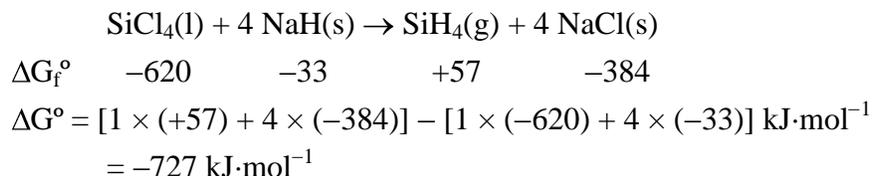# Chapter 9

PERIODIC TRENDS

Exercises

9.1   (a) A pair of elements in a compound whose sum of valence electrons adds up to eight.

(b) The relationship between an element and the element to its lower right in the periodic table. The diagonal relationship is found in the top left-hand corner of the periodic table.

9.3   An alum has the general formula: $M^+M^{3+}(SO_4^{2-})_2\cdot12H_2O$ or more correctly, $M^+[M(OH_2)_6]^{3+}(SO_4^{2-})_2\cdot6H_2O$, where M^+ is a large monopositive ion such as potassium or ammonium and M^{3+} is a small tripositive ion such as aluminum, chromium(III), or iron(III).

9.5   KF (m.p. 858°C), CaF_2 (m.p. 1418°C), GaF_3 (m.p. >1000°C), GeF_4 (m.p. −15°C), AsF_5 (m.p. −80°C), SeF_6 (m.p. <−35°C), BrF_5 (m.p. −60°C), KrF_2 (decomposes) [information from www.webelements.com]

The bonding in the potassium and calcium fluorides is ionic, while that for the germanium, arsenic, selenium, bromine, and krypton compounds is covalent. Assuming that the trend follows that of other series, the gallium compound is probably network covalent.

(a) The melting point decreases down the group as a result of the metallic bond throughout the metal lattice being weaker as the metal atoms become larger as the group is descended.

(b) The melting point increases down the group as the dispersion (London) forces between pairs of the covalently bonded atoms become stronger due to the increasing number of electrons.

(c) Carbon, at the top of the Group 14 elements, is network covalently bonded thus has a very high melting point. So is silicon. With germanium, tin, and lead, there is weak metallic bonding and thus low melting points.

9.7   (a) Hydrogen gas, H_2; (b) calcium metal.

9.9   As the group is descended, the cation radii increase (the charge density decreases). As a result the ionic bond will weaken and the melting point will be lower.

9.11   Scandium hydroxide, $Sc(OH)_3$.

9.13 $SO_3(s) + H_2O(l) \rightarrow H_2SO_4(aq)$
       $CrO_3(s) + H_2O(l) \rightarrow H_2CrO_4(aq)$

9.15   (a) Al_2O_3, Sc_2O_3.
       (b) P_2O_5, V_2O_5 (actually the phosphorus(V) oxide is usually written as P_4O_{10} to reflect its molecular structure).

9.17   Tin.

9.19   The other elements exist as dimers, N_2, O_2, F_2; thus they have nearly twice the number of electrons as monatomic neon and hence significantly higher melting points resulting from the stronger dispersion (London) forces.

9.21   Europium has the electron configuration $[Xe]6s^2 4f^7$. Forming the Eu^{2+} ion would retain the half-filled d orbital set.

9.23   (a) Indium(III) and bismuth(III); (b) cadmium(II) and lead(II).

9.25   Thallium(I) bromide (m.p. 460°C according to *Lange's Handbook of Chemistry*).

9.27   (a) $C \equiv O$; (b) $(C \equiv C)^{2-}$.

9.29   Yttrium, as its 3+ ion will be closest in size to the lanthanoid ions. In fact, yttrium was discovered along with many of the lanthanoid elements in ores near the Swedish town of Ytterby. Hence the name of yttrium and those of ytterbium, terbium, and erbium.
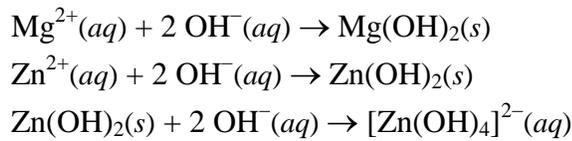
Beyond the Basics

9.31   Because the synthetic route involves a negative free energy change. For
example, one synthetic route is:

$$SiCl_4(l) + 4\ NaH(s) \rightarrow SiH_4(g) + 4\ NaCl(s)$$

ΔG_f^o −620   −33   +57   −384

$\Delta G^o = [1 \times (+57) + 4 \times (-384)] - [1 \times (-620) + 4 \times (-33)]$ kJ·mol^{-1}

       $= -727$ kJ·mol^{-1}

Thus, although the hydrogenation of the silicon tetrachloride by itself is
unfavorable, the formation of sodium chloride from sodium hydride
provides the "driving force" for the reaction.

9.33   Add excess hydroxide ion (Table 9.19). Magnesium hydroxide is basic,
thus there will be a white precipitate of magnesium hydroxide. Zinc
hydroxide will initally give a matching white precipitate, but being
amphoteric, in excess hydroxide ion, the precipitate will redissolve.

$Mg^{2+}(aq) + 2\ OH^-(aq) \rightarrow Mg(OH)_2(s)$

$Zn^{2+}(aq) + 2\ OH^-(aq) \rightarrow Zn(OH)_2(s)$

$Zn(OH)_2(s) + 2\ OH^-(aq) \rightarrow [Zn(OH)_4]^{2-}(aq)$

9.35   (a) 12−, (b) 7. The formula showing the theoretical oxidation states
would be $(Zn^{2+})_7[(P^{5+})_{12}(N^{3-})_{24}](Cl^-)_2$, compared with
$(Na^+)_8[(Al^{3+})_{12}(Si^{4+})_6(O^{2-})_{24}](Cl^-)_2$.

9.37   Li (+1); Be (+2); B (+3); C (+4); N (+3); O (+2). For Period 2, the
oxidation numbers reach a maximum at carbon, then decrease as nitrogen
and oxygen cannot exceed the octet in their bonding.
Na (+1); Mg (+2); Al (+3); Si (+4); P (+5); S (+6); Cl (+5). For Period 3,
the oxidation number matches the number of valence electrons except for
chlorine, which, as mentioned in the text, is most probably unable to attain
the highest oxidation number for steric reasons.

9.39 Fe_2O_3 (+3); RuO_4 (+8); OsO_4 (+8). For ruthenium and osmium, the
oxidation number is the same as the Group number.

9.41

	Group 15	Group 16	Group 17
Group 15	CN_2^{2-}	OCN^-	FCN
Group 16	OCN^-	CO_2	FCO^+