SCH3U0 – Exam Review Question Package

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Contents

1. Elemental Symbols, Fundamental Particles

1. Complete this table:

Symbol	p^{+1}	n^{o}	e^{-1}		Symbol	p^{+1}	n^{o}	e^{-1}
$^{1}_{1}H$					$^{17}_{8}O$			
$^{2}_{1}H$					$^{39}_{19}K$			
$^{4}_{2}He$					$^{40}_{19}K$			
$^{5}_{2}He$					$^{235}_{92}U$			
$^{6}_{3}Li$					$^{239}_{92}U$			
$^{7}_{3}Li$					$^{239}_{93}Np$			
$^{16}_{8}O$					$^{239}_{94}Pu$			

You'll need a copy of a periodic table for the following questions.

2. Give the numbers of neutrons, protons, and electrons in the atoms of each of the following isotopes

(a) radium-226

(b) carbon-14

(c) cesium-137

(d) iodine-131

3. Write the symbol for the isotope of plutonium (Pu) with 146 neutrons. The atomic number of plutonium is 94.

4. Write the symbols of the isotopes that contain the following.

(a) An isotope of silver whose atoms have 63 neutrons.

(b) An isotope of strontium whose atoms have 52 neutrons.

(c) An isotope of lead whose atoms have 126 neutrons.

(d) An isotope of fluorine whose atoms have 9 neutrons.

2. Answers - Elemental Symbols, Fundamental Particles

1. Complete this table:

Symbol	p^{+1}	n^{o}	e^{-1}		Symbol	p^{+1}	n^{o}	e^{-1}
$^{1}_{1}H$	1	0	1		$^{17}_{8}O$	8	9	8
$^{2}_{1}H$	1	1	1		$^{39}_{19}K$	19	20	19
$^{4}_{2}He$	2	2	2		$^{40}_{19}K$	19	21	19
$^{5}_{2}He$	2	3	2		$^{235}_{92}U$	92	143	92
$^{6}_{3}Li$	3	3	3		$^{239}_{92}U$	92	147	92
$^{7}_{3}Li$	3	4	3		$^{239}_{93}Np$	93	146	93
$^{16}_{8}O$	8	8	8		$^{239}_{94}Pu$	94	145	94

2. (a) $^{226}_{88}Ra$

(b) $^{14}_{6}C$

(c) $^{137}_{55}Cs$

(d) $^{131}_{53}I$

3. $^{240}_{94}Pu$

4. (a) $^{110}_{47}Ag$

(b) $^{90}_{38}Sr$

(c) $^{208}_{82}Pb$

(d) $^{19}_{9}F$

4. Electron Configurations Questions

1. Within any given shell, how do the energies of the s, p, d, and f subshells compare?

2. Within a subshell of "p", or "d" or "f" how to the energies of the orbitals compare?

3. What is Pauli's Exclusion Principle?

4. State Hund's Law.

5. What is the Aufbrau Principle?

6. How many unpaired electrons would be found in the ground state of
   (a) Mg
   (b) P
   (c) K

7. Give the electron configurations for each of the following:
   (a) O
   (b) F
   (c) Al
   (d) S
   (e) Ar

8. Predict the electron configurations for each of the following:
   (a) Ge
   (b) Cd
   (c) Gd
   (d) Sr

9. Which of the above atoms in question 8 would be paramagnetic?

10. If you can determine the electronic configuration of Uranium (Z = 92)

5. Answers – Electron Configuration Questions

1. s < p < d < f

2. All p's have the same energy, all d's have the same energy

3. An orbital can hold 0, 1, or 2 electrons only.

4. Each orbital of equal energy gets 1 electron first before any orbital gets a second electron provided they are available.

5. The boiling principle. Start at the lowest possible energy level and fill it, then move to the next highest energy level.

