

## Credits

### Photo Credits

**Chapter E** Page 5 top right: Richard Megna/Fundamental Photographs; Page 6 far left: Yui/Shutterstock; Page 6 top left: Kevron/Fotolia; Page 6 center left: AndrazG/Getty Images; Page 6 far right: Byron W. Moore/Shutterstock; Page 9 top right: Richard Megna/Fundamental Photographs; Page 9 bottom right: Richard Megna/Fundamental Photographs; Page 9 top left: Richard Megna/Fundamental Photographs; Page 9 bottom left: Pearson Education, Inc.; Page 17 center right: Gyvafoto/Shutterstock; Page 29 top left: Warren Rosenberg/Fundamental Photographs; Page 29 top center: Warren Rosenberg/Fundamental Photographs; Page 29 top right: Warren Rosenberg/Fundamental Photographs; Page 29 bottom left: Richard Megna/Fundamental Photographs; Page 29 bottom center: Warren Rosenberg/Fundamental Photographs; Page 29 bottom right: Warren Rosenberg/Fundamental Photographs; Page 32 center left: NASA. **Chapter 1** Page 37: Fotolia; Page 37 top right: Oneo/Fotolia; Page 38 bottom far left: RosaBetancourt/Alamy; Page 38 bottom center left: Cdrcom/Fotolia; Page 38 bottom center right: YinYang/iStock/Getty Images; Page 38 bottom right: Denis Larkin/Getty Images; Page 40 top left: Tomas Abad/Alamy; Page 42 top left: Charles D. Winters/Science Source; Page 42 top center: Charles D. Winters/Science Source; Page 42 top right: Joseph Calev/Shutterstock; Page 45 bottom right: Richard Megna/Fundamental Photographs; Page 50 top left: Hxdbzxy/iStock/Getty Images; Page 51 top left: Ksena32/Fotolia; Page 51 top right: Pearson Education, Inc.; Page 52 top left: Photo Researchers/Alamy Stock Photo; Page 57 right top: Pearson Education, Inc.; Page 57 right bottom: Marek/Fotolia; Page 62 top left: NASA; Page 70 top right: IBM Almaden Research Center; **Chapter 2** Page 77 top right: Excellent Photo/Getty Images; Page 78 top left: Matthias Kulka/Corbis; Page 78 left center: Elena Elisseeva/Shutterstock; Page 79 right center: Poznyakov/Shutterstock; Page 79 bottom right: Image Point Fr/Shutterstock; Page 80 top left: Bonita R. Cheshier/Shutterstock; Page 85 center right: Pearson Education, Inc.; Page 85 bottom right: Karin Hildebrand Lau/Shutterstock; Page 87 bottom left: Jerry Mason/Science Source; Page 87 bottom center left: Andrew Lambert/Science Source; Page 87 bottom center right: Andrew Lambert/Science Source; Page 88 top left: Michael Smith/Getty Images; Page 91 bottom right: Segre Collection/AIP/Science Source; Page 93 center right: Stephen Dunn/Getty Images; Page 93 center left: REUTERS/Tim Sharp; **Chapter 3** Page 115 top right: Popova Olga/Fotolia; Page 115 bottom left: Charles D. Winters/Science Source; Page 115 bottom right: Richard Megna/Fundamental Photographs; Page 129 top left: Lester V. Bergman/Corbis; Page 129 top 2nd image: Charles D. Winters/Science Source; Page 129 top third image: Joe Belanger/Alamy; Page 129 top fourth image: David J. Green/Alamy; Page 129 top fifth image: Studiomode/Alamy; Page 129 top sixth image: Jeff J Daly/Alamy; Page 129 top seventh image: Harry Taylor/Dorling Kindersley, Ltd.; Page 129 top 8th image: Richard Megna/Fundamental Photographs; Page 129 top right: Steve Gorton/Dorling Kindersley, Ltd.; Page 129 center right: Charles D. Winters/Science Source; Page 