional area varies with body height 131
12.5 Weightlifting – and the cross-sectional area of muscle 133
12.6 Estimating body fat from skinfold thickness measurements 136
12.7 Postscript 138
Problems 139

### Part IV

13 Introducing time 143
13.1 Frequency 143
13.2 Speed and velocity 144
13.3 Acceleration 145
13.4 Rates of flow of substances carried in fluids 145
13.5 Thinking about a formula 146
13.6 The concept of renal clearance 151
13.7 Relating the clearance formula for renal plasma flow to the Fick Principle 154
13.8 Creatinine clearance as a measure of GFR, and a convenient formula for estimating it 154
Problems 156

### Part V

14 Force, pressure, energy, work and power 161
14.1 Force and weight 161
14.2 Pressure 163
14.3 Columns of water, columns of blood 164
14.4 Osmotic pressure and colloid osmotic pressure (oncotic pressure) 165
14.5 Energy and work 167
14.6 Power 169
14.7 An overview of units – from mass to pressure and power 170
Problems 171

15 Lessons from another formula 173
15.1 Poiseuille’s equation and viscosity 173
15.2 Peripheral resistance 175
Problems 176

16 Heat and temperature 177
16.1 Temperature scales 177
16.2 The temperature coefficient, Q_{10} 179
16.3 Heat capacity and specific heat 179
Problems 180
CONTENTS

17 Gases: dry and wet gas mixtures, partial pressures, gases in solution 181
   17.1 A reminder of units 182
   17.2 Natural variations in atmospheric pressure 182
   17.3 The gas laws 182
   17.4 A closer look at Eq. (17.1) and the universal gas constant, with attention to units 183
   17.5 Treatment of gas mixtures – percentages 185
   17.6 Treatment of gas mixtures – partial pressures, tensions 186
   17.7 Water vapour pressure 186
   17.8 ‘Standard temperature and pressure, dry’ 187
   17.9 Dissolved O\textsubscript{2} and CO\textsubscript{2} in blood plasma and other fluids 189
   Problems 189

Part VI 193

18 Introduction to logarithms 195
   18.1 Definitions 196
   18.2 Rules for working with logarithms 196
   18.3 The usefulness of remembering \log\textsubscript{10} 2 196
   18.4 Logarithmic scales on graphs 197
   18.5 What about units? 201
   18.6 Natural logarithms 201
   Problems 202

19 Exponential time courses 203
   19.1 Use of semi-logarithmic plots 205
   19.2 Common complications 206
   Problems 207

20 Nernst equations in physiology and biochemistry: logarithms and ‘\textit{RT/\textit{zF}}’ 209
   20.1 More on \textit{RT/\textit{zF}} 210
   Problems 212

21 pH – two definitions and a possible dilemma for teachers 213
   21.1 pH as −\log[H\textsuperscript{+}] 214
   21.2 The true definition of pH: pH as a number on a conventional scale 215
   21.3 The meaning of 10\textsuperscript{−pH} 216
   21.4 Final comments 217
   Problems 217
CONTENTS

22 Equilibrium constants, the Henderson–Hasselbalch equation, dose–response curves 219
   22.1 Equilibrium constants 219
   22.2 Concentrations or activities? 222
   22.3 The Henderson–Hasselbalch equation 222
   22.4 Application of the Henderson–Hasselbalch equation to drugs 223
   22.5 The dependence of \([AB]\) on \([A]\) when \([\{B\} + \{AB\}]\) is constant 224
   22.6 Concentration–response curves and dose–response curves 227
       Problems 229

23 Buffering and acid–base balance 231
   23.1 Non-bicarbonate buffering 232
   23.2 A link with dose–response curves 235
   23.3 Bicarbonate buffering 236
   23.4 \(\text{CO}_2/\text{HCO}_3^-\) and non-bicarbonate buffers together 239
   23.5 The whole body: diet and the titratable acidity of urine 241
   23.6 Other aspects of acid–base balance 242
       Problems 243

Appendix A. Basic mathematics and mathematical language 245
Appendix B. Some non-metric units 253
Appendix C. Notes 255
Appendix D. Solutions to problems 265
References 287
Index 291