6. How many unpaired electrons would be found in the ground state of
   (a) Mg = 0
   (b) P = 3
   (c) K = 1

7. Give the electron configurations for each of the following:
   (a) O 1s2 2s2 2p4
   (b) F 1s2 2s2 2p5
   (c) Al 1s2 2s2 2p6 3s2 3p1
   (d) S 1s2 2s2 2p6 3s2 3p4
   (e) Ar 1s2 2s2 2p6 3s2 3p6

8. Predict the electron configurations for each of the following:
   (a) Ge 1s2 2s2 2p6 3s2 3p6 4s2 3d10 4p2
   (b) Cd 1s2 2s2 2p6 3s2 3p6 4s2 3d10 4p6 5s2 4d10
   (c) Gd 1s2 2s2 2p6 3s2 3p6 4s2 3d10 4p6 5s2 4d10 5p6 6s2 4f8 (actually 4f7 5d1)
   (d) Sr 1s2 2s2 2p6 3s2 3p6 4s2 3d10 4p6 5s2

9. Which of the above atoms in question 8 would be paramagnetic?
   a) and c) have unpaired electrons so they would be paramagnetic.

10. If you can determine the electronic configuration of Uranium (Z = 92)
    U 1s2 2s2 2p6 3s2 3p6 4s2 3d10 4p6 5s2 4d10 5p6 6s2 4f14 5d10 6p6 7s2 5f3 6d1

6. Electron Configurations of Ions

1. Which of the following sets of atomic number and configuration represent the ground state electron configuration of an atom or ion? State which atom or ion it is.

a) A = 8, 1s2 2s2 2p4
b) A = 11, 1s2 2s2 2p6
c) A = 14, 1s2 2s2 2p6 3s2
d) A = 22, 1s2 2s2 2p6 3s2 3p6 4s2

2. Write the correct electron configurations for:

a) Pb4+
b) S2-
c) Fe3+
d) Zn2+

3. Give the electron configurations for the following transition metal ions:

a) Sc3+
b) Cr2+
c) Ag1+
d) Ni3+

4. Of the following species (Sc0, Ca2+, Cl0, S2-, Ti3+), which are isoelectric?

5. Identify the group containing the element composed of atoms whose last electron:

a) enters and fills and 's' subshell.
b) enters but does not fill an 's' subshell.
c) is the first to enter a 'p' subshell.
d) is the next to the last in a given 'p' subshell.
e) enters and fills a given 'p' subshell.
f) is the first to enter a 's' subshell.
g) half fills a 'd' subshell.

6. Write the electron configuration for argon. Name two positive and two negative ions that have this configuration.

7. Answers – Electron Configuration of Ions

1. a) oxygen as a neutral atom
   b) lithium as a +1 ion
   c) silicon as a +2 ion
   d) titanium as a +2 ion

2. a) Pb4+ 1s2 2s2 2p6 3s2 3p6 4s2 3d10 4p6 5s2 4d10 5p6 6s2 4f14 5d8
   b) S2- 1s2 2s2 2p6 3s2 3p6
   c) Fe3+ 1s2 2s2 2p6 3s2 3p6 4s2 3d3
   d) Zn2+ 1s2 2s2 2p6 3s2 3p6 4s2 3d8

3. a) Sc3+ 1s2 2s2 2p6 3s2 3p6
   b) Cr2+ 1s2 2s2 2p6 3s2 3p6 4s2 3d2
   c) Ag1+ 1s2 2s2 2p6 3s2 3p6 4s2 3d10 4p6 5s0 4d10
   d) Ni3+ 1s2 2s2 2p6 3s2 3p6 4s2 3d5

4. Ca2+and S2-have the same electronic configuration with 18 electrons each.

5. a) The alkali earth metals
   b) The alkali metals
   c) The boron group
   d) The halogens
   e) The noble gases
   f) The alkali metals
   g) The manganese group

6. 1s2 2s2 2p6 3s2 3p6 4s2 = Ar = S-2, Cl-1, K+1 and Ca+2

8. Atomic and Ionic Size

1. What is the meaning of effective nuclear charge? How does the effective nuclear charge felt by the outer electrons vary going down a group? How does it change as we go from left to right across a period?