129 bottom right: Perennou Nuridsany/Science Source; Page 146 center left: Science Photos/Alamy; Page 146 center second: Richard Megna/Fundamental Photographs; Page 146 center third: Amana Images/Alamy; Page 146 center fourth: Jeff J Daly/Alamy; Page 146 center fifth: Charles D. Winters/Science Source; Page 146 center sixth: Steve Gorton/Dorling Kindersley, Ltd.; Page 146 center seventh: Charles D. Winters/Science Source; Page 146 center eighth: Ted Kinsman/Science Source; Page 146 bottom right: Manamana/Shutterstock; Page 146 right second bottom: Harry Taylor/Dorling Kindersley, Ltd.; Page 146 top right: Charles D. Winters/Science Source; Page 146 top right: Patrizio Semproni/Dorling Kindersley, Ltd.; **Chapter 4** Page 160 center: Malerapaso/iStock/Getty Images; Page 161 top left: Madlen/Shutterstock; Page 161 top right: Artjazz/Shutterstock; Page 161 bottom left: Richard Megna/Fundamental Photographs; Page 161 bottom center: Charles Falco/Science Source; Page 161 bottom right: Charles D. Winters/Science Source; Page 168 top left: Richard Megna/Fundamental Photographs; Page 168 bottom left: Richard Megna/Fundamental Photographs; Page 173 right center: Pearson Education, Inc.; Page 174 far left: Richard Megna/Fundamental Photographs; Page 174 center left: Richard Megna/Fundamental Photographs; Page 181 right center: NASA; Page 183 bottom right: Richard Megna/Fundamental Photographs;

Page 191 right center: Sinelev/Shutterstock; **Chapter 5** Page 204 background image: vaciav Volrab/Shutterstock; Page 224 left bottom: Pearson Education, Inc.; Page 224 bottom center: Pearson Education, Inc.; Page 224 bottom right: Pearson Education, Inc.; Page 225 right center: Pearson Education, Inc.; Page 226 top left: Pearson Education, Inc.; Page 238 top left: Kip Peticolas/Fundamental Photographs; Page 238 left center: Richard Megna/Fundamental Photographs; **Chapter 6** Page 276 center left: Richard Megna/Fundamental Photographs; **Chapter 7** Page 289 bottom right: Siede Preis/Getty Images; Page 289 bottom right: Michael Dalton/Photo Researchers, Inc.; Page 307 bottom right: Andrew Lambert/Science Source; Page 308 top left: Richard Megna/Fundamental Photographs; Page 308 top center: Richard Megna/Fundamental Photographs; Page 308 top right: Richard Megna/Fundamental Photographs; Page 308 bottom left: Richard Megna/Fundamental Photographs; Page 312 top left: Richard Megna/Fundamental Photographs; Page 312 top right: Richard Megna/Fundamental Photographs; Page 312 center right: Zoom Zoom/Getty Images; **Chapter 8** Page 319 bottom right: Javier Impelluso/Shutterstock; Page 329 top left: Richard Megna/Fundamental Photographs; Page 329 top center: Richard Megna/Fundamental Photographs; Page 329 top right: Richard Megna/Fundamental Photographs; Page 330 top left: Richard Megna/Fundamental Photographs; Page 331 center right: Stephanie Weiler/Corbis; Page 332 center left: Dorling Kindersley, Ltd.; Page 333 center left: Richard Megna/Fundamental Photographs; Page 338 center left: Leonori/Shutterstock; Page 338 bottom right: Richard Megna/Fundamental Photographs; Page 339 top right: Richard Megna/Fundamental Photographs; Page 341 center left: Richard Megna/Fundamental Photographs; Page 344 bottom left: Richard