

# Summary of contents

1	Fundamentals	3
2	Atomic structure and properties	73
3	Diatomic molecules	129
4	Structure and shape of polyatomic molecules	177
5	Solids	215
6	Acids and bases	263
7	Gases	301
8	Reaction kinetics	339
9	The language of organic chemistry	405
10	Isomerism and stereochemistry	449
11	Molecular spectroscopy	497
12	Analytical chemistry	559
13	Molecular characterization	605
14	Energy and thermochemistry	659
15	Entropy and Gibbs energy	703
16	Chemical equilibrium	743
17	Electrochemistry	775
18	Phase equilibrium and solutions	811
19	Organic reaction mechanisms	859
20	Halogenoalkanes: substitution and elimination reactions	913
21	Alkenes and alkynes: electrophilic addition and pericyclic reactions	957
22	Benzene and other aromatic compounds: electrophilic substitution reactions	997
23	Aldehydes and ketones: nucleophilic addition and $\alpha$ -substitution reactions	1047
24	Carboxylic acids and derivatives: nucleophilic acyl substitution and $\alpha$ -substitution reactions	1091
25	Hydrogen	1131
26	<i>s</i> -Block chemistry	1159
27	<i>p</i> -Block chemistry	1191
28	<i>d</i> -Block chemistry	1245

Maths Toolkit .....	1295
Appendix 1 Abbreviations and symbols for quantities and units .....	1323
Appendix 2 Representing reactions .....	1330
Appendix 3 Preparation and reactions of alcohols and amines .....	1332
Appendix 4 Organic oxidation and reduction reactions .....	1334
Appendix 5 Properties of the elements .....	1336
Appendix 6 Electronic configurations of the elements and some important ions .....	1344
Appendix 7 Thermodynamic data for organic and inorganic compounds ...	1348
Appendix 8 Ionic, atomic and van der Waals radii for selected elements ...	1359
Appendix 9 Acidity constants .....	1362
Appendix 10 Bond lengths and bond enthalpies .....	1364
Appendix 11 Electromagnetic spectrum .....	1367
Answers .....	1368
Index .....	1378

# Contents

Summary of contents	v
Contents	vii
A message to readers	xiv
Features of this book	xvi
Acknowledgements	xxi

---



## 1 Fundamentals 3

What do chemists do?

1.1	Chemistry: the central science	4
	Box 1.1 The Human Genome Project	6
1.2	Measurement, units, and nomenclature	7
1.3	Atoms and the mole	12
	Box 1.2 Mass spectrometry	14
	Box 1.3 The Amesbury Archer	17
1.4	Chemical equations	21
	Box 1.4 Atom efficiency and green chemistry	26
1.5	Working out how much you have	36
	Box 1.5 Measuring low concentrations	37
	Box 1.6 Measuring dissolved oxygen in river water	41
1.6	Energy changes in chemical reactions	43
	Box 1.7 Potential energy and kinetic energy	44
	Box 1.8 Enthalpy and internal energy	46
	Box 1.9 Butane hair stylers	48
1.7	States of matter and phase changes	50
	Box 1.10 Phase changes of water	53
1.8	Non-covalent interactions	55
	Box 1.11 Why is KEVLAR® so strong?	58
1.9	Chemical equilibrium: how far has a reaction gone?	59
	Box 1.12 Connecting equilibria and cave chemistry	61
	Concept review	68
	Questions	69

---



## 2 Atomic structure and properties 73

Imaging atoms

2.1	The classical picture of the atom	74
2.2	Electromagnetic radiation and quantization	77
	Box 2.1 Radiation from the Sun	80

2.3	Atomic spectra and the Bohr atom	85
	Box 2.2 Lighting up the sky	89
	Box 2.3 The composition of stars	91
2.4	The nature of the electron	92
2.5	Wavefunctions and atomic orbitals	95
	Box 2.4 The $p$ orbitals and complex numbers	103
	Box 2.5 The shapes of the $d$ orbitals	104
2.6	Many-electron atoms	104
	Box 2.6 Electron spin resonance spectroscopy	106
	Box 2.7 Atomic numbers and the Periodic Table	110
2.7	Atomic properties and periodicity	114
2.8	Nuclear chemistry	120
	Box 2.8 Dating the Amesbury Archer	122
	Box 2.9 Smoke detectors	124
	Concept review	126
	Questions	126



