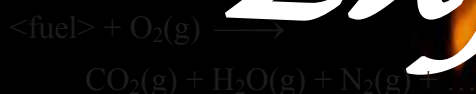


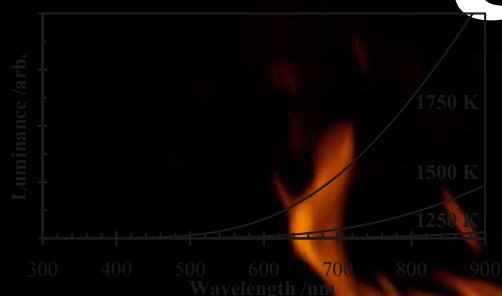
FIRE is the rapid reaction of a fuel and oxidizer at elevated temperature, producing a self-sustaining chemical reaction characterized by the emission of blackbody radiation and flames.

A dynamic balance exists between the reaction rate, temperature, and reactant availability.

General reaction



The flame color is characterized by the chemical nature of the fuel and additives. Every body also emits *blackbody* radiation based on its temperature.

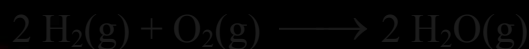


The red-orange color often seen is primarily blackbody emission from soot formed during the slow, incomplete combustion.

When oxygen is premixed with the fuel, combustion is rapid and complete, and the flames are nearly colorless.

The sharp divide between the flame and nothing is an excellent example of the non-linear nature of chemical kinetics!

The simplest combustion reaction:



Elementary reactions observed during hydrogen combustion include

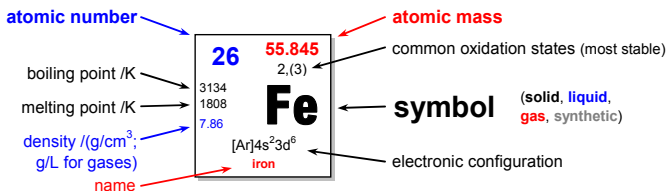


Exploring Chemistry

Roy Jensen

Periodic Table of

1																													
1 1.0080 <small>±1</small> H <small>1s¹</small> hydrogen		2																											
3 6.97 Li <small>[He]2s¹</small> lithium		4 9.012182 Be <small>[He]2s²</small> beryllium		3														4		5		6		7		8		9	
11 22.989769 Na <small>[Ne]3s¹</small> sodium		12 24.3050 Mg <small>[Ne]3s²</small> magnesium		19 39.0983 K <small>[Ar]4s¹</small> potassium		20 40.078 Ca <small>[Ar]4s²</small> calcium		21 44.955912 Sc <small>[Ar]4s²3d¹</small> scandium		22 47.867 Ti <small>[Ar]4s²3d²</small> titanium		23 50.9415 V <small>[Ar]4s²3d³</small> vanadium		24 51.9961 Cr <small>[Ar]4s¹3d⁵</small> chromium		25 54.938045 Mn <small>[Ar]4s²3d⁵</small> manganese		26 55.845 Fe <small>[Ar]4s²3d⁶</small> iron		27 58.933195 Co <small>[Ar]4s²3d⁷</small> cobalt									
37 85.4678 Rb <small>[Kr]5s¹</small> rubidium		38 87.62 Sr <small>[Kr]5s²</small> strontium		39 88.90585 Y <small>[Kr]5s²4d¹</small> yttrium		40 91.224 Zr <small>[Kr]5s²4d²</small> zirconium		41 92.906 Nb <small>[Kr]5s¹4d⁴</small> niobium		42 95.96 Mo <small>[Kr]5s¹4d⁵</small> molybdenum		43 [97.9072] Tc <small>[Kr]5s²4d⁵</small> technetium		44 101.07 Ru <small>[Kr]5s¹4d⁷</small> ruthenium		45 102.90550 Rh <small>[Kr]5s¹4d⁸</small> rhodium													
55 132.905452 Cs <small>[Xe]6s¹</small> cesium		56 137.327 Ba <small>[Xe]6s²</small> barium		71 174.9668 Lu <small>[Xe]6s²4f¹⁴5d¹</small> lutetium		72 178.49 Hf <small>[Xe]6s²4f¹⁴5d²</small> hafnium		73 180.94788 Ta <small>[Xe]6s²4f¹⁴5d³</small> tantalum		74 183.84 W <small>[Xe]6s²4f¹⁴5d⁴</small> tungsten		75 186.207 Re <small>[Xe]6s²4f¹⁴5d⁵</small> rhenium		76 190.23 Os <small>[Xe]6s²4f¹⁴5d⁶</small> osmium		77 192.217 Ir <small>[Xe]6s²4f¹⁴5d⁷</small> iridium													
87 [223.0197] Fr <small>[Rn]7s¹</small> francium		88 [226.0254] Ra <small>[Rn]7s²</small> radium		103 [261.1096] Lr <small>[Rn]7s²5f¹⁴6d¹</small> lawrencium		104 [265.1167] Rf <small>[Rn]7s²5f¹⁴6d²</small> rutherfordium		105 [268.1250] Db <small>[Rn]7s²5f¹⁴6d³</small> dubnium		106 [271.133] Sg <small>[Rn]7s²5f¹⁴6d⁴</small> seaborgium		107 [270] Bh <small>[Rn]7s²5f¹⁴6d⁵</small> bohrium		108 [277.150] Hs <small>[Rn]7s²5f¹⁴6d⁶</small> hassium		109 [276.151] Mt <small>[Rn]7s²5f¹⁴6d⁷</small> meitnerium													
57 138.90547 La <small>[Xe]6s²5d¹</small> lanthanum		58 140.116 Ce <small>[Xe]6s²4f¹5d¹</small> cerium		59 140.90765 Pr <small>[Xe]6s²4f³</small> praseodymium		60 144.242 Nd <small>[Xe]6s²4f⁴</small> neodymium		61 [144.9127] Pm <small>[Xe]6s²4f⁵</small> promethium		62 150.36 Sm <small>[Xe]6s²4f⁶</small> samarium																			
89 [227.0278] Ac <small>[Rn]7s²6d¹</small> actinium		90 232.0381 Th <small>[Rn]7s²6d²</small> thorium		91 [231.0359] Pa <small>[Rn]7s²5f²6d¹</small> protactinium		92 238.02891 U <small>[Rn]7s²5f³6d¹</small> uranium		93 [237.0482] Np <small>[Rn]7s²5f⁴6d¹</small> neptunium		94 [244.0642] Pu <small>[Rn]7s²5f⁶</small> plutonium																			