Megna/Fundamental Photographs; Page 344 bottom center: Richard Megna/Fundamental Photographs; Page 344 bottom right: Richard Megna/Fundamental Photographs; Page 346 top left: Chip Clark/Fundamental Photographs; Page 346 bottom center: Richard Megna/Fundamental Photographs; Page 348 top left: Pearson Education, Inc.; Page 348 top right: Charles D. Winters/Science Source; Page 348 bottom left: Richard Megna/Fundamental Photographs; Page 348 bottom right: Richard Megna/Fundamental Photographs; Page 354 bottom left: Richard Megna/Fundamental Photographs; Page 354 bottom center: Richard Megna/Fundamental Photographs; Page 354 bottom right: Richard Megna/Fundamental Photographs; Page 255 right center: Chris Cheadle/Getty Images; **Chapter 9** Page 369 bottom left: Pearson Education; Page 369 bottom center: Page 374 bottom left: Palette7/Shutterstock; Page 376 right center: Page 382 bottom center: Pearson Education, Inc.; Page 382 bottom right: Stan Fellerman/Corbis; Page 396 bottom right: Richard Megna/Fundamental Photographs; Page 409 bottom right: Md8speed/Shutterstock; **Chapter 10** Page 423 right center: Wjarek/Fotolia; Page 426 bottom left: Michael Dalton/Fundamental Photographs; Page 458 bottom left: Pearson Education, Inc.; **Chapter 11** Page 462 center: NASA; Page 464 top left: Physics Central; Page 471 bottom center: Richard Megna/Fundamental Photographs; Page 476 top left: Doug/Getty Images; Page 476 bottom left: Andrei Kuzmik/Shutterstock; Page 477 top right: NASA; Page 477 bottom right: Iris Sample Processing; Page 478 top left: Richard Megna/Fundamental Photographs; Page 478 top center: Richard Megna/Fundamental Photographs; Page 479: Maridav/Fotolia; Page 483 bottom center: Michael Dalton/Fundamental Photographs; Page 487 left: Royal Society of Chemistry; Page 487 center left: Royal Society of Chemistry; Page 487 center right: Royal Society of Chemistry; Page 487 right: Royal Society of Chemistry; Page 488 top right: Reika/Shutterstock; Page 490 center left: Pearson Education, Inc.; Page 490 top center: DK Images; Page 490 top right: Can Balcioglu/Shutterstock; Page 494 bottom left: NG Images/Alamy Stock Photo; Page 495 center right: Pearson Education, Inc.; Page 499 center left: Daniel Taeger/Shutterstock; Page 499 center right: Dorling Kindersley, Ltd.; Page 500 top left: Nivaldo J. Tro; **Chapter 12** Page 485 12-00-01 Ted Kinsman/Science Source; Page 507 bottom right: OMIKRON/Science Source; Page 516 bottom left: Volodymyr Goynyk/Shutterstock; Page 516 bottom center left: Andrew Syred/Science Source; Page 516 bottom center right: Sashkin/Shutterstock; Page 516 bottom right: Mirka Moksha/Shutterstock; Page 518 top left: Mariusz Szczygiel/Fotolia; Page 518 bottom left: Charles D. Winters/Science Source; Page 518 bottom right: Baris Muratoglu/Getty Images; Page 521 top left: Sandatlas/Shutterstock; Page 521 top right: Tim Parmenter/The Natural History Museum, London/Dorling Kindersley, Ltd; Page 522 center left: Lijuan Guo/Fotolia; Page 523 bottom right: Isifa Image Service Sro/Rex/Newscom; Page 524 top left: Jmalov/iStock/Getty Images; Page 524 left center: Richard Megna/Fundamental Photographs; Page 524 left center: Nikada/iStock/Getty Images; Page 524 left bottom: Johnny