BASIC CHEMISTRY C

ANSWERS

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HAASE FORLAG

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Preface

Basic Chemistry C. Answers contains the answers to the numbered problems presented in *Basic Chemistry C*. These answers are intended for students who wish to confirm the correctness of the answers they arrive at.

The answers are presented as precisely and concisely as possible, and are accompanied by explanations only when necessary and when several answers are possible. For example, the answer will not state ”$n(Na_2SO_4)$ = 0.0300 mol” if it is enough to write ”0.0300 mol”. Yet, the answer will state amount and result, such as ”$[H_3O^+]$ = 0.055 M and $[OH^-]$ = 1.8×10^{-13} M”, to avoid ambiguity. In other words, the student cannot expect to find the correct, full presentation of answers for all the calculations carried out. That is a habit students must develop in the course of classroom instruction and their own study.

The answers presented in this answer key are calculated using the atomic masses given in the periodic table at the end of *Basic Chemistry C*. The results have been rounded off using accepted rules of practice.

Comments and suggestions regarding the answer key, explanations and errors will be gratefully accepted.

Vibeke Axelsen
Ole Vesterlund Nielsen

1. a) $CH_4 + H_2O \rightarrow CO + 3H_2$
b) $CO + 2H_2 \rightarrow CH_3OH$
c) $3H_2 + N_2 \rightarrow 2NH_3$
d) $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

2. In a *mixture* of two elements, the atoms of the elements are not bonded to each other. For example, in a mixture of H_2 and O_2, the H atoms are not bonded to the O atoms. In a *chemical compound* of two elements, the atoms of the elements *are* bonded to each other. For example, a chemical compound of H_2 and O_2 could be H_2O (water).

3. H: one hydrogen atom, but could also be the chemical symbol for the element hydrogen
2H: two hydrogen atoms (not bonded to each other)
H_2: one dihydrogen molecule (two hydrogen atoms bonded together)
$2H_2$: two dihydrogen molecules
$H_2(g)$: dihydrogen in its gas state
$H_2(l)$: dihydrogen in its liquid state
$H_2(s)$: dihydrogen in its solid state

4. –

5. –

6. a) 2 protons, 2 neutrons and 2 electrons
b) 19 protons, 20 neutrons and 19 electrons
c) 92 protons, 146 neutrons and 92 electrons

7. $^{14}_{6}C$ has 6 protons and 8 neutrons, while $^{14}_{7}N$ has 7 protons and 7 neutrons.

8. 15.99940 u, which can be rounded off to 15.9994 u (see the table on p. 193).

9. Co is the chemical symbol for the element cobalt, while CO is a chemical compound of the elements carbon and oxygen (named carbon monoxide).

10. The atomic nucleus of chromium and the atomic nucleus of bismuth together contain 107 protons.

11. a) P, Ne, C and Se b) Se

12. Gruppe 15, 4th period, arsenic, As

13. $(16.00\ u/18.016\ u) \times 100\ \% = 88.81\ \%$ which is rounded off to 89 %

14. a) Al^{3+}: 13 protons and 10 electrons (Ne structure)
b) S^{2-}: 16 protons and 18 electrons (Ar structure)
c) Fe^{2+}: 26 protons and 24 electrons (not a noble gas structure)
d) Ca^{2+}: 20 protons and 18 electrons (Ar structure)
e) H^{+}: 1 proton and 0 electrons (not a noble gas structure)
f) H^{-}: 1 proton and 2 electrons (He structure)

15. $BaBr_2$, FeS, $FeCl_3$, Al_2O_3, Ag_2O, Cu_2O, CuO, Mg_3N_2, KF

16. a) $Fe(NO_3)_3$ b) $(NH_4)_2CO_3$
c) $Mg(NO_3)_2 \times 6H_2O$ d) $Ba(OH)_2 \times 8H_2O$