2. Choose the larger atom in each pair:
(a) Na or Si;
(b) P or Sb.

3. Choose the larger atom in each pair:
(a) Al or Cl;
(b) Al or In.

4. Choose the largest atom from among the following: Ge, As, Sn, Sb.

5. In what region of the periodic table are the largest atoms found? Where are the smallest atoms found?

6. Place the following in order of increasing size: N3-, Mg2+, Na+, F-, O2-, Ne.

7. Why are the size changes among the transition elements more gradual than those among the representative elements?

8. Choose the larger particle in each pair:
(a) Na or Na+;
(b) Co3+ or Co2+;
(c) Cl or Cl-.

9. Use the periodic table to choose the largest atom or ion in each set.
(a) Ge, Te, Se, Sn;
(b) C, F, Br, Ga;
(c) Fe, Fe2+, Fe3+ ;
(d) O, O2-, S, S2-

10. Which ion would be larger:
(a) Fe2+ or Fe3+,
(b) O- or O2-?

11. What two factors are most important in determining the size of an atom?

12. Explain the relative sizes of the atoms within a given group of the periodic table. Illustrate your answer with specific examples.

13. Compare the relative sizes of neutral atoms and their positive ions.

14. List the following particles in order of decreasing size: Kr, Sr2+, Rb+.

15. Compare the sizes of a negative ion and its neutral atom. Illustrate with specific examples.

16. List the following particles in order of decreasing size: K+, Ar, S2-, Cl-, Ca2+.

17. Arrange the following elements in increasing order of their atom's size. Ca, Ba, Be

18. Arrange the following elements in increasing order of their atom's size. Li, Rb, K,

10. Answers - Atomic and Ionic Size

1. The effective nuclear charge is a measure of the amount of pull a nucleus has. It decreases as you down a group due to incresed electron shell interference. It increases as you go across a period because the number of protons increases by the shell stays basically the same.

2. (a) Na (b) Sb

3. (a) Al (b) In

4. Sn

5. The largest atoms are found in the Alkali metals. The smallest are in the halogens.

6. Mg2+, Na+, Ne, F-, O2-, N3-

7. Because the 'd' orbita;s are being filled while the size is taken from the outer shell of 's' orbitals.

8. (a) Na (b) Co2+ (c) Cl-

9. (a) Sn (b) Ga (c) Fe (d) S2-

10. (a) Fe2+ (b) O2-

11. The number of shells of electrons and the amount of nuclear charge (i.e. the number of protons)

12. As you go down a group the relative sizes become larger due to iuncreasing numbers of shells.

13. Neutral atoms are always larger than their positive ions. As an atom becomes positive it loses electrons. It is the electrons that determine size, therefore the positive ion becomes smaller.

14. Kr, Rb+,Sr2+

15. Neutral atoms are always smaller than their negative ions. As an atom becomes negative it gains electrons. It is the electrons that determine size, therefore the negative ion becomes larger.

16. Ca2+, K+, Ar, Cl-, S2-

17. Be, Ca, Ba

18. Li, K, Rb, Cs

12. Nomenclature 1

Using the positive and negative ions given below make up the correct formulas.

1. NH_4^{+} and PO_4^{3-}
2. H^{+} and BO_3^{3-}
3. Li^{+} and CO_3^{2-}
4. Na^{+} and SO_4^{2-}
5. K^{+} and CrO_4^{2-}
6. Rb^{+} and $Cr_2O_7^{2-}$
7. Cs^{+} and HPO_4^{2-}
8. Be^{2+} and $Cr_2O_7^{2-}$
9. Mg^{2+} and CrO_4^{2-}
10. B^{3+} and HPO_4^{2-}
11. Ca^{2+} and SO_4^{2-}
12. Sr^{+2} and CO_3^{2-}
13. Ba^{+2} and BO_3^{3-}
14. B^{+3} and PO_4^{3-}
15. NH_4^{+} and HPO_4^{2-}
16. H+ and $Cr_2O_7^{2-}$
17. Rb^{+} and CO_3^{2-}
18. Ca^{2+} and HPO_4^{2-}
19. B^{+3} and $Cr_2O_7^{2-}$
20. Be^{+2} and BO_3^{3-}

Using the IUPAC names below come up with the correct molecular formulas.

1. Ammonium borate
2. Potassium phosphate
3. Beryllium sulphate
4. Hydrogen chromate
5. Sodium monohydrogen phosphate
6. Boron chromate
7. Potassium dichromate
8. Magnesium carbonate
9. Ammonium sulphate
10. Calcium phosphate
11. Hydrogen phosphate
12. Cesium borate
13. Sodium carbonate
14. Strontium dichromate
15. Barium monohydrogen phosphate
16. Barium chromate
17. Lithium sulphate
18. Beryllium chromate
19. Magnesium borate
20. Cesium dichromate

Give the Correct IUPAC names for the following molecular formulas.