Franzen/Getty Images; Page 525 top right: Luisa Leal Photography/Shutterstock; Page 528 center: Jwblinn/Shutterstock; **Chapter 13** Page 538 whole page: Masonjar/Shutterstock; Page 540 top left: Biology Pics/Science Source; Page 540 bottom left: Charles D Winters/Getty Images; Page 549 top left: Richard Megna/Fundamental Photographs; Page 549 top center: Richard Megna/Fundamental Photographs; Page 549 top right: Richard Megna/Fundamental Photographs; Page 550 top left: Richard Megna/Fundamental Photographs; Page 550 center left: Pearson Education, Inc.; Page 558 top left: Peter Gudella/Shutterstock; Page 564 top left: Avantgarde/Fotolia; Page 571 bottom left: Pearson Education, Inc.; Page 571 bottom center: Pearson Education, Inc.; Page 571 bottom right: Pearson Education, Inc.; Page 572 top left: Rubber Ball/Alamy;

Page 572 top right: Dtimiraos/iStock/Getty; **Chapter 14** Page 620 left center: NASA; Page 621 top left: NASA; Page 621 top center: NASA; **Chapter 15** Page 640 top left: Martin McCarthy/E+/Getty Images; Page 671 top left: Richard Megna/Fundamental Photographs; Page 671 top right: Richard Megna/Fundamental Photographs; **Chapter 16** Page 687 top right: Karandaev/Fotolia; Page 687 center left: Leonori/Shutterstock; Page 687 center right: Mitch Hrdlicka/Photodisc/Getty Images; Page 688 top left: Pearson Education, Inc.; **Chapter 17** Page 742 top left: Richard Megna/Fundamental Photographs; Page 742 top center: Richard Megna/Fundamental Photographs; Page 742 top right: Richard Megna/Fundamental Photographs; Page 755 bottom left: Richard Megna/Fundamental Photographs; Page 755 bottom center: Richard Megna/Fundamental Photographs; Page 755 bottom right: Richard Megna/Fundamental Photographs; Page 768 top right: Pearson Education, Inc.; Page 769 top right: Pearson Education, Inc.; Page 774 left center: National Park Service(Nps.gov); Page 775 right center: Richard Megna/Fundamental Photographs; Page 776 top left: Charles D. Winters/Science Source; Page 776 top center: Charles D. Winters/Science Source; Page 781 left center: Richard Megna/Fundamental Photographs; Page 781 left bottom: Richard Megna/Fundamental Photographs; Page 783 top left: Richard Megna/Fundamental Photographs; Page 783 bottom left: Richard Megna/Fundamental Photographs; Page 783 center right: Richard Megna/Fundamental Photographs; **Chapter 18** Page 798 top left: Eryrie/Alamy Stock Photo; Page 798 left center: Motoring Picture Library/Alamy Stock Photo; Page 798 left bottom: Shubroto Chattopadhyay/Spirit/Corbis; Page 799 center left: BlackJack3D/E+/Getty Images; Page 799 center right: [www.sandatlas.org/Shutterstock](http://www.sandatlas.org/Shutterstock); Page 799 bottom center: Paradoxdes/Fotolia; Page 800 top center: Richard Megna/Fundamental Photographs; Page 800 bottom left: Kocur, Johan; Page 803 bottom right: Svetlana Lukienko/Shutterstock; Page 805 top left: Jan Will/Fotolia; Page 826 center left: Ryan McVay/Photodisc/Getty Images; **Chapter 19** Page 850 top left: Richard Megna/Fundamental Photographs; Page 850 top right: Richard Megna/Fundamental Photographs; Page 851 bottom right: Alejandro Díaz Díez/AGE Fotostock America Inc.; Page 861 top right: Richard Megna/Fundamental Photographs; Page 870 top left: Dave King/Courtesy of Duracell Ltd/Dorling Kindersley, Ltd; Page 871 right center: Paul Mogford/Alamy Stock Photo; Page 876 top left: Charles D. Winters/Science Source; Page 879 bottom right: StockPhotosArt/Shutterstock; Page 880 top left: Donovan Reese/The Image Bank/Getty Images; Page 880 bottom left: Alan Pappe/ Stockbyte/Getty Images; Page 881 top right: Steve Goodwin/iStock/Getty Images Plus; Page 881 center: Pearson Education, Inc.; **Chapter 20** Page 894 left center: iStock/Getty Images Plus; Page 894 bottom center: Science Source; Page 895 top right: Stringer/Getty Images; Page 895 bottom right: Klaus Guldbrandsen/Science Source; Page 903 right center: United States Air Force; Page 903 bottom right: Hank Morgan/Science Source; Page 907 right center: Baz Ratner/Thomson Reuters (Markets) LLC; Page 907 bottom right: Ken Babione/iStock/Getty Images Plus; Page 908 top left; Page 911 top right: American Institute of Physics/Emilio Segre Visual Archives; Page 912 top left: Stocktrek/Photodisc/Getty Images; Page 912 center page: Franklin D. Roosevelt Library; Page 913 top center: Elena Aliaga/iStock/Getty Images Plus; Page 914 top left: Kyodo/Associated Press; Page 917 bottom center: General Atomics MS 15-124; Page 918 top left: Fox Photos/Stringer/Hulton Archive/Getty Images; Page 918 bottom left: David Parker/Science Source; Page 919 top right: Fermilab/Science Source; Page 923 top center: BSIP/UIG Via Getty Images; Page 923 bottom right: D. Silbersweig/Science Source; Page 924 top center: Centre Oscar Lambret/Science Source; Page 924 bottom left: Cordelia Molloy/Science Source; Page 932 top right: Craig Ellenwood/Alamy Stock Photo; **Chapter 21** Page 936 top left: Pearson Education, Inc.; Page 949 top right: Chad Koski/iStock / Getty Images Plus; Page 950 bottom left: John Casey/Fotolia; Page 955 top right: Pearson Education, Inc.; Page 964 bottom center: Lyudmila Suvorova/Shutterstock; Page 965 top center: Andreas Von Einsiedel/Dorling Kindersley Limited; Page 966 bottom center: Olga Shelego/iStock/Getty Images Plus; Page 967 top left: Yasonya/Shutterstock; **Chapter 22** Page 986 top left: Tim Parmenter/Dorling Kindersley Limited; Page 986 lower top left: Tim Parmenter/Dorling Kindersley Limited; Page 986 center left: Harry Taylor/Dorling Kindersley Limited; Page 986 center: Harry Taylor/Dorling Kindersley Limited; Page 986 center right: Asya Babushkina/Shutterstock; Page 996 center left: Richard Megna/Fundamental Photographs; Page 996 center right: Richard Megna/Fundamental Photographs; Page 1001 center right: Richard Megna/Fundamental Photographs; Page 1001 center right: Richard Megna/Fundamental Photographs; Page 1002 top left: Richard Megna/Fundamental Photographs; Page 1005 bottom right: Richard Megna/Fundamental Photographs;

## Text Credits

**Chapter E** Page 3: Albert Einstein, "Physik und realität" (Physics and Reality), Journal of the Franklin Institute, March 1936, Vol 221, No. 3, p. 349. **Chapter 1** Page 35: Roger Joseph Boscovich, Philosophiae Naturalis Theoria (A theory of natural philosophy), **Section 1.5**, 1763, English translation by James Mark Child, 1922, Open Court Publishing. Chicago and London; page 41: Diogenes Laertius IX. Lives of Eminent Philosophers.