All properties at 298.15 K and 1 bar unless noted.

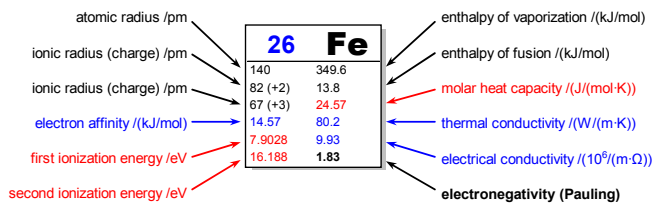
the Elements

																		18 2 4.002602 4.216 0.8 (26 bar) 0.1787 $1s^2$ helium He			
										13 5 10.81 4273 2352 2.34 $[He]2s^22p^1$ boron B		14 6 12.011 5100 4098 (sub.) 2.62 $[He]2s^22p^2$ carbon C		15 7 14.0069 77.4 63.29 1.2506 $[He]2s^22p^3$ nitrogen N		16 8 15.9994 90.188 54.8 1.429 $[He]2s^22p^4$ oxygen O		17 9 18.998403 85.01 53.53 1.696 $[He]2s^22p^5$ fluorine F		10 20.1797 27.102 24.48 0.8999 $[He]2s^22p^6$ neon Ne	
										13 13 26.981539 2792 933.52 2.702 $[Ne]3s^33p^1$ aluminum Al		14 14 28.085 3538 1683 2.33 $[Ne]3s^33p^2$ silicon Si		15 15 30.973762 550 317.3 1.82 $[Ne]3s^33p^3$ phosphorus P		16 16 32.07 717.8 388.36 2.07 $[Ne]3s^33p^4$ sulfur S		17 17 35.45 238.6 172.17 3.214 $[Ne]3s^33p^5$ chlorine Cl		18 18 39.948 87.5 84 1.7824 $[Ne]3s^33p^6$ argon Ar	
10 28 58.6934 3186 1726 8.90 $[Ar]4s^23d^8$ nickel Ni		11 29 63.546 2840 1356 8.96 $[Ar]4s^13d^{10}$ copper Cu		12 30 65.38 1180 692.73 7.14 $[Ar]4s^23d^{10}$ zinc Zn		31 69.723 2477 302.93 5.907 $[Ar]4s^23d^{10}4p^1$ gallium Ga		32 72.63 3103 1210.6 5.323 $[Ar]4s^23d^{10}4p^2$ germanium Ge		33 74.92160 886 (sub.) 1090 (26 bar) 5.72 $[Ar]4s^23d^{10}4p^3$ arsenic As		34 78.96 958.1 490 4.79 $[Ar]4s^23d^{10}4p^4$ selenium Se		35 79.904 331.93 266 3.119 $[Ar]4s^23d^{10}4p^5$ bromine Br		36 83.798 120.9 116.6 3.708 $[Ar]4s^23d^{10}4p^6$ krypton Kr					
46 106.42 3213 1825 12.02 $[Kr]4d^{10}$ palladium Pd		47 107.8682 2435 1235.08 10.50 $[Kr]5s^14d^{10}$ silver Ag		48 112.411 1038 594.1 8.65 $[Kr]5s^24d^{10}$ cadmium Cd		49 114.818 2353 429.76 7.31 $[Kr]5s^24d^{10}5p^1$ indium In		50 118.710 2875 505.12 7.30 $[Kr]5s^24d^{10}5p^2$ tin Sn		51 121.760 1860 903.89 6.684 $[Kr]5s^24d^{10}5p^3$ antimony Sb		52 127.60 1263.1 722.7 8.24 $[Kr]5s^24d^{10}5p^4$ tellurium Te		53 126.90447 487.35 (35 bar) 266 4.93 $[Kr]5s^24d^{10}5p^5$ iodine I		54 131.293 166.1 161.3 5.88 $[Kr]5s^24d^{10}5p^6$ xenon Xe					
