

- <sup>1</sup> P. Calvert, “Advanced Materials,” In *The New Chemistry*, N. Hall, Ed., Cambridge University Press: Cambridge, UK, 2000, pp. 352-374; see “Background Reading”.
- <sup>2</sup> R. Hoffman, *Solids and Surfaces: A Chemist’s View of Bonding in Extended Structures* VCH Publishers: New York, 1988; see “Background Reading”.
- <sup>3</sup> S. J. Hawkes, *J. Chem. Educ.* 89, 694 (2012).
- <sup>4</sup> P. P. Edwards, “What, Why, and When is a Metal,” In *The New Chemistry*, N. Hall, Ed., Cambridge University Press: Cambridge, UK, 2000, pp. 85–114; see “Background Reading”; P. P. Edwards, R. L. Johnston, C. N. R. Rao, D. P. Tunstall, and F. Hensel, *Phil. Trans. R. Soc. Lond. A* 356, 5 (1998).
- <sup>5</sup> A. E. van Arkel, *Moleculen en Kristallen*, van Stockum: s’Gravenhage, 1941; A. E. van Arkel, *Molecules and Crystals*, Butterworths: London, 1949.
- <sup>6</sup> T. R. Geballe and T. Oka, *Nature (London)*, 384, 334 (1996).
- <sup>7</sup> A more detailed description of the periodic trend is given in G. Wulfsberg, *Inorganic Chemistry*, University Science Books: Sausalito, CA, 2000, pp. 620–623.
- <sup>8</sup> R. E. Peirls, *Ann. J. H. Poincaré* 5, 177 (1935); D. Landau, *Phys. Z. Sowjetunion* 11, 26 (1937).
- <sup>9</sup> B. Pan, J. Xiao, J. Li, P. Liu, C. Wang, and G. Yang, *Sci. Adv.*, 1, 1500857 (2015); M. Davenport, *Chem. Eng. News* Nov. 23, 2015, p. 30.
- <sup>10</sup> W. A. Chalifoux and R. R. Tykwinski, *Nature Chemistry*, 2, 967 (2010).
- <sup>11</sup> Y. Tobe and T. Wakabayashi, in F. Diederich, P. J. Stang, and R. R. Tykwinski, Eds., *Acetylene Chemistry: Chemistry, Biology, and Material Science*, Wiley-VCH: Weinheim, 2005, Chapter 9.
- <sup>12</sup> B. D. Cutforth, R. J. Gillespie, and P. K. Ummat, *Rev. Chim. Minérale*, 13, 119 (1976).
- <sup>13</sup> L. E. Murr and W. H. Kinard, *Am. Sci.* 81, 152 (1993).
- <sup>14</sup> R. Steudel and B. Eckert, *Top. Curr. Chem.* 230, 1 (2003).
- <sup>15</sup> A. R. Oganov, J. Chen, C. Gatti, Y. Ma, Y. Ma, C. W. Glass, Z. Liu, T. Yu, O. O. Kurakevych, and V. L. Solozhenko, *Nature (London)* 457, 863 (2009); see “Background Reading”.
- <sup>16</sup> The entire March 1992 issue of *Accounts of Chemical Research* (vol. 25, no. 3) was devoted to reviews of fullerene chemistry; see “Background Reading”.
- <sup>17</sup> H. W. Kroto, J. R. Heath, S. C. O’Brien, R. F. Curl, and R. E. Smalley, *Nature (London)* 318, 162 (1985).

- <sup>18</sup> W. Krätschmer, L. D. Lamb, K. Fostiropoulos, and D. R. Huffman, *Nature (London)* 347, 354 (1990).
- <sup>19</sup> J. B. Howard, J. T. McKinnon, and M. E. Johnson, *Nature (London)* 352, 139 (1991); J.-F. Tremblay, *Chem. Eng. News* Aug. 11, 2003, p.11.