17. K_2S K_2SO_3 K_2SO_4

18. a) iron(III) sulfate b) ammonium sulfate
c) copper(II) nitrate trihydrate

19. a) 48 protons and 50 electrons
b) 11 protons and 10 electrons
c) 9 protons and 10 electrons

20. –

21. Ag_2SO_4 (T), Ag_2S (T), $Ba(NO_3)_2$ (L), $PbSO_4$ (T), $ZnCl_2$ (L)

22. a) $NH_4NO_3(s) \rightarrow N_2O(g) + 2H_2O(g)$
b) $2NH_4NO_3(s) \rightarrow 2N_2(g) + O_2(g) + 4H_2O(g)$

23. Approximately 32 g remains dissolved, and approximately 68 g precipitates out, lying on the bottom of the beaker.

24. a) At 100 °C, approximately 76 g of ammonium chloride will dissolve. So, 50 g will dissolve completely.
b) Approximately 48 °C

25. $Na_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$
$SO_4^{2-}(aq) + Ba^{2+}(aq) \rightarrow BaSO_4(s)$

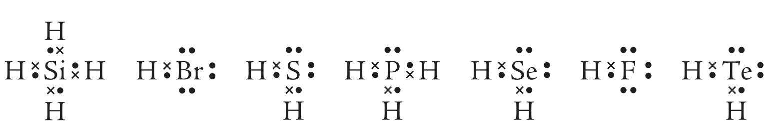
26. a) Cl^-, Br^-, I^-, SO_4^{2-}, CO_3^{2-}, OH^-, S^{2-}, PO_4^{3-}
b) Examples: $3Pb^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Pb_3(PO_4)_2(s)$
c) No, a simple precipitation reaction to prove the presence of lead(II) ions is not possible in practice for several reasons. For example, the amount of lead(II) ions in the hot tea is too little to form a visible precipitate. In addition, the tea contains several others compounds that might interfere with the experiment.

27. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$
exothermic

28. a) $CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2Cl^-(aq)$ b) – c) –

29. a) dinitrogen
b) dinitrogen oxide
c) sulfur dioxide
d) sulfur trioxide
e) sulfur hexafluoride
f) phosphorus trichloride
g) dinitrogen trioxide
h) dinitrogen pentoxide
i) tetraarsenic

30. a) I_2
b) S_8
c) CS_2
d) NO
e) NO_2
f) N_2O_4
g) H_2O
h) PCl_5
i) P_4O_{10}

31. 

32. Three chlorine atoms, making the formula PCl_3.

33.  O=O

34.  H–C≡N

35. –

36. The octet rule will not hold when both molecules contain an odd number of electrons.

37. Approximately 3.1×10^{25} C atoms.

38. C–Cl is weakly polar, where Cl is the negative pole.

39. For example, $AlCl_3$, BeI_2, LiI
For example, NaCl, KCl

40. Methanal is polar and soluble in water.

41. No, oil floats on the surface of water. Fatty acids are nonpolar.

42. Yes. For example, in order of decreasing density: dichloromethane (weakly polar), water (polar), heptane (non-polar)

43.
a) CH_3OH: The molecule contains a hydrophilic group (–OH) and one carbon atom with hydrophobic groups. As a whole, the molecule is hydrophilic and soluble in water.
b) CH_3CH_2OH: A hydrophilic group and two carbon atoms with hydrophobic groups. As a whole, the molecule is hydrophilic and soluble in water.
c) $CH_3CH_2CH_2CH_2CH_2OH$: A hydrophilic group and five carbon atoms with hydrophobic groups. As a whole, the molecule is hydrophobic and barely soluble in water.
d) CO_2: The molecule is a linear structure (O=C=O). Therefore, it is hydrophobic, even though C=O is a hydrophilic group. The molecule is, therefore, barely soluble in water.
e) CCl_4: The C–Cl group is hydrophobic. The molecule is hydrophobic and thereby hardly soluble in water.
f) $CH_3CH_2NH_2$: The molecule contains a hydrophilic group ($-NH_2$) and two carbon atoms with hydrophobic groups. As a whole, the molecule is hydrophilic and soluble in water.
g) $CH_2OHCH_2CH_2CH_2OH$: The molecule has two hydrophilic groups (–OH) and four carbon atoms with hydrophobic groups. As a whole, the molecule is hydrophilic and soluble in water.