78 195.084 4100 2045 21.45 $[Xe]6s^14f^{14}5d^9$ platinum Pt		79 196.966569 3081 1337.58 19.32 $[Xe]6s^14f^{14}5d^{10}$ gold Au		80 200.59 629.73 234.28 13.546 $[Xe]6s^24f^{14}5d^{10}$ mercury Hg		81 204.384 1730±10 576.7 11.85 $[Xe]6s^24f^{14}5d^{10}6p^1$ thallium Tl		82 207.2 2013 600.652 11.34 $[Xe]6s^24f^{14}5d^{10}6p^2$ lead Pb		83 208.98040 1833±5 544.5 9.80 $[Xe]6s^24f^{14}5d^{10}6p^3$ bismuth Bi		84 [208.9824] 1235 527 9.4 $[Xe]6s^24f^{14}5d^{10}6p^4$ polonium Po		85 [209.9871] 610 575 387 $[Xe]6s^24f^{14}5d^{10}6p^5$ astatine At		86 [222.0176] 211 202 9.73 $[Xe]6s^24f^{14}5d^{10}6p^6$ radon Rn					
110 [281] - - - $[Rn]7s^25f^{14}6d^9$ darmstadtium Ds		111 [280.164] - - - $[Rn]7s^25f^{14}6d^{10}$ roentgenium Rg		112 [285.174] - - - $[Rn]7s^25f^{14}6d^{10}$ copernicium Cn		113 [285] - - - $[Rn]7s^25f^{14}6d^{10}7p^1$ ununtrium Uut		114 [289.187] - - - $[Rn]7s^25f^{14}6d^{10}7p^2$ flerovium Fl		115 [288] - - - $[Rn]7s^25f^{14}6d^{10}7p^3$ ununpentium Uup		116 [293] - - - $[Rn]7s^25f^{14}6d^{10}7p^4$ livermorium Lv		117 [294] - - - $[Rn]7s^25f^{14}6d^{10}7p^5$ ununseptium Uus		118 [294] - - - $[Rn]7s^25f^{14}6d^{10}7p^6$ ununoctium Uuo					
63 151.964 1800 1095 5.259 $[Xe]6s^24f^7$ europium Eu		64 157.25 3546 1586 7.895 $[Xe]6s^24f^75d^1$ gadolinium Gd		65 158.925 3503 1629 8.27 $[Xe]6s^24f^9$ terbium Tb		66 162.500 2840 1685 8.536 $[Xe]6s^24f^{10}$ dysprosium Dy		67 164.93032 2973 1747 8.80 $[Xe]6s^24f^{11}$ holmium Ho		68 167.259 3141 1802 9.05 $[Xe]6s^24f^{12}$ erbium Er		69 168.93421 2223 1818 9.33 $[Xe]6s^24f^{13}$ thulium Tm		70 173.054 1469 1092 6.98 $[Xe]6s^24f^{14}$ ytterbium Yb							
95 [243.0614] 2880 1267 13.6 $[Rn]7s^25f^7$ americium Am		96 [247.0704] - 1613 13.5 $[Rn]7s^25f^76d^1$ curium Cm		97 [247.0703] - - - $[Rn]7s^25f^9$ berkelium Bk		98 [251.0796] - - - $[Rn]7s^25f^{10}$ californium Cf		99 [252.0830] - - - $[Rn]7s^25f^{11}$ einsteinium Es		100 [257.0951] - - - $[Rn]7s^25f^{12}$ fermium Fm		101 [258.0984] - - - $[Rn]7s^25f^{13}$ mendeleevium Md		102 [259.1010] - - - $[Rn]7s^25f^{14}$ nobelium No							

A printable version of this periodic table is available from www.RoguePublishing.ca