- <sup>20</sup> L. Becker, J. L. Bada, R. E. Winans, J. E. Hunt, T. E. Bunch, and B. M. French, *Science (Washington, DC, U.S.)* 265, 642 (1994); D. Heymann, L. P. Felipe Chibante, R. R. Brooks, W. S. Wolbach, and R. E. Smalley, *Science (Washington, DC, U.S.)* 265, 645 (1994); L. Becker, T. E. Bunch, and L. J. Allamandola, *Nature (London)* 400, 227 (1999); Y. Zhang and S. Kwok, *Astrophys. J.* 730, 126 (2011).
- <sup>21</sup> S. Margadonna, C. M. Brown, T. J. S. Dennis, A. Lappas, P. Pattison, K. Prassides, and H. Shinohara, *Chem. Mater.* 10, 1742 (1998).
- <sup>22</sup> T. J. S. Dennis, T. Kai, K. Asato, T. Tomiyama, H. Shinohara, T. Yoshida, Y. Kobayashi, H. Ishiwatari, Y. Miyake, K. Kikuchi, and Y. Achiba, *J. Phys. Chem. A* 103, 8747 (1999).
- <sup>23</sup> M. D. Diener and J. M. Alford, *Nature (London)* 393, 668 (1998).
- <sup>24</sup> P. D. W. Boyd, P. Bhyrappa, P. Paul, J. Stinchcombe, R. D. Bolskar, Y. Sun, and C. A. Reed, *J. Am. Chem. Soc.* 117, 2907 (1995); Y. Sun and C. A. Reed, *Chem. Commun. (Cambridge, UK)* 1997, 747.
- <sup>25</sup> X.-B. Wang and L.-S. Wang, *Annu. Rev. Phys. Chem.* 60, 105 (2009).
- <sup>26</sup> E. K. Campbell, M. Holz, D. Gerlich, and J. P. Maier, *Nature (London)* 523, 322 (2015).
- <sup>27</sup> G. Oszlányi, G. Bortel, G. Faigel, L. Gránásy, G. M. Bendele, P. W. Stephens, and L. Forró, *Phys. Rev. B: Condens. Matter Mater. Phys.* 54, 849 (1996).
- <sup>28</sup> M. Saunders, H. A. Jiménez-Vásquez, R. J. Cross, S. Mroczkowski, M. L. Gross, D. E. Giblin, and R. J. Poreda, *J. Am. Chem. Soc.* 116, 2193 (1994)
- <sup>29</sup> L. Becker and T. E. Bunch, *PNAS* 97, 2979 (2000).
- <sup>30</sup> K. Komatsu, M. Murata, and Y. Murata, *Science (Washington, DC, U.S.)* 307, 238 (2005).
- <sup>31</sup> R. E. Smalley, *J. Am. Chem. Soc.* 107, 7779 (1985).
- <sup>32</sup> X. Lu, L. Feng, T. Akasaka, and S. Nagase, *Chem. Soc. Rev.* 41, 7723 (2012); H. Cong, B. Yu, T. Akasaka, and X. Lu, *Coord. Chem. Rev.* 257, 2880 (2013), see “Background Reading”.
- <sup>33</sup> S. Aoyagi et al. *Nature Chemistry* 2, 678 (2010).
- <sup>34</sup> M Takata, B. Umeda, E. Nishibori, M. Sakata, Y. Saito, M. Ohno, and H. Shinohara, *Nature (London)* 377, 46 (1995); H. Suematsu, Y. Murakami, H. Kawata, Y. Fujii, N. Hamaya, O.

- Shimomura, K. Kikuchi, Y. Achiba, and I. Ikemoto, *Mat. Res. Soc. Symp. Proc.* 349, 213 (1994).
- <sup>35</sup> T. Guo, M. D. Diener, Y. Chai, M. J. Alford, R. E. Haufler, S. M. McClure, T. Ohno, J. H. Weaver, G. E. Scuseria, and R. E. Smalley, *Science (Washington, DC, U.S.)* 257, 1661 (1992).
- <sup>36</sup> J.-P. Dognon, C. Clavaguéra, and P. Pyykkö, *J. Am. Chem. Soc.* 131, 238 (2009).