44.
a) 0.729 g/mL
b) 81.1 g (81.2 g if the density is calculated to 4 decimals)

45. 17.8 mL

46. 98.09 u, 133.33 u, 342.17 u, 278.03 u, 46.07 u

47. 63.0 %

48. 87.1 %

49. The ratio between the masses $m(Cl)/m(Na)$ = 40 mg/25 mg = 1.6 is by and large equal to the ratio between the atomic masses $m(Cl)/m(Na)$ = 35.45 u/ 22.99 u = 1.54. If rounded off masses are used, then the numbers fit more or less.

50. 0.021 mol

51. 2516 g

52. a) 83.9 g/mol b) No. It could be, for example, C_6H_{12}

53. 1.61×10^{21} molecules

54. a) 0.0626 mol Cu and 0.0313 mol O b) Cu_2O

55. 680 g dioxygen and 575 g carbon dioxide

56. 11.8 g CO_2, 4.84 g H_2O and 4.30 g SO_2

57. a) 156 g b) 269 g

58. 538 g

59. 25 g dioxygen, 23 g carbon dioxide, 14 g water

60. a) 24.8 g b) 20.9 g c) 97.6 %

61. 35.9 g Al and 64.1 g S

62. Calculate the amount of the two compounds and then the ratio between the compounds. The amounts are not equivalent.

63. 10.28 g HCl

64. 24 L

65. a) 0.132 mol b) 3.16 L

66. a) 3.9 mol b) 170 g

67. 4.81×10^{-5} % 0.481 ppm 481 ppb

68. a) 1005 g b) 9.045 g
c) Weigh out 9.045 g NaCl and dissolve it in water. Transfer the solution to a 1 L volumetric flask and add water up to the mark to make a 1 L solution.

69. a) 4.0 mL b) 3.2 g c) 3.1 %

70. a) 51.8 % b) 51.8 %

71. a) 0.0300 mol b) 4.26 g c) –

72. a) 15.6 g b) 40.0 mL

73. 0.00400 M

74. $[Ba^{2+}]$ = 0.15 M $[Cl^-]$ = 0.30 M

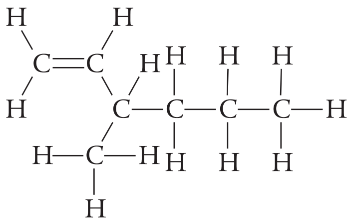
75. $[Al^{3+}]$ = 0.100 M $[SO_4^{2-}]$ = 0.150 M

76. $[Ca^{2+}]$ = 0.020 M $[Al^{3+}]$ = 0.030 M $[Cl^-]$ = 0.130 M

77. $c(Pb(NO_3)_2)$ = 0.0100 M $[Pb^{2+}]$ = 0.0100 M $[NO_3^-]$ = 0.0200 M

78. a) $n(AgNO_3)$ = 0.0466 mmol
b) $n(NaCl)$ = 0.0466 mmol
c) $m(NaCl)$ = 2.72 mg
$c_{mass}(NaCl)$ = 1.06 %

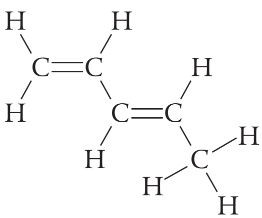
79. a)

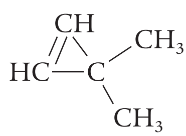


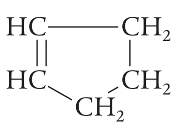
b) C_7H_{14}

c) The spatial structure around the two double-bonded C atoms is planar; the spatial structure around the other C atoms is tetrahedral.