Periodic Table of

1																	
1 H																	
25 154 (-1) — 72.77 13.598 — 2.20	0.44936 0.05868 28.84 0.1815 — 2.20																
2																	
3 Li	4 Be																
145 78 (+1) — 59.63 5.3915 75.639	145.92 3 25.08 84.7 10.80 0.98	105 34 (+2) — — 9.3227 18.211	292.4 12.2 16.40 200 31.30 1.57														
11 Na	12 Mg																
180 98 (+1) — 52.87 5.1386 47.282	96.96 2.598 28.28 141 21.00 0.93	150 79 (+2) — — 7.6457 15.035	127.4 8.954 24.79 156 22.60 1.31														
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co									
220 133 (+1) — 48.39 4.3406 31.632	79.87 2.334 29.32 102.4 13.90 0.82	180 106 (+2) — 2.37 6.1128 11.871	153.6 8.54 25.25 200 29.80 1.00	160 83 (+3) — 18.14 6.5616 12.800	314.2 14.1 26.97 15.8 1.77 1.36	140 86 (+2) 61 (+4) 7.62 6.8280 13.575	421 15.45 24.89 21.9 2.34 1.54	135 79 (+2) 54 (+5) 50.66 6.7461 14.655	0.452 20.9 24.96 30.7 4.89 1.63	140 82 (+2) 62 (+3) 64.26 6.7668 16.485	344.3 16.9 23.40 93.7 7.74 1.66	140 91 (+2) 52 (+4) — 7.4343 15.640	226 12.05 26.37 7.82 0.70 1.55	140 82 (+2) 67 (+3) 14.57 7.9028 16.188	349.6 13.8 24.57 80.2 9.93 1.83	135 82 (+2) 64 (+3) 63.87 7.8810 17.080	376.5 16.19 24.75 100 17.20 1.88
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh									
235 149 (+1) — 46.88 4.1768 27.289	72.216 2.192 31.02 58.2 7.79 0.82	200 127 (+2) — 4.63 5.6952 11.030	144 8.3 26.29 35.3 7.62 0.95	180 106 (+3) — 29.62 6.2186 12.230	363 11.4 26.67 17.2 1.66 1.22	155 109 (+2) 87 (+4) 41.10 6.6342 13.163	58.2 16.9 24.63 22.7 2.36 1.33	145 74 (+4) 69 (+5) 86.16 6.7585 14.303	682 26.4 24.16 53.7 6.93 1.60	145 92 (+2) 62 (+6) 72.17 7.0923 16.168	598 32 23.99 138 18.70 2.16	135 95 (+4) 72 (+5) 53.07 7.2757 15.235	660 24 20.56 50.6 6.70 1.90	130 77 (+3) 65 (+4) 101.31 13.70 16.790	595 24 24.05 117 7.4592 2.20	135 75 (+3) 67 (+4) 109.71 7.4592 18.034	493 21.5 24.90 150 21.10 2.28
55 Cs	56 Ba *	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir									
260 165 (+1) — 45.51 3.8939 23.157	67.74 2.092 31.90 35.9 4.89 0.79	215 142 143 (+2) — 13.95 5.2122 10.004	142 7.75 28.01 18.4 3.00 0.89	175 85 (+3) — — 5.4257 13.888	355.9 18.6 26.25 16.4 1.85 1.27	155 84 (+4) — =0 6.8249 14.925	575 24.06 24.99 23 3.12 1.30	145 72 (+3) 64 (+5) 31.07 7.8872 15.546	743 31.6 25.33 57.5 7.61 1.50	135 62 (+6) — 78.64 7.9805 17.619	824 35.4 23.90 174 18.90 2.36	135 715 60 (+7) 14.47 7.8768 13.059	715 33.2 24.21 47.9 5.42 1.90	130 67 (+4) — 106.14 8.7060 16.583	746 31.8 24.73 87.6 10.90 2.20	135 75 (+3) 68 (+4) 150.89 9.1206 16.583	604 26.1 24.99 147 19.70 2.20
87 Fr	88 Ra **	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt									
— 180 (+1) — 44.38 3.9384 —	— 215 162 (+2) — 27.12 18.6 5.2785 10.147	— 88 (+3) — — 10 4.8712 —	— — — 23 — — —	— — — 58 — — —	— — — — — — —	— — — — — — —	— — — — — — —	— — — — — — —	— — — — — — —								



All properties at 298.15 K and 1 bar unless noted.

*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm
195 122 (+3) — 45.35 5.5770 11.059	414 6.2 26.39 13.5 1.26 1.10	185 107 (+3) — — 5.5387 10.882	414 5.46 26.62 11.4 1.15 1.12	185 106 (+3) — — 5.4620 10.572	296.8 7.14 26.77 16.5 1.48 1.13	185 104 (+3) — — 5.5252 10.779
**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu
195 162 (+2) — 33.77 5.1718 12.126	— 99 (+3) — 12 6.0838 11.504	180 16.1 27.84 54 6.53 1.30	180 113 (+3) 89 (+5) 47 5.29 1.50	175 103 (+3) 80 (+6) 27.6 3.80 1.38	175 110 (+3) 82 (+6) 6.3 0.82 1.36	175 108 (+3) 81 (+6) 6.74 0.67 1.28

Last revised 01.2014

If I have seen further, it is by standing on the shoulders of giants.
Isaac Newton

Exploring Chemistry

Dedicated to those who have come before me
and to those destined to see further still.