1. $(NH_4)_2CO_3$
2. Rb_2HPO_4
3. $Li_2Cr_2O_7$
4. $MgHPO_4$
5. $SrHPO_4$
6. Na_3BO_3
7. H_2SO_4
8. $Sr_3(PO_4)_2$
9. $BaSO_4$
10. $B_2(SO_4)_3$
11. Rb_3PO_4
12. Rb_2CrO_4
13. $MgCr_2O_7$
14. $(NH_4)_2Cr_2O_7$
15. Cs_2CO_3
16. $Ca_3(BO_3)_2$
17. $SrCrO_4$
18. $B_2(CO_3)_3$
19. H_2CO_3
20. Na_2CrO_4

13. Answers – Nomenclature 1

1. $(NH_4)_4PO_4$
2. H_3BO_3
3. Li_2CO_3
4. Na_2SO_4
5. K_2CrO_4
6. $Rb_2Cr_2O_7^{2-}$
7. Cs_2HPO_4
8. $BeCr_2O_7$
9. $MgCrO_4$
10. $B_2(HPO_4)_3$
11. $CaSO_4$
12. $SrCO_3$
13. $Ba_3(BO_3)_2$
14. BPO_4
15. $(NH_4)_2HPO_4$
16. $H_2Cr_2O_7$
17. Rb_2CO_3
18. $CaHPO_4$
19. $B_2(Cr_2O_7)_3$
20. $Be_3(BO_3)_2$

Using the IUPAC names below come up with the correct molecular formulas.

1. $(NH_4)BO_3$
2. K_3PO_4
3. $BeSO_4$
4. H_2CrO_4
5. Na_2HPO_4
11. H_3PO_4
12. Cs_3BO_3
13. Na_2CO_3
14. $SrCr_2O_7$
15. $BaHPO_4$

6. $B_2(CrO_4)_3$
7. $K_2Cr_2O_7$
8. $MgCO_3$
9. $(NH_4)_2SO_4$
10. $Ca_3(PO_4)_2$
16. $BaCrO_4$
17. Li_2SO_4
18. $BeCrO_4$
19. $Mg_3(BO_3)_2$
20. $Cs_2Cr_2O_7$

Give the Correct IUPAC names for the following molecular formulas.

1. ammonium carbonate
2. rubidium biphosphate
3. lithium dichromate
4. magnesiu biphosphate
5. strontium biphosphate
6. sodium borate
7. hydrogen sulphate
8. strontium phosphate
9. barium sulphate
10. boron sulphate
11. rubidium phosphate
12. rubidium chromate
13. magnesium dichromate
14. ammonium dichromate
15. cesium carbonate
16. calcium borate
17. strontium chromate
18. boron carbonate
19. hydrogen carbonate
20. sodium chromate

15. Nomenclature 2

Using the IUPAC formulas below come up with correct names

1. $ScCl_3$
2. $Cr(NO_3)_6$
3. MnO
4. $Fe(MnO_4)_2$
5. CoF_3
6. $Ni_3(PO_4)_2$
7. $CuCl_2$
8. ZnO
9. GeS_2
10. $AgCl$
11. Cd_3N_2
12. SnF_2
13. $Sb(ClO_3)_5$
14. $Pb(SO_4)_2$
16. PtO_2
17. Zn_3P_2
18. $Sn(HSO_4)_4$
19. Au_2O_3
20. $Bi_3(BO_3)_5$
21. NiN
22. TiO_2
23. VSO_4
24. $Cr(H_2PO_4)_3$
25. $W(MnO_4)_4$
26. UO_2
27. Pu_2O_5
28. $Fe(HCO_3)_3$
29. HgI

Given the names below provide the correct IUPAC formulas.