80. Some possibilities are:



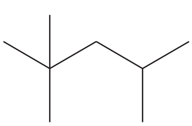




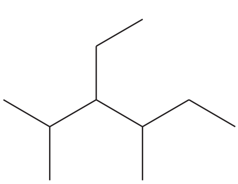
There are more than 20 solutions.

81. –

82.

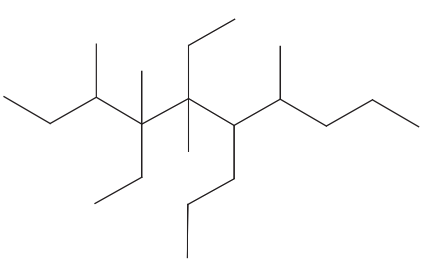


C_8H_{18}

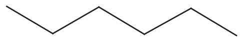


$C_{10}H_{22}$

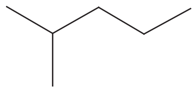
83.



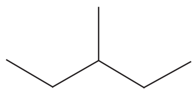
84.



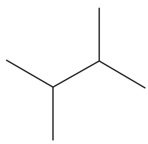
hexane



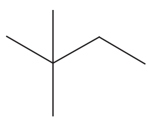
2-methylpentane



3-methylpentane

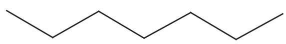


2,3-dimethylbutane

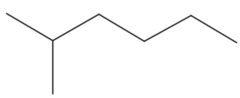


2,2-dimethylbutane

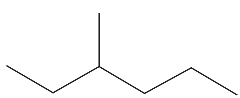
85.



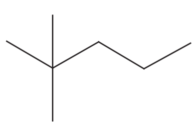
heptane



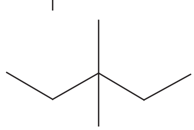
2-methylhexane



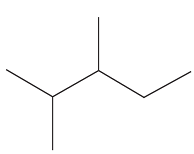
3-methylhexane



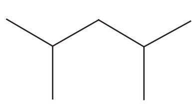
2,2-dimethylpentane



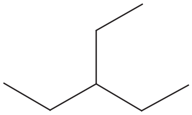
3,3-dimethylpentane



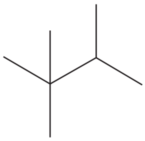
2,3-dimethylpentane



2,4-dimethylpentane

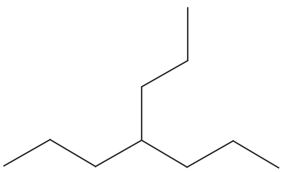


3-ethylpentane



2,2,3-trimethylbutane

86.



87. a) 5-ethyl-2,2,6-trimethylheptane
b) 3,4-dimethylhexane

88. Butane is the isomer with the longest carbon chain, which is why its boiling point is the highest.

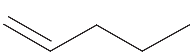
89. $2C_{14}H_{30}(l) + 43O_2(g) \rightarrow 28CO_2(g) + 30H_2O(g)$

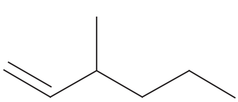
90. $2C_8H_{18}(l) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(g)$

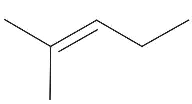
91. There are four possible structural formulas for the reaction's product. The names of the compounds are: 1-bromoheptane, 2-bromoheptane, 3-bromoheptane and 4-bromoheptane.

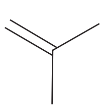
92. Four different groups are bonded to the double-bonded carbon atoms, which is why the *cis*- and *trans*- prefixes are not unique. Disregarding the two possible structures around the double bond, the name of the compound is 4-methylhept-3-ene (the name is not complete).

93.