Roy Jensen

Exploring Chemistry

ISBN ——— (field test IV)

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SUMMARY Table of Contents

Chapter 1. Foundations	1
<i>ATOMS</i>	57
Chapter 2. Atomic Theory	59
Chapter 3. Quantum Theory	84
<i>MOLECULAR ENTITIES</i>	163
Chapter 4. Molecular Entities	165
Chapter 5. Classical Bonding: the Electron Domain Model	235
Chapter 6. Quantum Mechanical Bonding Theories	267
Chapter 7. Instrumental and Chemical Analysis	334
<i>MOLECULAR INTERACTIONS</i>	401
Chapter 8. Intermolecular Forces	403
Chapter 9. States of Matter: Condensed Phases	434
Chapter 10. States of Matter: Gases	502
<i>REACTIONS</i>	559
Chapter 11. Chemical Reactions	561
Chapter 12. Synthetic Chemistry	599
<i>REACTION RATES</i>	607
Chapter 13. Chemical Kinetics	609
Chapter 14. Multistep Kinetics	668
<i>CHEMICAL EQUILIBRIA</i>	695
Chapter 15. Principles of Chemical Equilibria	698
Chapter 16. Acid-Base Equilibria	757
Chapter 17. Ionic Equilibria	834

<i>REACTION ENERGETICS</i>	861
Chapter 18. Thermochemistry	864
Chapter 19. Thermodynamics	933
Chapter 20. Electrochemistry	989
<i>APPLICATIONS OF CHEMISTRY</i>	1061
Chapter 21. Atmospheric Chemistry	1062
Chapter 22. Biochemistry	1067
Chapter 23. Chemical Engineering	1068
Chapter 24. Cosmetic chemistry	1069
Chapter 25. Energetic Materials	1070
Chapter 26. Environmental Chemistry	1095
Chapter 27. Forensic Science	1096
Chapter 28. Materials Engineering	1097
Chapter 29. Nanoscience	1104
Chapter 30. Nuclear Science	1105
Chapter 31. Food and Nutrition Science	1139
Chapter 32. Pharmaceutical Chemistry	1143
<i>APPENDICES</i>	A-1
Appendix A. Mathematical Review	A-2
Appendix B. Tabulated Scientific Data	A-17
Appendix C. Answers	A-61
Appendix D. Credits	A-64
<i>INDEX</i>	A-67

Chemistry in Action

These short stories illustrate or augment the chapter concepts.

Healthy? foods ...	5	Thalidomide: a medical disaster	222
Pseudoscience	9	Radicals in society ...	239
The consequences of ignoring units ... a real-world example	14	Modelling in vivo protein folding	268
The dose maketh the poison – Paracelcius	17	I see!	280
The reality of scientific measurement	19	Strengthening drill bits and saw blades	281
Natural products are healthy, naturally!	24	Color the world!	299
Waterfree urinals	28	Fun in the sun ...	301
Coffee!	31	Excimers: excited dimers	302
The fall of the Romans ...	34	Monitoring automobile emissions	303
You are what you drink	66	Trust me: let the computer do the math	307
Just nuke it!	86	Imaging heat	323
Color your world	88	Quantum wells and dots	325
Reflection in the mirror	89	That's a fake!	341
Towards a functional cloaking device	91	Hey! Your shirt's glowing!	344
Solar emissions	94	Smile for the camera! ☺	347
A new thermometer	95	Greenhouse gases: who? what? where? when? why?	354
Nondestructive elemental analysis	97	What's under your clothes?	354
Digital cameras colour your world	98	Medical instrument development	355
Good sun, bad sun ...	102	Atmospheric analysis by satellites	368
The double helix	106	Proteomics: deducing protein sequences	368
Electron microscopy	107	Drug and explosive detection ...	371
Ultrafast titanium:sapphire lasers	110	Chemicals! in our food	375
Quantum biology	112	Biochemical detectors	384
Active noise cancellation: headphones, cars, airplanes, ...	114	Lather, rinse, repeat	386
X-rays on demand	135	Cleansing the body of metal ions	390
Aurora: the northern and southern lights	137	Miniaturizing chemistry: lab on a chip	394
How they work: lasers!	142	Aligning molecules with electromagnetic fields	406
The levitating minister	144	H ⁺ , H ₃ O ⁺ , ... , what difference does it make?	418
Carbohydrates	168	Stain-B-Gone!	422
Salt of the Earth	171	Tarnish-B-Gone!	422
Have a cavity? Need a filling?	173	The aqueous solubility of oxygen	423
Rock hounds	186	Antioxidants: vitamins C and E	426
Miracle cancer drugs?	189	Ethanol blended fuels	428
Dihydrogen monoxide: the invisible killer	192	Tagging	429
Household desiccants	195	'Freezing' or 'crystallization'?	436
Fossil fuels	210	"I'll have a coffee please, decaf."	438
"Natural and artificial flavours"	214	Carbon sequestration	442
Steroids, naturally!	215	Quasicrystals: the "impossible" crystal	448