Open Source Learning, Change and Growth, page 21; Eugene Cassen, *Encounter with the Infinite*, Vol. 2 (p.453), translated by R. D. Hicks, London: Loeb Classical Library. Copyright © 1925; page 41: Thomas Kuhn, *The Structure of Scientific Revolutions*, Chicago: University of Chicago Press, 1962; page 46: J. J. Thomson, "Cathode Rays," *Philosophical Magazine*, 44, 293 (1897); page 49: Samuel Glasstone, *Sourcebook on Atomic Energy*, 2nd edition. Princeton, NJ: Van Nostrand, 1958, p. 93. **Chapter 2** Page 75: Heisenberg, *Physics and Beyond: Encounters and Conversations* (1971), New York: Harper Row, p. 75. **Chapter 3** Page 113: D. Mendeleef, *The Principles of Chemistry*, Vol. 1; translation from the Russian by George Kamensky, New York: Longmans, Green and Co., 1905, p. 240. **Chapter 4** Page 159: Gilbert N. Lewis (1875–1946), in a letter to Linus Pauling in 1939. **Chapter 5** Page 205: George Gore, *The Art of Scientific Discovery or the General Conditions and Methods of Research in Physics and Chemistry*, 1878, London: Longmans, Green and Co. **Chapter 6** Page 251: In Barbara Marinacci (ed.), *Linus Pauling in His Own Words: Selections from his Writings, Speeches, and Interviews*. New York: The Linus Pauling Institute, 1995, p. 110. **Chapter 7** Page 287: In Barbara Marinacci (ed.), *Linus Pauling in His Own Words: Selections from his Writings, Speeches, and Interviews*. New York: The Linus Pauling Institute, 1995, p. 43. **Chapter 8** Page 319: Sir Karl Popper, edited by W. W. Bartley, *The Open Universe : An Argument for Indeterminism* (1992), London: Routledge, p. 44. **Chapter 9** Page 367: The Feynman Lectures on Physics, Vol. I, New Millenium Edition, New York: Basic Books, p. 4–1. Copyright: 1963 by California Institute of Technology. **Chapter 10** Page 415: James Clerk Maxwell, *The Scientific Papers of James Clerk Maxwell: Volume II*, Cambridge University Press, 2011, p. 48. **Chapter 11** Page 463: *Chemistry Imagined*, Roald Hoffmann and Vivian Torrence, Smithsonian Institution Press, Washington, 1993. **Chapter 12** Page 505: Andre K. Geim, "Random Walk to Graphene," Nobel Lecture, Dec. 8, 2010, pp. 84–85. **Chapter 13** Page 539: François-Marie Raoult, originally published in *Comptes Rendus* 104, 1430–3 (May 23, 1887), as translated and published by Henry M. Leicester & Herbert S. Klickstein, *A Source Book in Chemistry, 1400–1900* (Cambridge, MA: Harvard University Press, 1952), p. 475. **Chapter 14** Page 585: Sir Cyril Hinshelwood-Nobel Lecture: "Chemical Kinetics in the Past Few Decades," Nobelprize.org. Nobel Media AB 2014. Web. 22 Mar 2016. [http://www.nobelprize.org/nobel\\_prizes/chemistry/laureates/1956/hinshelwood-lecture.html](http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1956/hinshelwood-lecture.html). **Chapter 15** Page 639: Alfred J. Lotka, *Elements of Mathematical Biology*, 1956, p. 281. **Chapter 16** Page 685: Gilbert Newton Lewis, *Valence and the Structure of Atoms and Molecules*, American Chemical Society Monograph Series, New York: The Chemical Catalog Company, 1923, p. 138. **Chapter 17** Page 739: In Joseph William Mellor, *Mellor's Modern Inorganic Chemistry*, Longmans, Green & Company, London, 1967, p. 177. **Chapter 18** Page 797: Sir Arthur Stanley Eddington, *The Nature of the Physical World*, New York: MacMillan, 1929, p. 74. **Chapter 19** Page 845: *Le Opere*, Vol. 1, 149. In Giuliano Pancaldi, *Volta: Science and Culture in the Age of Enlightenment* (2005), 190. **Chapter 20** Page 893: Eve Curie, *Madame Curie: A Biography*, Doubleday, 1937, p. 341. **Chapter 21** Page 935: In Lawrence R. Hafstad, "Atomic Power for Aircraft," *Bulletin of the Atomic Scientists* (Nov 1949), p. 310, citing Friedrich Wohler's letter to J. J. Berzelius (28 Jan 1835). Date of letter identified in Alan L. Mackay, *A Dictionary of Scientific Quotations* (1991), 267. **Chapter 22** Page 985: In George B. Kauffman, *Alfred Werner: Founder of Coordination Chemistry*, 1966, Springer-Verlag, Berlin, Germany, p. iii.

*Not for Distribution*

*Not for Distribution*