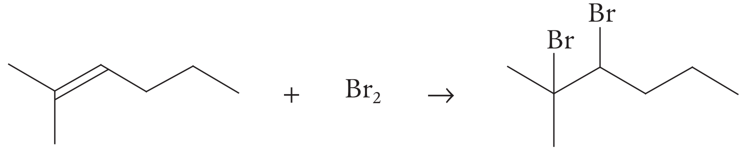




94. but-1-ene, *cis*-but-2-ene and *trans*-but-2-ene

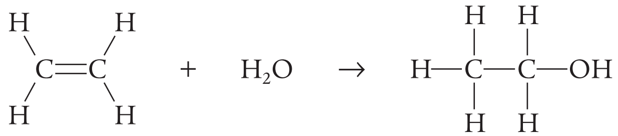
95. $C_{18}H_{38}$ and C_8H_{18} are alkanes.
C_6H_{12} and C_2H_4 are alkanes.

96.

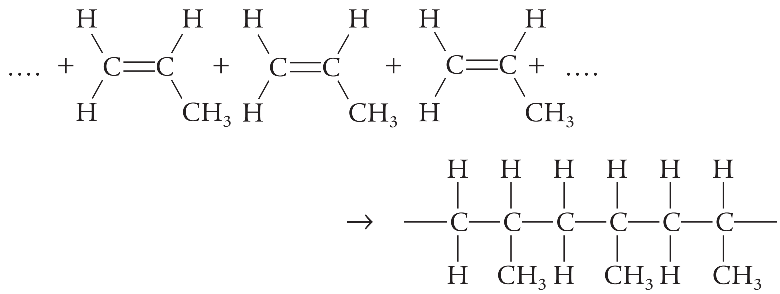


97. Pentane

98.



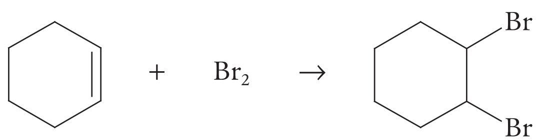
99.



100. a) C_8H_{12}
b) $C_{10}H_{16}$

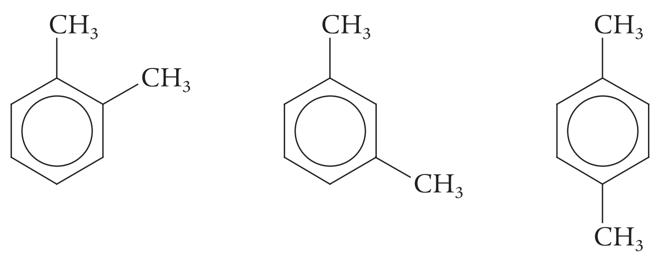
101. $C_6H_{12}(l) + 9O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$

102.



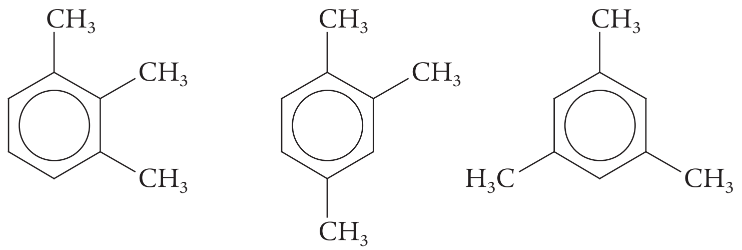
The product's name is 1,2-dibromcyclohexane

103. a)

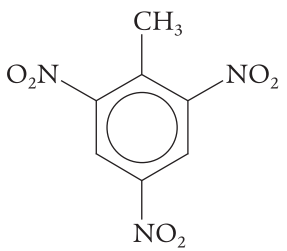


b) No

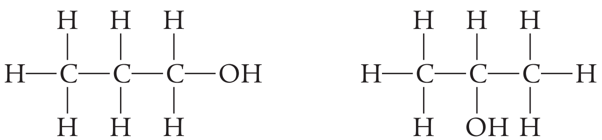
c) There are three: 1,2-, 1,4- and 3,5-trimethylbenzene:



104.