Gemstones	449	Substituting one poison for another	602
Story: piezoelectric	450	OUCH! My arm — I think it's broken!	603
Story: superconductors	450	Crying over onions	604
Glass: liquid or solid?	450	Kinetics of reactions involving solids and liquids	622
Polarizing effects	454	Table sugar is not as common as you might think ...	629
Polarized phones	456	Temperatures in the kitchen	638
Oil on water	460	Kicking the habit ...	645
Camping in the rain	460	Drug homology	647
Forensic analysis of pen ink	463	Ozone depletion? Preposterous!	650
Improved bullet-proof vests ...	466	Biomass → petroleum	654
High-altitude cooking	468	Applying the scientific method to kinetic mechanisms	676
Cold-climate living	469	Competitive drug inhibition	681
Ahhh, coffee!	473	Inverse Arrhenius reactions	682
The specialized blend of hydrocarbons in jet fuel	475	Modeling the combustion of hydrogen	685
Denatured alcohol ...	484	Advanced modeling: energy balance	686
Road deicing ... and ice cream	489	Modeling the pyrolysis of ethane	686
Zone refining	489	Cleaning the air	709
Molecular mass determination	490	Nuances of the carbon dioxide-carbonic acid equilibria ...	738
Antifreeze ... antiboil	491	Acid rain	741
Intravenous (IV) solutions	495	Acids and bases in society	762
Dialysis	496	Fluorination of drinking water	772
Filtered water	497	Disinfecting swimming pools	777
Rifling	504	Buffering the body	791
SCUBA systems	505	Beyond acid-base buffers	796
The crying game	514	Constipational relief ...	799
Gas density: an important consideration in research ...	515	The accuracy of pH calculations	815
Fallout from a punctured natural gas line	520	Tooth decay — an equilibrium experience	845
The discovery of argon	525	FIRE!	866
Relative humidity	526	Biological standard state	869
Cycling enthusiasts: the pros and cons of carbon dioxide inflators	543	Microwave ovens	874
The reaction failed ... accidental discoveries in chemistry	563	Fire suppression	880
Combustion products: gas or liquid	567	A nice day at the beach ...	886
Hair, pulp, lasers, rockets, and bacteria	568	High performance racing	892
An explosion that may save your life	571	Water is an ash, not a fuel	896
Swimming pool chemistry	574	Production of sulfuric acid: the contact process	899
Making Viagra greener	588	Things that go boom!	908
Kicking the habit ...	589	Fossil fuel production	916
Mood swings	589	Really, really cool!	938
Making drugs for a living ...	600	Thermodynamic connections	943
Love drugs ...	601	Forming you	947

An expensive fire!	951	When things go wrong making rocket fuel ...	1072
Synthesis gas	961	Model rocketry	1074
H⁺, H₃O⁺, ... , which is it?	965	Propelling the space shuttle	1076
Thermodynamics and kinetics of ammonia synthesis	974	Hypergolics	1077
ATP synthesis	977	Staying alive in the bomb business	1079
Iron production	977	Munitions disposal	1080
Rust formation	978	Shooting wells — the original fracking	1082
Acetaminophen, aspirin, ibuprofen, ... and grapefruit?	979	Nitrogen explosives	1085
Cleaning silverware	989	Burning Kuwait	1085
Thar's gold in them thar hills!	999	Smoking near fireworks? What could go wrong?	1087
More power, longer life	1017	A flare! — someone is in trouble	1089
Oceanic batteries	1018	DANGER! in your own home	1094
All batteries are created equal ... not!	1020	Damascus steel: lost and found	1098
“Blow into this tube until it beeps.”	1021	Aerogel	1103
Rust-free automobiles	1025	Cloaking: from Star Trek to Harry Potter to Artemis Fowl	1103
Pressure treated lumber	1025	What happens when something ‘cooks’?	1139
Permanently coloured and protected metal ...	1026	Well done!	1139
Biological sensors	1036	Cooking eggs	1140
Electrochemistry of NO₃⁻ and SO₄²⁻	1044	Cooking sausages	1141
Human electrochemistry	1044	Smoking cannabis — how stupid is that?	1144
Bringing it all together: GOLD!	1057	Redefining normal	1146
Autocatalytic decomposition of gunpowder	1071		

EXPANDED Table of Contents

SUMMARY Table of Contents	iv
Chemistry in Action	vii
EXPANDED Table of Contents	xi
Preface	xxii
Chapter 1. Foundations	1
1.1 Chemistry: the science of change	2
1.2 Scientific inquiry	4
1.3 Système Internationale d'Unités (the Metric system)	9
1.4 Scientific measurement	14
1.5 Significant digits	18
1.6 Dimensional analysis	25
1.7 Chemistry primer	29
1.8 Additional resources	41
Summary	43
Exercises	45