## 3 Diatomic molecules

129

### Molecules in space

3.1	Features of diatomic molecules	130
	Box 3.1 How can we measure bond lengths?	132
3.2	The Lewis model	133
	Box 3.2 Magnetic behaviour	136
3.3	Electronegativity	136
3.4	Valence bond theory and molecular orbital theory	138
3.5	Valence bond theory	139
	Box 3.3 Molecular wavefunctions for $H_2$	140
	Box 3.4 How to make an unreactive molecule react	142
3.6	Molecular orbital theory	144
3.7	Molecular orbitals in hydrogen ( $H_2$ )	144
	Box 3.5 Linear combinations of atomic orbitals	148
3.8	Molecular orbital energy level diagrams	149
	Box 3.6 The formation of hydrogen molecules in space	150
3.9	Linear combinations of $p$ orbitals	153
3.10	Bonding in fluorine ( $F_2$ ) and oxygen ( $O_2$ )	156
	Box 3.7 Oxygen in the atmosphere	159

3.11	<i>s-p</i> mixing	160
	Box 3.8 Measuring the energies of molecular orbitals	160
	Box 3.9 The colours of the polar lights	163
3.12	Heteronuclear diatomics	165
	Box 3.10 Linear combinations of atomic orbitals in LiH	167
	Box 3.11 Using nitrogen monoxide to send biological signals	173
	Concept review	174
	Questions	174



## 4 Structure and shape of polyatomic molecules

177

Xenon compounds

	Box 4.1 Representing structures	178
4.1	The Lewis model	179
	Box 4.2 N <sub>2</sub> O: from laughing gas to dragsters	182
4.2	Valence shell electron pair repulsion theory	183
	Box 4.3 The fluorinating ability of ClF <sub>3</sub>	190
	Box 4.4 Nitrates in water	192
4.3	Bond polarity and polar molecules	195
4.4	Valence bond theory for polyatomic molecules	196
	Box 4.5 Ethene and the ripening of fruit	200
4.5	Resonance	203
4.6	A molecular orbital approach to the bonding in polyatomic molecules	205
4.7	Partial molecular orbital schemes	208
	Box 4.6 Boron hydrides	211
	Concept review	212
	Questions	213



## 5 Solids

215

Zeolites

5.1	Covalent network structures	217
	Box 5.1 Nanotubes and nanotechnology	218
	Box 5.2 Superconductors	221
5.2	Structures based on the packing of spheres	222
5.3	Metallic bonding	232
	Box 5.3 CD writers and re-writers	235
5.4	Structures of compounds	237
	Box 5.4 X-ray crystallography	239
	Box 5.5 Self-cleaning windows	243
5.5	The ionic model	246
5.6	Calculating lattice energy	253
	Box 5.6 Determining the Madelung constant	254
5.7	Predicting bond types	258
	Concept review	259
	Questions	259



## 6 Acids and bases

263

Acids and bases in the garden

6.1	Brønsted-Lowry acids and bases	264
	Box 6.1 Solvation	265
	Box 6.2 Acids, alkalis, and human tissue	267
6.2	The strengths of acids and bases	268
	Box 6.3 Acidic water in disused mines	273
	Box 6.4 Controlling pH in a swimming pool	277
6.3	Buffer solutions	279
	Box 6.5 Buffering in the blood	281
6.4	pH changes in acid-base titrations	282
6.5	Indicators	287
6.6	Oxoacids	290
6.7	Acidic and basic oxides	294
	Box 6.6 Cooking with acids and bases	294
6.8	Lewis acids and bases	295
	Box 6.7 Superacids	297
	Concept review	297
	Questions	298



## 7 Gases

301

Breathing under water

7.1	The gas laws: an empirical approach	303
7.2	Using the ideal gas equation	307
	Box 7.1 Car air bags	311
7.3	Mixtures of gases	313
7.4	Kinetic molecular theory and the gas laws	316
	Box 7.2 Calculating the pressure of a gas	318
7.5	The speeds of molecules in a gas	319
	Box 7.3 Measuring the distribution of speeds in a gas	322
	Box 7.4 Enriching uranium: a practical application of effusion	325
7.6	Real gases	330
	Concept review	335
	Questions	336



## 8 Reaction kinetics

339

Methane in the troposphere

8.1	Why study reaction kinetics?	340
8.2	What is meant by the rate of a reaction?	341
8.3	Monitoring the progress of a reaction	344
8.4	Elementary reactions	345
	Box 8.1 Deriving the integrated rate equation for a first order reaction	350
	Box 8.2 Deriving the integrated rate equation for a second order reaction	351