105. a)



b) propan-1-ol, 2-methylpropane-1-ol, propan-2-ol, 2-methylpropane-2-ol

106. All three molecules contain only a few hydrophobic groups compared to the number of hydrophilic groups.

107. a) 20 mL

b) $n(NH_3) = 8.2 \times 10^{-4}$ mol

c) $m(NH_3) = 14 \times 10^{-3}$ g = 14 mg; that is, the content of NH_3 is 14 mg/m^3, which corresponds exactly to the threshold limit value shown in Table 17.

108. If the pentane vapours are evenly distributed in a space, the pentane concentration will be 157 mg/m^3. The threshold limit value is not exceeded.

109. a) 1180 g b) 425 g c) 11.7 M

110. $H_2SO_4(aq) + NaCl(s) \rightarrow NaHSO_4(s) + HCl(g)$ or

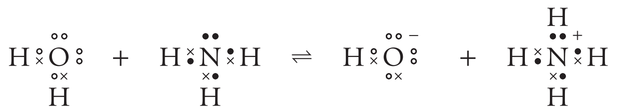
$H_2SO_4(aq) + 2NaCl(s) \rightarrow Na_2SO_4(s) + 2HCl(g)$

111.

NO_3^-	CN^-	F^-	HCO_3^-	Br^-
HI	HCN	HCO_3^-	H_2CO_3	H_3PO_4

112. CO_2 does not contain hydrogen and, therefore, cannot be an acid. Carbonic acid is the name of the compound H_2CO_3. It is formed when CO_2 is dissolved in water.

113. a) $H_3PO_4(aq) + H_2O(l) \rightleftharpoons H_2PO_4^-(aq) + H_3O^+(aq)$
b) $H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons HPO_4^{2-}(aq) + H_3O^+(aq)$
c) $HPO_4^{2-}(aq) + H_2O(l) \rightleftharpoons PO_4^{3-}(aq) + H_3O^+(aq)$

114. 

115. $CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$

116. In this case, the hydronium ions and hydroxide ions also react:
$H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l)$
The chemical reactions are written as:
$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$

117. Ammonium chloride is formed:
$HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$
The reaction between the acid HCl and the base NH_3 produces NH_4^+ and Cl^-, which together form an ionic lattice.

118. a) $H_2O(l) + CO_3^{2-}(aq) \rightleftharpoons OH^-(aq) + HCO_3^-(aq)$
b) $H_2O(l) + PO_4^{3-}(aq) \rightleftharpoons OH^-(aq) + HPO_4^{2-}(aq)$

119. a)

Na^+	Cl^-
K^+	SO_4^{2-}
Na^+	CO_3^{2-}
Na^+	HSO_4^-
NH_4^+	Cl^-

b) Acids: HSO_4^- NH_4^+
Bases: Cl^- SO_4^{2-} CO_3^{2-} HSO_4^-
Of those mentioned HSO_4^- is amphiprotic.