<i>ATOMS</i>	57
Overview	58
Chapter 2. Atomic Theory	59
2.1 Early atomic models	59
2.2 Current model of atomic structure	60
2.3 The periodic table	69
Summary	78
Exercises	80
Chapter 3. Quantum Theory	84
3.1 Electromagnetic radiation	84
3.2 The development of modern physics	92
3.3 Quantum mechanics	113
3.4 Quantum numbers	116
3.5 Orbitals	124
3.6 Shielding and effective nuclear charge	130
3.7 Orbital energies	131
3.8 Electronic configurations	135
3.9 Stability on the periodic table	140
APPLICATION: magnetism	143
APPLICATION: periodic trends	144
APPLICATION: atomic hydrogen	149
Summary	154
Exercises	155
Summary	161

<i>MOLECULAR ENTITIES</i>	163
Overview	164
Chapter 4. Molecular Entities	165
4.1 Classification of multiatomic entities	165
4.2 Chemical bond properties	175
4.3 Oxidation states	184
4.4 Inorganic nomenclature	186
4.5 Organic nomenclature	198
4.6 Organic isomers	215
Summary	228
Exercises	229
Chapter 5. Classical Bonding: the Electron Domain Model	235
5.1 Historical bonding models	235
5.2 The electron domain model	237
5.3 Three-dimensional geometries	244
5.4 Structure prediction	248
5.5 Symmetry and the dipole moment	258
Summary	261
Exercises	262
Chapter 6. Quantum Mechanical Bonding Theories	267
6.1 Valence bond theory	270
6.2 Molecular orbital theory	286
6.3 Ligand field theory	309
6.4 Band theory	315
APPLICATION: electronics	318
Summary	326
Exercises	328
Chapter 7. Instrumental and Chemical Analysis	334
7.1 Spectroscopic analysis	335
7.1a Gamma-ray spectroscopy	339
7.1b X-ray spectroscopy	339
7.1c Ultraviolet-visible (UV-Vis) spectroscopy	342
7.2d Infrared (IR) spectroscopy	348
7.2e Microwave spectroscopy	354
7.2f NMR spectroscopy	356
7.2 Mass spectrometry	368
APPLICATION: identifying chemical entities	371
7.3 Electrochemical analysis	371
7.4 Separation strategies: chromatography	372

APPLICATION: chemometrics	375
7.5 Compositional analysis	376
7.6 The titration process	387
7.7 Looking forward	393
Summary	394
Exercises	395
Summary	400

<i>MOLECULAR INTERACTIONS</i>	401
Overview	402
Chapter 8. Intermolecular Forces	403
8.1 Charge distributions within entities	403
8.2 Intermolecular bonding	407
8.3 Intermolecular bonding in pure substances	407
8.4 Intermolecular bonding in mixtures	415
8.5 Aqueous solubility	416
8.6 Miscibility	424
Summary	430
Exercises	432
Chapter 9. States of Matter: Condensed Phases	434
9.1 Phase diagrams	436
9.2 Crystalline solids	443
9.3 Amorphous solids	450
9.4 Liquid crystals	451
9.5 Liquids	458
9.6 Solutions	469
9.7 Mixtures of volatile entities	476
9.8 Colligative properties	484
9.9 Colloidal suspensions	498
Summary	498
Exercises	499
Chapter 10. States of Matter: Gases	502
10.1 Ideal gas law	502
10.2 Standard conditions	505
10.3 Combined gas equation	506
10.4 Concentration and density of gases	513
10.5 Gas mixtures	518
10.6 The atmosphere	521
10.7 Real gases	529
10.8 Kinetic-molecular theory of gases	536
Summary	548
Exercises	549
Summary	558

<i>REACTIONS</i>	559
Overview	560
Chapter 11. Chemical Reactions	561
11.1 Types of chemical equations	561
11.2 Classification of chemical equations	563
11.3 Reduction-oxidation reactions	572
11.4 Matrix balancing of chemical equations	578
11.5 Working with chemical equations	583
Summary	590
Exercises	591
Chapter 12. Synthetic Chemistry	599
Summary	604
Exercises	605
Summary	606

<i>REACTION RATES</i>	607
Overview	608
Chapter 13. Chemical Kinetics	609
13.1 Reaction rate	609
13.2 Reaction order	612
13.3 Determining reaction order: initial rates method	615
13.4 Integrated rate equations	619
13.5 Pseudo- n^{th} order approximation	628
13.6 Determining reaction order: monitoring reaction profiles	630
13.7 Factors affecting the rate constant	634
13.8 Catalysis	645
Summary	655
Exercises	657
Chapter 14. Multistep Kinetics	668
14.1 Elementary reactions	668
14.2 Analytical reaction mechanisms	671
14.3 Numerical reaction mechanisms	684
Summary	690
Exercises	691
Summary	694