- <sup>37</sup> S. Iijima and T. Ichihashi, *Nature (London)* 363, 603 (1993); D. S. Bethune, C. H. Klang, M. S. de Vries, G. Gorman, R. Savoy, J. Vasquez, and R. Beyers, *Nature (London)* 363, 605 (1993).
- <sup>38</sup> S. Iijima, *Nature (London)* 354, 56 (1991).
- <sup>39</sup> Z. K. Tang, L. Zhang, N. Wang, X. X. Zhang, G. H. Wen, G. D. Li, J. N. Wang, C. T. Chan, and P. Sheng, *Science (Washington, DC, U.S.)* 292, 2462 (2001).
- <sup>40</sup> M. Freitag, in M. J. O’Connell, ed., *Carbon Nanotubes: Properties and Applications*, Boca Raton: CRC Taylor & Francis, 2006, p.83; see “Background Reading”.
- <sup>41</sup> R. Chavan, U. Desai, P. Mhatre, and R. Chinchole, *Int. J. Pharm. Sci. Reviews Research* 13, 125 (2012).
- <sup>42</sup> F. Yang et al. *Nature (London)* 510, 522 (2014).
- <sup>43</sup> J. R. Sanchez-Valencia, T. Dienel, O. Gröning, I. Shorubalko, A. Mueller, M. Jansen, K. Amsharov, P. Ruffleux, and R. Fasel, *Nature (London)* 512, 61 (2014).
- <sup>44</sup> C. A. Poland, R. Duffin, I. Kinloch, A. Maynard, W. A. H. Wallace, A. Seaton, V. Stone, S. Brown, W. MacNee, and K. Donaldson, *Nature Nanotechnology* 3, 423 (2008).
- <sup>45</sup> J. P. Ryman-Rasmussen, M. F. Cesta, A. R. Brody, J. K. Shipley-Phillips, J. I. Everitt, E. W. Tewksbury, O. R. Moss, B. A. Wong, D. E. Dodd, M. E. Andersen, and J. C. Bonner, *Nature Nanotechnology* 4, 747 (2009).
- <sup>46</sup> G. M. Mutlu, G. R. Scott Budinger, A. A. Green, D. Urich, S. Soberanes, S. E. Chiarella, G. F. Alheid, D. R. McCrimmon, I. Szleifer, and M. C. Hersam, *Nano Lett.* 10, 1664 (2010).
- <sup>47</sup> K. S. Novoselov, A. K. Geim, S. V. Morozov, D. Jiang, Y. Zhang, S. V. Dubonos, I. V. Grigorieva, and A. A. Firsov, *Science (Washington, DC, U.S.)* 306, 666 (2004).
- <sup>48</sup> A. K. Geim and K. S. Novoselov, *Nat. Mater.* 6, 183 (2007) ; see “Background Reading”.
- <sup>49</sup> A. K. Geim and P. Kim, *Sci. Amer.* 298(6), 90 (2008); see “Background Reading”.
- <sup>50</sup> M. Matsumoto, Y. Saito, C. Park, T. Fukushima, and T. Aida, *Nature Chemistry* 7, 730 (2015).

- <sup>51</sup> Summarized in M. Kertész, *Adv. Quantum Chem.* 15, 161 (1982); A. G. MacDiarmid, *Synth. Metals* 125, 11 (2002).
- <sup>52</sup> J. M. Williams, *Adv. Inorg. Chem. Radiochem.* 26, 235 (1983).
- <sup>53</sup> F. C. Frank, *Philos. Mag. Lett.* 66, 81 (1992).
- <sup>54</sup> D. Schneider, *Sci. Am.* 275(4), 28 (1996); L. Stixrude and R. E. Cohen, *Science (Washington, DC, U.S.)* 267, 1972 (1995).
- <sup>55</sup> P. Mori-Sánchez, A. M. Pendàs, and V. Luaña, *J. Am. Chem. Soc.* 124, 14721 (2002); see “Background Reading”.
- <sup>56</sup> S. J. Hawkes, *J. Chem. Educ.* 86, 431 (2009).