1. Chromous chloride
2. Ferric nitrate
3. Plumbic hydroxide
4. Cobaltous bisulphate
5. Nickelic borate
6. Cuprous sulphate
7. Cupric monohydrogen phosphate
8. Mercurous bromide
9. Bismuthic carbonate
10. Stannous bicarbonate
11. Mercuric oxide
12. Plumbous chloride
13. Bismuthous fluoride
14. Plumbic nitrate
15. Stannic bisulphate
16. Chromium (II) sulphate
17. Manganese (IV) phosphide
18. Iron (III) sulphide
19. Cobalt (II) dichromate
20. Nickel (III) nitride
21. Copper (I) cyanide
22. Zinc carbonate
23. Cadmium phosphate
24. Mercury (II) iodide
25. Gold (III) permangante
26. Platinum (II) acetate
27. Vanadium (V) chromate
28. Aluminum biphosphate
29. Uranium (V) nitrate
30. Silver hydroxide

16. Answers - Nomenclature 2

1. Scandium chloride
2. Chromium(VI) nitrate
3. Manganese(II) oxide, Manganous oxide
4. Iron(II) permanganate, Ferrous permanagante
5. Cobalt(II) fluoride, Cobaltic fluoride
6. Nickel(II) phosphate, Nickelous phosphate
7. Copper(II) chloride, Cupric chloride
8. Zinc oxide
9. Germanium sulphide
10. Silver chloride
11. Cadmium nitride
12. Tin(II) fluoride, Stannous fluoride
13. Antimony(V) chlorate, Stibbinic chlorate
14. Lead(IV) sulphate, Plumbic sulphate
16. Platinum(IV) oxide, Plantinic oxide
17. Zinc phosphide
18. Tin(IV) bisulphate, Stannic bisulphate
19. Gold(III) oxide, Auric oxide
20. Bismuth(V) borate, Bismuthic borate
21. Nickel(III) nitride, Nickelic nitride
22. Titanium(IV) oxide, Titanic oxide
23. Vanadium(II) sulphate, Vanadinous sulphate
24. Chromium(III) dihydrogen phosphate, Chromic dihydrogen phosphate
25. Tungsten(IV) permanganate
26. Uranium(IV) oxide, Uranic oxide
27. Plutonium(V) oxide
28. Iron(III) bicarbonate, Ferric bicarbonate
29. Mercury(I) iodide, Mercurous iodide

Given the names below provide the correct IUPAC formulas.

1. $CrCl_2$
2. $Fe(NO_3)_3$
3. $Pb(OH)_4$
4. $Co(HSO_4)_2$
5. $NiBO_3$
6. Cu_2SO_4
7. $CuHPO_4$
8. $HgBr$
9. $Bi_2(CO_3)_5$
10. $Sn(HCO_3)_2$
11. HgO
12. $PbCl_2$
16. $CrSO_4$
17. Mn_3P_4
18. Fe_2S_3
19. $CoCr_2O_7$
20. NiN
21. $CuCN$
22. $ZnCO_3$
23. $Cd_3(PO_4)_2$
24. HgI_2
25. $Au(MnO_4)_3$
26. $Pt(CH_3COO)_2$
27. $V_2(CrO_4)_5$

13. BiF_3
14. $Pb(NO_3)_4$
15. $Sn(HSO_4)_4$
28. $Al_2(HPO_4)_3$
29. $U(NO_3)_5$
30. AgOH

17. Nomenclature 3

Using the formulas below come up with the correct IUPAC names.

1. $NaNO_2$
2. $Ti(SO_3)_2$
3. $NiPO_3$
4. Ag_3AsO_4
5. $Sn(BrO_2)_2$
6. $Be(MnO_4)_2$
7. Li_2CrO_3
8. $KClO_4$
9. NaClO
10. $Ca(IO_4)_2$
11. $Bi(IO)_5$
12. $Tl(NO_3)_3$
13. $PbSO_4$
14. K_2SO_3
15. $Ca_3(PO_4)_2$
16. Hg_3AsO_3
17. $Cr(BrO_3)_6$
18. Li_2MnO_4
19. $Tc(ClO_3)_7$
20. $Ba(IO_2)_2$
21. $NaBrO_3$
22. $Ni(MnO_4)_3$
23. $AuClO_2$
24. $Co(IO_3)_3$
25. $Ba_3(PO_3)_2$
26. Mg_3AsO_4
27. $Zn(ClO_3)_2$
28. $Cd(NO_2)_2$
29. Ag_2SO_4
30. $LiBrO_2$
31. $TlPO_3$
32. $Bi(NO_3)_5$
33. $Ti(BrO_2)_4$
34. $Co_2(SO_3)_3$
35. $Fe_3(AsO_3)_2$
36. $AlPO_4$
37. $Sn(IO_3)_4$
38. $Tc(IO)_7$
39. $Al(IO_2)_3$
40. $Pb(CrO_3)_2$

Given the names below provide the correct IUPAC formulas.