Box 8.3	Atmospheric lifetime of methane	357
Box 8.4	Using flash photolysis to monitor ClO* radicals	360
8.5	Complex reactions: experimental methods	362
Box 8.5	The stopped-flow technique	363
Box 8.6	Deriving the integrated rate equation for a zero order reaction	369
Box 8.7	Pharmacokinetics	369
8.6	Complex reactions: reaction mechanisms	373
8.7	Effect of temperature on the rate of a reaction	383
8.8	Theories of reactions	390
8.9	Catalysis	395
Box 8.8	Enzyme kinetics	397
	Concept review	398
	Questions	399



## 9 The language of organic chemistry 405

Designer medicines for treating high blood pressure: an ACE approach

9.1	Why are organic compounds important?	406
Box 9.1	Friedrich Wöhler: first synthesis of a naturally occurring organic compound	407
Box 9.2	Some landmark laboratory syntheses of natural products	408
9.2	Drawing organic compounds	409
9.3	Carbon frameworks and functional groups	413
9.4	Naming organic compounds	415
9.5	Hydrocarbons	415
Box 9.3	Alkyl group substituents	417
Box 9.4	Is butter healthier than margarine?	422
9.6	Functional groups containing one or more heteroatoms	426
Box 9.5	The DDT dilemma	428
Box 9.6	An organic workup	431
Box 9.7	Pain-killing alkaloids	434
9.7	Functional groups containing carbonyl groups	435
Box 9.8	Sulfonic acids and related compounds	438
Box 9.9	An artificial sweetener	441
9.8	Naming compounds with more than one functional group	443
	Concept review	445
	Questions	445



## 10 Isomerism and stereochemistry 449

Bitter isomers in beer

10.1	Isomerism	450
10.2	Conformational isomers	453
Box 10.1	Shaping up for maximum activity	457
Box 10.2	Drawing cyclohexane rings	463
Box 10.3	The shape of cholesterol and its role in the body	465

10.3	Configurational isomers: <i>E</i> - and <i>Z</i> -isomers	468
	Box 10.4 A natural selection: biosynthesis of fatty acids	471
10.4	Configurational isomers: isomers with chiral centres	473
	Box 10.5 Some landmarks in chirality	474
	Box 10.6 The <i>D/L</i> nomenclature	477
	Box 10.7 Thalidomide—from villain to hero?	483
	Box 10.8 Using diastereomers to separate enantiomers: resolution	485
	Concept review	493
	Questions	493




---

## 11 Molecular spectroscopy 497

### Searching for life on Mars

11.1	Introduction to molecular spectroscopy	498
11.2	Molecular energies and spectroscopy	500
	Box 11.1 Particle in a one-dimensional box	501
11.3	General principles of spectroscopy	504
	Box 11.2 Lasers	511
11.4	Rotational spectroscopy	513
	Box 11.3 Using rotational spectroscopy to monitor ClO <sup>•</sup> radicals in the atmosphere	522
11.5	Vibrational spectroscopy	524
	Box 11.4 The simple harmonic oscillator model for a diatomic molecule	527
	Box 11.5 Atmospheric concentrations of carbon dioxide	533
	Box 11.6 Degrees of freedom and normal modes of vibration	534
11.6	Electronic spectroscopy	537
	Box 11.7 Electronic spectroscopy and colour	538
11.7	Spin resonance spectroscopy	542
	Box 11.8 Spin-spin coupling in NMR spectra	549
	Box 11.9 Magnetic resonance imaging (MRI)	553
	Concept review	555
	Questions	556




---

## 12 Analytical chemistry 559

### Drugs in sport

12.1	Carrying out an analysis	561
	Box 12.1 Analysing food contaminants	568
12.2	Electrochemical methods of analysis	570
	Box 12.2 Rapid blood analysis using electrochemical methods	574
12.3	Chromatography	575
	Box 12.3 Monitoring PCBs in the environment	584
	Box 12.4 Gas chromatograph-mass spectrometry (GC-MS)	586
	Box 12.5 Chiral HPLC	588
12.4	Spectroscopic methods of analysis	590
	Box 12.6 Alcohol analysis and drink-driving	590
	Box 12.7 A pulse oximeter	593



12.5	Atomic spectrometry	595
	Box 12.8 Why is the temperature so important in atomic emission spectrometry?	596
	Concept review	601
	Questions	602