- <sup>57</sup> W. Grochala, R. Hoffman, J. Feng, and N. W. Ashcroft, *Angew. Chem. Intl. Ed.* 46, 3620 (2007); see “Background Reading”.
- <sup>58</sup> S. Yoo, H. Cynn, F. Gygi, G. Galli, V. Iota, M. Nicol, S. Carlson, D. Häusermann, and C. Mailhot, *Phys. Rev. Lett.* 83, 5527 (1999).
- <sup>59</sup> Many more also become superconducting: K. Shimizu, “Elemental Superconductors,” in H. Rogalla and P. H. Kes, Eds., *100 Years of Superconductivity*. Boca Raton: CRC Press, 2012, pp. 279–282.
- <sup>60</sup> R. Reichlin, K. E. Brister, A. K. McMahan, M. Ross, S. Martin, Y. K. Vohra, and A. L. Ruoff, *Phys. Rev. Lett.* 62, 669 (1989).
- <sup>61</sup> A. S. Balchin and H. G. Drickamer, *J. Chem. Phys.* 34, 1948 (1961).
- <sup>62</sup> M. I. Eremets, A. G. Gavriliuk, I. A. Trojan, D. A. Dzivenko, and R. Boehler, *Nat. Mater.* 3, 558 (2004).
- <sup>63</sup> L. Zhu, Z. Wang, Y. Wang, G. Zou, H.-k. Mao, and Y. Ma, *PNAS* 109, 751 (2012).
- <sup>64</sup> P.-M. Robitaille, *Prog. Phys.* 3, 60 (2011).
- <sup>65</sup> M. I. Eremets and I. A. Troyan, *Nat. Mater.* 10, 927 (2011).
- <sup>66</sup> M.-S. Miao and R. Hoffman, *Acc. Chem. Res.* 47, 1311 (2014).
- <sup>67</sup> Y. Ma, M. Eremets, A. R. Oganov, Y. Xie, I. Trojan, S. Medvedev, A. O. Lyakhov, M. Valle, and V. Prakapenka, *Nature (London)* 458, 182 (2009).
- <sup>68</sup> W. Zhang, A. R. Oganov, A. F. Goncharov, Q. Zhu, S. E. Boulfelfel, A. O. Lyakhov, E. Stavrou, M. Somayazulu, V. B. Prakapenka, and Z. Konöpková, *Science (Washington, DC, U.S.)* 342, 1502 (2013).

- <sup>69</sup> X. Wang, H. Lin, Y. Ma, and M.-s. Miao, *arXiv.org, e-Print Article, Condensed Matter*, 2012(1-5), 1206.2874v1 [cond-mat.mtrl-sci], 2012.
- <sup>70</sup> M.-s. Miao, *Nature Chemistry* 5, 846 (2013).
- <sup>71</sup> J. J. Gilman, *J. Chem. Educ.* 76, 1330 (1999).
- <sup>72</sup> M. Liu, V. I. Artyukhov, H. Lee, F. Xu, and B. I. Yakobson, *ACS Nano* 7, 10075 (2013).
- <sup>73</sup> 24. A. R. Miedema, R. Boom, and F. R. de Boer, *J. Less-Common Metals* 41, 283 (1975).
- <sup>74</sup> R. Hultgren, P. D. Desai, D. T. Hawkins, M. Gleiser, and K. K. Kelley, *Selected Values of the Thermodynamic Properties of Binary Alloys*, American Society for Metals: Metals Park, Novelty, OH, 1973.
- <sup>75</sup> L. J. Parker, T. Atou, and J. V. Badding, *Science (Washington, DC, U.S.)* 273, 95 (1996); T. Atou, M. Hasegawa, L. J. Parker, and J. V. Badding, *J. Am. Chem. Soc.* 118, 12104 (1996).
- <sup>76</sup> C. Guminski, "Amalgams," in J. H. Westbrook and R. L. Fleischer, *Intermetallic Compounds: Vol. 3, Principles and Practice*. Wiley: Chichester, 2002, p. 21; C. Guminski, *Polish J. Chem.* 78, 1733 (2004).