1. Calcium nitrite
2. Iron (II) sulphite
3. Beryllium phosphate
4. Cobaltous sulphate
5. Tin (II) hypoiodite
6. Barium phosphate
7. Potassium hypochlorite
8. Aurous arsenite
9. Plumbic chlorate
10. Silver nitrate
11. Titanium (IV) phosphite
12. Potassium chromate
13. Cadmium perchlorate
14. Mercury (II) phosphate
15. Chromium (VI) iodite
16. Nickel (III) chromite
17. Silver tungstate
18. Aluminum bromite
19. Tin(II) arsenate
20. Bismuth (V) hypochlorite
21. Mercurous bromate
22. Chromium (II) periodate
23. Barium bromite
24. Lithium perchlorate
25. Bismuthous nitrite
26. Calcium sulphite
27. Chromium (VI) nitrate
28. Gold (III) sulphate
29. Beryllium arsenate
30. Aluminum hypochlorite
31. Potassium iodate
32. Thallium (III) sulphate
33. Mercuric nitrite
34. Cadmium arsenite
35. Magnesium bromate
36. Aluminum chlorite
37. Strontium tellurite
38. Magnesium chlorate
39. Zinc chlorite
40. Thalium (III) iodite

19. Answers - Nomenclature 3

Using the formulas below come up with the correct IUPAC names.

1. Sodium nitrite
2. Titanium(IV) sulphite, Titanic sulphite
3. Nickel(III) phosphate, Nickelic phosphite
4. Silver arsenate
5. Tin(II) bromite, Stannous bromite
6. Beryllium permanganate
7. Lithium chromite
8. Potassium perchlorate
9. Sodium hypochlorite
10. Calcium periodate
11. Bismuth(V) hypoiodite, Bismuthic hypoiodite
12. Thallium(III) nitrate, Thallic nitrate
13. Lead(II) sulphate, Plumbus sulphate
14. Potassium sulphite
15. Calcium phosphate
16. Mercury(I) arsenite, Mercurous arsentite
17. Chromium(VI) bromate
18. Lithium permanganate
19. Technicium chlorate
20. Barium iodite
21. Sodium bromate
22. Nickel(III) permanganate, Nickelic permanganate
23. Gold(I) chlorite, Aurous chlorite
24. Cobalt(III) iodate, Cobaltic iodate
25. Barium phosphate
26. Magnesium arsenate
27. Zinc chlorate
28. Cadmium nitrite
29. Silver sulphate
30. Lithium bromite
31. Thallium(III) phosphate, Thallic phosphite
32. Bismuth(V) nitrate, Bismuthic nitrate
33. Titanium(IV) bromite, Titanic bromite
34. Cobalt(III) sulphite, Cobaltic sulphite
35. Iron(II) arsenite, Ferrous arsenite
36. Aluminum phosphate
37. Tin(IV) iodate, Stannic iodate
38. Technicium hypoiodite
39. Aluminum iodite
40. Lead(IV) chromite, Plumbic chromite

Given the names below provide the correct IUPAC formulas

1. $Ca(NO_3)_2$
2. $FeSO_3$
3. $Be_3(PO_4)_2$
4. $CoSO_4$
5. $Sn(IO)_2$
6. $Ba_3(PO_4)_2$
7. $KClO$
8. Au_3AsO_3
9. $Pb(ClO_3)_4$
10. $AgNO_3$
11. $Ti_3(PO_3)_4$
12. K_2CrO_4
13. $Cd(ClO_4)_2$
14. $Hg_3(PO_4)_2$
15. $Cr(IO_2)_6$
16. $Ni_2(CrO_3)_3$
17. Ag_2WO_4
18. $Al(BrO_2)_3$
19. $Sn_3(AsO_4)_2$
20. $Bi(ClO)_5$
21. $HgBrO_3$
22. $Cr(IO_4)_2$
23. $Ba(BrO_2)_2$
24. $LiClO_4$
25. $Bi(NO_2)_3$
26. $CaSO_3$
27. $Cr(NO_3)_6$
28. $Au_2(SO_4)_3$
29. $Be_3(AsO_4)_2$
30. $Al(ClO)_3$
31. KIO_3
32. $Tl_2(SO_4)_3$
33. $Hg(NO_2)_2$
34. $Cd_3(AsO_3)_2$
35. $Mg(BrO_3)_2$
36. $Al(ClO_2)_3$
37. $SrTeO_3$
38. $Mg(ClO_3)_2$
39. $Zn(ClO_2)_2$
40. $Tl(IO_2)$

21. Nomenclature 4

Using the formulas below come up with the correct IUPAC names.