## 12.6 Isotopic composition and isotopic fractionation 605

Using isotope ratios to analyse orange juice

13.1	Mass spectrometry	606
	Box 13.1 Ionization methods	608
	Box 13.2 Using tandem mass spectrometry in newborn screening	617
13.2	Infrared spectroscopy	619
13.3	Nuclear magnetic resonance spectroscopy	627
	Box 13.3 Running an NMR spectrum	629
	Box 13.4 Magnetic field strength and resolution	629
	Box 13.5 Drawing a $^1\text{H}$ NMR spectrum	642
13.4	Structure determination using a combination of techniques	648
	Box 13.6 Determining degrees of unsaturation	649
	Concept review	654
	Questions	655



## 14 Energy and thermochemistry 659

Launching the Space Shuttle

14.1	Energy changes in chemistry: heat and work	660
	Box 14.1 James Joule and the equivalence of heat and work	661
14.2	Enthalpy and enthalpy changes	666
	Box 14.2 Which freezes first, hot water or cold?	669
14.3	Enthalpy changes in chemical reactions	670
	Box 14.3 Comparing fuels	677
	Box 14.4 Thermochemistry for faster food	678
14.4	Variation of enthalpy with temperature	681
	Box 14.5 Deriving the Kirchoff equation	683
14.5	Internal energy and the First Law of thermodynamics	685
	Box 14.6 Isothermal expansion of an ideal gas	686
	Box 14.7 Nitroglycerine: the chemistry of an explosive	692
14.6	Measuring energy changes	693
	Box 14.8 Calorimetry, food, and metabolism	696
	Concept review	698
	Questions	699



## 15 Entropy and Gibbs energy 703

Protein folding

15.1	What are spontaneous processes?	704
15.2	Entropy and the Second Law of thermodynamics	708
	Box 15.1 Variation of the entropy of a substance with temperature	711

15.3	The Third Law and absolute entropies	712
	Box 15.2 Determination of standard entropy,	713
	Box 15.3 What is the lowest temperature that can be reached?	715
15.4	Entropy changes in chemical reactions	716
	Box 15.4 What happens when proteins don't fold correctly?	721
15.5	Gibbs energy	722
	Box 15.5 Gibbs energy: the balance between enthalpy and entropy change	724
	Box 15.6 Thermodynamics of addition polymerization	727
	Box 15.7 Obtaining silicon for use in silicon chips	731
	Box 15.8 Energetics of biochemical reactions	732
	Box 15.9 How much work can you get from glucose?	734
15.6	Variation of Gibbs energy with conditions	735
	Box 15.10 Obtaining metals from ores	737
	Concept review	739
	Questions	740



## 16 Chemical equilibrium 743

Equilibria in the oceans

16.1	Gibbs energy and equilibrium	745
	Box 16.1 Solubility equilibria	749
16.2	The direction of a reaction: the reaction quotient	750
	Box 16.2 Equilibrium in fizzy water	752
16.3	Gibbs energy and equilibrium constants	753
	Box 16.3 Deriving the relation between $\Delta_r G^\ominus$ and $K$	754
	Box 16.4 Contrails from jet aircraft	756
16.4	Calculating the composition of a reaction at equilibrium	758
	Box 16.5 Chalk, lime, and mineral water: an example of heterogeneous equilibrium	762
16.5	Effect of conditions on reaction yields and $K$	762
16.6	Applying the thermodynamics in Chapters 14, 15, and 16	768
	Box 16.6 A case study in reaction thermodynamics: the Haber process	769
	Concept review	770
	Questions	770



## 17 Electrochemistry 775

Electrical energy on the move

17.1	What is electrochemistry?	776
17.2	Ions in solution	778
	Box 17.1 Pure water and conductivity	781
17.3	Electrochemical cells	782
	Box 17.2 Electrochemical cells as portable energy sources	784
	Box 17.3 Practical measurement of $E^\ominus$ values	792
17.4	Thermodynamics of electrochemical cells	793
	Box 17.4 Corrosion as an electrochemical process	798
	Box 17.5 Bioelectrochemistry: nerve cells and ion channels	801

17.5	Electrolysis	802
	Box 17.6 Electrolysis and rechargeable batteries	805
	Concept review	807
	Questions	807

## **18 Phase equilibrium and solutions** **811**

Supercritical fluids

18.1	Phase behaviour of single components	812
	Box 18.1 Liquid crystals	820
18.2	Quantitative treatment of phase transitions	821
	Box 18.2 Deriving the Clapeyron equation	824
	Box 18.3 Deriving the Clausius-Clapeyron equation	827
18.3	Intermolecular interactions	830
18.4	Phase behaviour in two-component systems	835
	Box 18.4 Perfluorocarbons and blood substitutes	846
	Box 18.5 Reverse osmosis and water purification	850
	Concept review	855
	Questions	855