- <sup>77</sup> C. Hogue, "Quicksilver Quandary", *Chem. Eng. News* May 28, 2007, p. 26.
- <sup>78</sup> K. R. C. Gisser, M. J. Geselbracht, A. Cappellari, L. Hunsberger, A. B. Ellis, J. Perepezko, and G. C. Lisensky, *J. Chem. Educ.* 71, 334 (1994).
- <sup>79</sup> A. B. Ellis, M. J. Geselbracht, B. J. Johnson, G. C. Lisensky, and W. R. Robinson, *Teaching General Chemistry: A Materials Science Companion*, American Chemical Society: Washington, D.C., 1993, p.119; see "Background Reading".
- <sup>80</sup> P. W. Stephens and A. I. Goldman, *Sci. Am.* 264(4), 44 (1991), see "Background Reading"; A. I. Goldman, J. W. Anderegg, M. F. Besser, S.-L. Chang, D. W. Delaney, C. J. Jenks, M. J. Kramer, T. A. Lograsso, D. W. Lynch, R. W. McCallum, J. E. Shield, D. J. Sordelet, and P. A. Thiel, *Am. Sci.* 84, 230, (1996), see "Background Reading".
- <sup>81</sup> H. Takakura, C. P. Gómez, A. Yamamoto, M. de Boissieu, and A. P. Tsai, *Nat. Mater.* 6, 58 (2007).
- <sup>82</sup> A. Sneed, *Sci. Am.* 311(4), 29 (2014).
- <sup>83</sup> J. F. Herbst, *Am. Sci.* 81, 252 (1993); G. Boebinger, A. Passner, and J. Bevk, *Sci. Am.* 274(6), 58 (1995).
- <sup>84</sup> B. Halford, *Chem. Eng. News* Nov. 30, 2009, p. 32.

- <sup>85</sup> Z.-m. Xiu, Q.-b. Zhang, H. L. Puppala, V. K. Colvin, and P. J. J. Alvarez, *Nano Lett.* 12, 4271 (2012).
- <sup>86</sup> B. Meier, *New York Times*, Oct. 1, 2011, p. A1; B. Meier, *New York Times*, Dec. 28, 2011, p. A1; “Dangerous Devices—Metal Hips: Missed Alarms,” *Consumer Reports*, May 2012, p. 27.
- <sup>87</sup> M. Jacoby, *Chem. Eng. News* Aug. 4, 2012, p. 29.
- <sup>88</sup> K. Duanmu and D. G. Truhlar, *J. Phys. Chem. C* 118, 28069 (2014).
- <sup>89</sup> N. R. Jana, L. Gearheart, and C. J. Murphy, *J. Phys. Chem. B* 105, 4065 (2001).
- <sup>90</sup> B. P. Khanal and E. R. Zubarev, *J. Am. Chem. Soc.* 130, 12634 (2008).
- <sup>91</sup> J. Li, X. Li, H.-J. Zhai, and L.-S. Wang, *Science (Washington, DC, U.S.)* 299, 864 (2003).
- <sup>92</sup> H.-F. Zhang, M. Stender, R. Zhang, C. Wang, J. Li, and L.-S. Wang, *J. Phys. Chem. B* 108, 12259 (2004).
- <sup>93</sup> P. Pyykkö and N. Runeberg, *Angew. Chem. Int. Ed.* 41, 2174 (2002).
- <sup>94</sup> F. Scherbaum, A. Grohmann, B. Huber, C. Krüger, and A. Schmidbaur, *Angew. Chem. Intl. Ed.* 27, 1544 (1988); A. Schmidbaur, *Gold Bull.* 23, 11 (1990).
- <sup>95</sup> H. Schmidbaur, *Chem. Soc. Rev.* 24, 391 (1995), see “Background Reading”; M. J. Katz, K. Sakai, and D. B. Leznoff, *Chem. Soc. Rev.* 37, 1884 (2008), see “Background Reading”.
- <sup>96</sup> X. Li, B. Kiran, J. Li, H.-J. Zhai, and L.-S. Wang, *Angew. Chem. Int. Ed.* 41, 4786 (2002).