1. HF
2. HI
3. HCN
4. H_3PO_3
5. H_3AsO_3
6. H_2SO_4
7. H_2CrO_3
8. $HBrO_3$
9. HNO_3
10. $HClO_3$
11. HIO_3
12. $HClO_3$

Given the names below provide the correct IUPAC formulas.

1. Hydrochloric acid
2. Hydrobromic acid
3. Phosphoric acid
4. Arsenic acid
5. Carbonic acid
6. Sulphurous acid
7. Chromous acid
8. Cyanic acid
9. Nitrous acid
10. Perchloric acid
11. Acetic acid
12. Iodous acid

22. Answers - Nomenclature 4

Using the formulas below come up with the correct IUPAC names.

1. hydrofluoric acid
2. hydroiodic acid
3. cyanic acid
4. phosphorous acid
5. Arsenious acid
6. sulphuric acid
7. chromic acid
8. bromous acid
9. nitric acid
10. chlorous acid
11. iodous acid
12. chloric acid

Given the names below provide the correct IUPAC formulas.

1. HCl
2. HBR
3. H_3PO_4
4. H_3AsO_4
5. HCO_3
6. H_2SO_3
7. H_2CrO_2
8. HCN
9. HNO_2
10. $HClO_4$
11. CH_3COOH
12. HIO_2

24. Simple Sight Equations and Word Equations

1. When sulphur trioxide (SO_3), which is present in smoggy air in trace concentrations, reacts with water, sulphuric acid (H_2SO_4), a very corrosive acid, forms as the only product. Write a balanced equation for this reaction and describe its stoichiometry in words.
2. Write the equation that expresses in acceptable chemical shorthand the information given in the statement, "Iron can be made to react with molecular oxygen to give iron oxide having the formula Fe_2O_3."
3. Balance the following skeleton equations:

   (a) $SO_2 + O_2 \text{--->} SO_3$ (e) $N_2 + H_2 \text{---->} NH_3$

   (b) $Mg + O_2 \text{-->} MgO$ (f) $P + O_2 \text{------->} P_4O_{10}$

   (c) $NO + O_2 \text{--->} NO_2$ (g) $KClO_4 \text{-------->} KCl + O_2$

   (d) $HgO \text{-------->} Hg + O_2$ (h) $PbO_2 \text{-------->} PbO + O_2$
4. Write the balanced equation for the formation of table salt, NaCl (sodium chloride), from sodium (Na), and gaseous chlorine (Cl_2).
5. Although bright and shiny, aluminum objects are covered with a tight, invisible coating of aluminum oxide, (Al_2O_3) that forms when freshly exposed aluminum (Al) reacts with oxygen. Write the balanced equation for this reaction.
6. Balance these equations.

   a) $Sn(s) + O_2(g) \text{----->} SnO(s)$

   b) $Ca(s) + Br_2(g) \text{---->} CaBr_2(s)$

   c) $P_4(s) + Cl_2(g) \text{---->} PCl_5(g)$

   d) $C(s) + O_2(g) \text{---->} CO_2(g)$
7. Balance the following equations.

   a) $Zn + S \text{----->} ZnS$ e) $Na + O_2 \text{----->} Na_2O$

   b) $H_2 + P \text{----->} PH_3$ f) $O_2 \text{----->} O_3$

   c) $As + O_2 \text{----->} As_2O_3$ g) $As + H_2 \text{----->} AsH_3$

   d) $H_2 + S \text{----->} H_2S$ h) $Sb + O_2 \text{----->} Sb_2O_3$

25. Answers - Simple Sight Equations and Word Equations

1. $H_2O + SO_3 \text{----->} H_2SO_4$

2. $4\ Fe + 3\ O_2 \text{---->} Fe_2O_3$

3. (a) $2\ SO_2 + O_2 \text{--->} 2\ SO_3$ (e) $N_2 + 3\ H_2 \text{---->} 2\ NH_3$