c) Conjugate bases: SO_4^{2-} NH_3
Conjugate acids: HCl HSO_4^- HCO_3^- H_2SO_4

120. a) 8.34 b) basic c) 2.2×10^{-6} M

121. 2.14

122. $[OH^-] = 0.0040$ M
$[H_3O^+] = 2.5 \times 10^{-12}$ M, pH = 11.6
pH = 11.9

123. $[H_3O^+] = 0.055$ M $[OH^-] = 1.8 \times 10^{-13}$ M

124. $[H_3O^+] = 2.0 \times 10^{-5}$ M $[OH^-] = 5.0 \times 10^{-10}$ M acidic

125. a) red b) orange c) yellow-green d) green
e) blue violet

126. a) 0.00161 mol b) 1:1 c) 0.0805 M

127. Phenolphthalein or thymol blue.

128. a) oxidation: $2Na \rightarrow 2Na^+ + 2e^-$ reduction: $Cl_2 + 2e^- \rightarrow 2Cl^-$
b) oxidation: $Ca \rightarrow Ca^{2+} + 2e^-$ reduction: $Br_2 + 2e^- \rightarrow 2Br^-$
c) oxidation: $2Al \rightarrow 2Al^{3+} + 6e^-$ reduction: $3S + 6e^- \rightarrow 3S^{2-}$
d) oxidation: $4Al \rightarrow 4Al^{3+} + 12e^-$ reduction: $3O_2 + 12e^- \rightarrow 6O^{2-}$

129. a) No reaction
b) $Zn(s) + 2Ag^+(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$
c) No reaction
d) $Pb(s) + Cu^{2+}(aq) \rightarrow Pb^{2+}(aq) + Cu(s)$

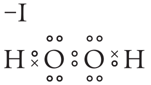
130. $Ca(s) + 2H_2O(l) \rightarrow Ca^{2+}(aq) + 2OH^-(aq) + H_2(g)$
Calcium hydroxide precipitates out:
$Ca^{2+}(aq) + 2OH^-(aq) \rightarrow Ca(OH)_2(s)$

131. $3Ag^+(aq) + Al(s) \rightarrow 3Ag(s) + Al^{3+}(aq)$

132. −II, +IV, +VI, +IV, +IV, +VI, −II and 0
Highest: +VI (= main group number)
Lowest: –II (= main group number minus 8).

133. +II, +IV, +I, −III, −II, +III, −I, +IV, +V, +V, +III and 0
Highest: +V (= main group number)
Lowest: –III (= main group number minus 8)

134. −I

135. 

The electrons in the bonds between the two O atoms must be shared between the O atoms. That leaves seven electrons in the outermost shell of each O atom, making the oxidation number of each −I.

136. +II

137. a) +III to Al and −I to Cl
b) +III to P and −I to Cl
c) +I to H, −I to Cl and +II to C

138. a) $4H^+(aq) + Cu(s) + 2NO_3^-(aq) \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(l)$
b) $4H^+(aq) + 3Fe^{2+}(aq) + NO_3^-(aq) \rightarrow 3Fe^{3+}(aq) + NO(g) + 2H_2O(l)$
c) $2H^+(aq) + 3H_2S(aq) + 8NO_3^-(aq) \rightarrow 3SO_4^{2-}(aq) + 8NO(g) + 4H_2O(l)$
d) $2OH^-(aq) + Pb^{2+}(aq) + ClO^-(aq) \rightarrow PbO_2(s) + Cl^-(aq) + H_2O(l)$
e) $2I^-(aq) + 2Fe^{3+}(aq) \rightarrow I_2(s) + 2Fe^{2+}(aq)$
f) $4H^+(aq) + PbO_2(s) + 2Cl^-(aq) \rightarrow Pb^{2+}(aq) + Cl_2(g) + 2H_2O(l)$
g) $14H^+(aq) + 6I^-(aq) + Cr_2O_7^{2-}(aq) \rightarrow 3I_2(s) + 2Cr^{3+}(aq) + 7H_2O(l)$
h) $6H^+(aq) + 5I^-(aq) + IO_3^-(aq) \rightarrow 3I_2(s) + 3H_2O(l)$

139. $[Fe^{2+}] = 0.0660$ M

140. a) $2H^+(aq) + H_2O_2(aq) + 2I^-(aq) \rightarrow 2H_2O(l) + I_2(aq)$
b) $n(S_2O_3^{2-}) = 0.086$ mmol $n(I_2) = 0.043$ mmol
c) $n(H_2O_2) = 0.043$ mmol
d) $c(H_2O_2) = 0.86$ M
e) 1 L cleaning fluid contains 29 g H_2O_2, corresponding to 2.9 % ≈ 3 % H_2O_2.