- <sup>97</sup> J. Autschbach, B. A. Hess, M. P. Johansson, J. Neugebauer, M. Patzchke, P. Pyykkö, M. Reiher, and D. Sundholm, *Phys. Chem. Chem. Phys.* 6, 11 (2004).
- <sup>98</sup> G. Schmid, *Chem. Soc. Rev.* 37, 1909 (2008); see “Background Reading”.
- <sup>99</sup> G. Schmid, M. Harms, J.-O. Malm, J.-O. Bovin, J. van Ruitenbeck, H. W. Zandbergen, and W. T. Fu, *J. Am. Chem. Soc.* 115, 2046 (1993).
- <sup>100</sup> F. M. Mulder, T. A. Stegink, R. C. Thiel, L. J. de Jongh, and G. Schmid, *Nature (London)* 367, 716 (1994).
- <sup>101</sup> M. M. Labes, P. Lowe, and L. F. Nichols, *Chem. Rev.* 79, 1 (1979).
- <sup>102</sup> S. M. Condren, G. C. Lisensky, A. B. Ellis, K. J. Nordell, T. F. Kuech, and S. A. Stockman, *J. Chem. Ed.* 78, 1033 (2001).
- <sup>103</sup> M. W. Geis and J. C. Angus, *Sci. Am.*, 276(4), 84 (1992).
- <sup>104</sup> J. C. Meyer, A. Chuvilin, G. Algara-Siller, J. Biskupek, and U. Kaiser, *Nano Lett.* 9, 2683 (2009).

- <sup>105</sup> K. S. Kim, C. T. Kingston, A. Hrdina, M. B. Jakubinek, J. Guan, M. Plunkett, and B. Simard, *ACS Nano* 8, 6211 (2014).
- <sup>106</sup> G. Algara-Siller et al. *Angew. Chem. Int. Ed.* 33, 7450 (2014).
- <sup>107</sup> K. S. Novoselov, D. Jiang, F. Schedin, T. J. Booth, V. V. Khotkevich, S. V. Morozov, and A. K. Geim, *PNAS* 102, 10451 (2005).
- <sup>108</sup> P. D. Antunez, D. H. Webber, and R. L. Brutchey, *Chem. Mater.* 25, 2385 (2013).
- <sup>109</sup> C. N. R. Rao, U. Maitra, and U. V. Waghmare, *Chem. Phys. Lett.* 609, 172 (2014).
- <sup>110</sup> R. Tenne, *Nat. Nanotechnol.* 1, 103 (2006); see “Background Reading”.
- <sup>111</sup> D. L. Lide, ed., *Handbook of Chemistry and Physics*, 84<sup>th</sup> ed., CRC Press: Boca Raton, FL, 2003, pp. 12-101 to 12-105.
- <sup>112</sup> D. H. Webber and R. L. Brutchey, *J. Am. Chem. Soc.* 135, 15722 (2013).
- <sup>113</sup> J. Nagamatsu, N. Nakagawa, T. Muranaka, Y. Zenitani, and J. Akimitsu, *Nature (London)* 410, 63 (2001).
- <sup>114</sup> R. H. T. Wilke, S. L. Bud'ko, P. C. Canfield, and D. K. Finnemore, *High Temperature Superconductors* 175 (2010).
- <sup>115</sup> G. D. Sproul, *J. Chem. Educ.* 70, 531 (1993); G. D. Sproul, *J. Phys. Chem.* 98, 6699 (1994).
- <sup>116</sup> W. B. Jensen, *J. Chem. Educ.* 72, 395 (1995).
- <sup>117</sup> G. Wulfsberg, *Inorganic Chemistry*, University Science Books: Sausalito, CA, 2000, pp. 775–778.
- <sup>118</sup> G. Sproul, *J. Chem. Educ.* 78, 387 (2001).
- <sup>119</sup> *Lange's Handbook of Chemistry*, 13<sup>th</sup> ed., Dean, J. A., Ed., McGraw-Hill: New York, 1985, pp. 6-6 to 6-19.