CHEMICAL EQUILIBRIA	695
Overview	696
Chapter 15. Principles of Chemical Equilibria	698
15.1 Kinetics of equilibrium systems	699
15.2 Equilibrium constants	700
15.3 Magnitude of the equilibrium constant	706
15.4 Reaction quotient	711
15.5 Equilibria involving solids, liquids, and solvents	712
15.6 Primary factors affecting equilibria	715
15.7 Secondary factors affecting equilibria	718
15.8 Types of equilibria	720
15.9 ICE tables	722
15.10 Multiple equilibria systems	733
Summary	747
Exercises	748
Chapter 16. Acid-Base Equilibria	757
16.1 Acid-base theories	761
16.2 Solvent effects	763
16.3 Factors affecting acid and base strength	768
16.4 Relationship between K_a and K_b	770
16.5 The pX scale	771
16.6 Dilute solutions and very weak acids and bases	778
16.7 Mixtures of weak acids and bases	781
16.8 Buffers	785
16.9 Acid-base indicators	797
16.10 Titrations	800
Summary	820
Exercises	822
Chapter 17. Ionic Equilibria	834
17.1 Solubility equilibria	834
17.2 Selective precipitation	845
17.3 Formation equilibria	850
17.4 Competing equilibria	854
Summary	856
Exercises	857
Summary	860

<i>REACTION ENERGETICS</i>	861
Overview	862
Chapter 18. Thermochemistry	864
18.1 Thermodynamic conventions	868
18.2 Heat	873
18.3 Work	887
18.4 Internal energy and the first law of thermodynamics	888
18.5 Heat and work with varying reaction conditions	889
18.6 Methods of determining the reaction enthalpy	893
18.7 Thermochemistry	905
18.8 Calorimetry	910
Summary	917
Exercises	918
Chapter 19. Thermodynamics	933
19.1 Entropy	934
19.2 Third law of thermodynamics	944
19.3 Second law of thermodynamics	945
19.4 Reversible reactions	947
19.5 Gibbs free energy	948
19.6 Temperature dependence of ΔX	952
19.7 Standard Gibbs free energy calculations	955
19.8 ΔX in standard and non-standard conditions	957
19.9 Thermodynamics and equilibria	961
19.10 Thermodynamics and kinetics	973
19.11 Coupled chemical reactions	977
Summary	979
Exercises	980
Chapter 20. Electrochemistry	989
20.1 Balancing reduction-oxidation reactions	990
20.2 Electrochemical cells	994
20.3 Electrochemical conventions	995
20.4 Relating cell potentials to thermodynamics	1002
20.5 Relating cell potentials to equilibria	1009
APPLICATION: voltaic cells	1016
APPLICATION: concentration cells	1028
APPLICATION: electrolytic cells	1037
Summary	1045
Exercises	1046
Summary	1059

<i>APPLICATIONS OF CHEMISTRY</i>	<i>1061</i>
Chapter 21. Atmospheric Chemistry	1062
21.1 Atmospheric composition	1062
21.2 Photochemical processes	1062
21.3 Chemical processes	1062
21.4 Greenhouse gases	1064
Chapter 22. Biochemistry	1067
Chapter 23. Chemical Engineering	1068
Chapter 24. Cosmetic chemistry	1069
Chapter 25. Energetic Materials	1070
25.1 Safety	1071
25.2 Propellants	1073
25.3 Explosives	1077
25.4 Pyrotechnics	1087
25.5 Fireworks	1091
Summary	1094
Chapter 26. Environmental Chemistry	1095
Chapter 27. Forensic Science	1096
Chapter 28. Materials Engineering	1097
28.1 A brief history	1097
28.2 Interdisciplinary nature of materials engineering	1099
28.3 The materials paradigm	1100
28.4 Classes of materials	1101
Chapter 29. Nanoscience	1104

Chapter 30. Nuclear Science	1105
30.1 Nucleosynthesis	1106
30.2 Nuclear stability and radioactive decay	1112
30.3 Measuring radioactive decay	1120
30.4 Applications	1122
Summary	1133
Exercises	1135
Chapter 31. Food and Nutrition Science	1139
31.1 Atoms and molecules: the building blocks of food	1139
31.2 Taste, aroma, and flavour	1141
31.3 Heating and eating	1141
31.4 Cooking utensils	1141
31.5 Food additives – flavorants & preservatives	1141
31.6 Nutrition	1142
Summary	1142
Chapter 32. Pharmaceutical Chemistry	1143
32.1 Pharmacodynamics	1143
32.2 Pharmacokinetics	1143
32.3 Medicinal pharmaceuticals	1144
32.4 Recreational pharmaceuticals	1144
32.5 Reality check	1145
<i>APPENDICES</i>	<i>A-1</i>
Appendix A. Mathematical Review	A-2
Appendix B. Tabulated Scientific Data	A-17
Appendix C. Answers	A-61
Appendix D. Credits	A-64
<i>INDEX</i>	<i>A-67</i>