## **19 Organic reaction mechanisms** **859**

Antidotes for nerve agents

	Box 19.1 The birth of organic reaction mechanisms	861
19.1	Fundamental concepts of organic reaction mechanisms	861
	Box 19.2 Natural cascades	862
	Box 19.3 George Olah and carbocations	866
	Box 19.4 Anticancer agents	881
19.2	Classification of organic reaction mechanisms	885
	Box 19.5 Natural acids and bases	891
	Box 19.6 Natural acid-base catalysis	894
	Box 19.7 Aspirin	898
	Box 19.8 Superglue and fingerprints	901
19.3	Reaction selectivity	906
	Concept review	910
	Questions	911

## **20 Halogenoalkanes: substitution and elimination reactions** **913**

Alternative pesticides to bromomethane

	Box 20.1 Natural organohalogens	914
20.1	Structure and reactivity of halogenoalkanes	915
20.2	Preparation of halogenoalkanes	917
	Box 20.2 Teflon and radical polymerization	919
20.3	The mechanisms of nucleophilic substitution reactions	925
	Box 20.3 Designer solvents	928
	Box 20.4 Epoxy resins	937
20.4	The mechanisms of elimination reactions	939
	Box 20.5 Muscle relaxants	943

20.5	Substitution versus elimination reactions	950
	Concept review	953
	Questions	954



## 21 Alkenes and alkynes: electrophilic addition and pericyclic reactions 957

The citric acid cycle

21.1	Structure and reactivity of alkenes and alkynes	958
	Box 21.1 Ethene production in plants	961
21.2	Preparation of alkenes and alkynes	962
21.3	Electrophilic addition reactions of alkenes	965
	Box 21.2 Adding HBr to alkenes in the presence of peroxides	969
	Box 21.3 Making ethanol on a large scale	976
	Box 21.4 Why is benzene carcinogenic?	983
21.4	Pericyclic reactions of alkenes	984
21.5	Electrophilic addition reactions of alkynes	989
	Concept review	993
	Questions	994



## 22 Benzene and other aromatic compounds: electrophilic substitution reactions 997

Azo dyes: the start of the rainbow

22.1	The structure of benzene and other aromatic compounds	998
	Box 22.1 A short history of benzene	1000
	Box 22.2 Making phenol from benzene	1001
	Box 22.3 From coal tar dyes to pharmaceuticals	1006
22.2	Electrophilic substitution reactions of benzene	1008
	Box 22.4 Substituted benzenes in sport	1015
	Box 22.5 Cleaning up the Friedel-Crafts acylation	1020
22.3	Reactivity of substituted benzenes in electrophilic substitutions	1021
22.4	The synthesis of substituted benzenes	1030
	Box 22.6 The biological action and synthesis of Viagra	1033
	Box 22.7 The synthesis and biological action of salbutamol	1041
	Concept review	1043
	Questions	1044



## 23 Aldehydes and ketones: nucleophilic addition and $\alpha$ -substitution reactions 1047

Rhodopsin and vision

23.1	The structure and reactions of aldehydes and ketones	1048
	Box 23.1 Cortisone and cortisol	1052

23.2	nucleophilic addition reactions of aldehydes and ketones	1053
	Box 23.2 Oxidizing alcohols to carbonyls	1056
	Box 23.3 Hydride transfer in nature	1058
	Box 23.4 A short history of organometallics	1061
	Box 23.5 The structure of glucose	1065
	Box 23.6 Imines and hydrazones in organic synthesis	1071
23.3	$\alpha$ -Substitution reactions of aldehydes and ketones	1074
23.4	Carbonyl-carbonyl condensation reactions	1081
	Concept review	1087
	Questions	1088




---

## 24 Carboxylic acids and derivatives: nucleophilic acyl substitution and $\alpha$ -substitution reactions

PET plastics

**1091**

24.1	Structure and reactions of carboxylic acids and derivatives	1092
	Box 24.1 Oxytocin, the hormone of love	1092
	Box 24.2 Relative reactivity of carboxylic acid derivatives	1095
24.2	Nucleophilic acyl substitution reactions	1099
	Box 24.3 <i>Fragrant esters</i>	1101
	Box 24.4 Halogenation of carboxylic acids	1102
	Box 24.5 Combinatorial chemistry	1107
	Box 24.6 Making soap	1112
	Box 24.7 Hydrolysis of nitriles to form carboxylic acids	1117
24.3	$\alpha$ -Substitution and carbonyl-carbonyl condensation reactions	1118
	Concept review	1126
	Questions	1127





---

## 25 Hydrogen

The planet Jupiter

**1131**

25.1	Elemental hydrogen	1132
	Box 25.1 The hydrogen economy	1133
25.2	Compounds of hydrogen	1135
	Box 25.2 Hydrogen storage	1138
	Box 25.3 Hydrofluoric acid	1145
25.3	Hydrogen bonding	1147
	Box 25.4 Hydrogen bonding and life	1149
	Box 25.5 Burning ice	1152
25.4	Isotope effects	1153
	Box 25.6 Tritium	1153
	Concept review	1156
	Questions	1156




## 26 s-Block chemistry

1159

## Biominerals

26.1	The Group 1 elements	1160
26.2	Group 1 compounds	1162
	Box 26.1 Why is sodium peroxide more stable to heating than lithium peroxide?	1164
	Box 26.2 Is salt bad for you?	1167
26.3	Group 1 ions in solution	1170
26.4	Group 1 coordination chemistry	1171
26.5	Reaction of Group 1 metals with liquid ammonia	1173
26.6	The Group 2 elements	1173
	Box 26.3 Building materials	1175
26.7	Group 2 compounds	1176
	Box 26.4 Hard water	1181
26.8	Group 2 coordination chemistry	1182
	Box 26.5 Chlorophylls	1182
26.9	Lithium and beryllium as exceptional elements	1184
26.10	Organometallic compounds	1185
26.11	Diagonal relationships	1186
	Concept review	1187
	Questions	1188

---



## 27 p-Block chemistry

1191

## Photochemical smog

27.1	General aspects and trends in the p block	1193
27.2	Group 13: boron, aluminium, gallium, indium, and thallium	1199
	Box 27.1 Recycling aluminium	1201
27.3	Group 14: carbon, silicon, germanium, tin, and lead	1206
	Box 27.2 The greenhouse effect and global warming	1208
	Box 27.3 Silicones—shiny hair and cosmetic surgery	1210
27.4	Group 15: nitrogen, phosphorus, arsenic, antimony, and bismuth	1213
	Box 27.4 Fluxional molecules	1220
	Box 27.5 Firearms and forensic science	1221
27.5	Group 16: oxygen, sulfur, selenium, tellurium, and polonium	1222
	Box 27.6 The ozone layer	1224
	Box 27.7 Sulfur on Io	1225
27.6	Group 17: fluorine, chlorine, bromine, iodine, and astatine	1230
	Box 27.8 Chlorofluorocarbons and the ozone hole	1232
27.7	Group 18: helium, neon, argon, krypton, xenon, and radon	1238
	Box 27.9 Using argon to date rocks	1239
27.8	p-Block organometallic chemistry	1241
	Concept review	1242
	Questions	1243



## 28 *d*-Block chemistry

1245

### Colouring with metal pigments

Box 28.1	Technetium and imaging the brain	1247
28.1	The <i>d</i> -block elements	1248
28.2	Chemistry of the first row <i>d</i> -block elements	1253
28.3	Coordination chemistry	1256
Box 28.2	The extraction of gold	1259
Box 28.3	Platinum anti-cancer drugs	1266
Box 28.4	Coordination networks	1269
28.4	Crystal field theory	1270
28.5	Filling the <i>d</i> orbitals	1273
28.6	Colour in coordination compounds	1280
28.7	Magnetic properties	1283
Box 28.5	Ferromagnetism and recording information	1284
28.8	Aqueous chemistry of the first row <i>d</i> -block ions	1286
Box 28.6	Trapping metal ions using the chelate effect	1287
Box 28.7	Haemoglobin and the transport of oxygen	1289
	Concept review	1291
	Questions	1292

Maths Toolkit	1295
Appendices	
Appendix 1 Abbreviations and symbols for quantities and units	1323
Appendix 2 Representing reactions	1330
Appendix 3 Preparation and reactions of alcohols and amines	1332
Appendix 4 Organic oxidation and reduction reactions	1334
Appendix 5 Properties of the elements	1336
Appendix 6 Electronic configurations of the elements and some important ions	1344
Appendix 7 Thermodynamic data for organic and inorganic compounds	1348
Appendix 8 Ionic, atomic and van der Waals radii for selected elements	1359
Appendix 9 Acidity constants	1362
Appendix 10 Bond lengths and bond enthalpies	1364
Appendix 11 Electromagnetic spectrum	1367
Answers	1368
Index	1378