   (b) $2\ Mg + O_2 \text{-->} 2\ MgO$ (f) $4\ P + 5\ O_2 \text{------->} P_4O_{10}$

   (c) $2\ NO + O_2 \text{--->} 2\ NO_2$ (g) $KClO_4 \text{-------->} KCl + 2\ O_2$

   (d) $2\ HgO \text{-------->} 2\ Hg + O_2$ (h) $2\ PbO_2 \text{-------->} 2\ PbO + O_2$

4. $2\ Na + Cl_2 \text{------->} 2\ NaCl$

5. $4\ Al + 3\ O_2 \text{------>} 2\ Al_2O_3$

6. a) $2\ Sn(s) + O_2(g) \text{----->} 2\ SnO(s)$

   b) $Ca(s) + Br_2(g) \text{---->} CaBr_2(s)$

   c) $P_4(s) + 10\ Cl_2(g) \text{---->} 4\ PCl_5(g)$

   d) $C(s) + O_2(g) \text{---->} CO_2(g)$

7. Balance the following equations.

   a) $Zn + S \text{----->} ZnS$ e) $4\ Na + O_2 \text{----->} 2\ Na_2O$

   b) $3\ H_2 + 2\ P \text{----->} 2\ PH_3$ f) $3\ O_2 \text{----->} 2\ O_3$

   c) $4\ As + 3\ O_2 \text{----->} 2\ As_2O_3$ g) $2\ As + 3\ H_2 \text{----->} 2\ AsH_3$

   d) $H_2 + S \text{----->} H_2S$ h) $4\ Sb + 3\ O_2 \text{----->} 2\ Sb_2O_3$

27. Balancing More Complex Reactions

1. Balance the following equations and state their type:

(a) $Ca(OH)_2$ + HCl -----> $CaCl_2$ + H_2O

(b) $AgNO_3$ + $CaCl_2$ -----> $Ca(NO_3)_2$ + AgCl

(c) Fe_2O_3 + C ------> Fe + CO_2

(d) P_4O_{10} + H_2O -------> H_3PO_4

(e) $Pb(NO_3)_2$ + Na_2SO_4 ------> $PbSO_4$ + $NaNO_3$

(f) Fe_2O_3 + H_2 ------> Fe + H_2O

(g) Al + H_2SO_4 ------> $Al_2(SO_4)_3$ + H_2

2. Balance the following equations and state their type:

(a) $Mg(OH)_2$ + HBr ------> $MgBr_2$ + H_2O

(b) Al_2O_3 + H_2SO_4 ------> $Al_2(SO_4)_3$ + H_2O

(c) $KHCO_3$ + H_3PO_4 ------> K_2HPO_4 + H_2O + CO_2

(d) C_9H_{20} + O_2 --------> CO_2 + H_2O

3. Balance the following equations and state their type:

(a) CaO + HNO_3 ------> $Ca(NO_3)_2$ + H_2O

(b) Na_2CO_3 + $Mg(NO_3)_2$ -----> $MgCO_3$ + $NaNO_3$

(c) $(NH_4)_3PO_4$ + NaOH ------> Na_3PO_4 + NH_3 + H_2O

(d) $LiHCO_3$ + H_2SO_4 ------> Li_2SO_4 + H_2O + CO_2

(e) C_4H_{10} + O_2 --------> CO_2 + H_2O

(f) CH_4 + Cl_2 -----> CCl_4 + HCl

(g) NaOH + H_2SO_4 -------> Na_2SO_4 + H_2O

(h) CH_4 + O_2 ------> CO_2 + H_2O

(i) $Al(OH)_3$ + H_2SO_4 ------> $Al_2(SO_4)_3$ + H_2O

(j) $Ca(NO_3)_2(aq)$ + $Na_2CO_3(aq)$ ------> $CaCO_3(aq)$ + $NaNO_3(aq)$

4. Balance the following equations and state their type:

(a) Fe_2O_3 + HNO_3 ------> $Fe(NO_3)_3$ + H_2O

(b) $C_{21}H_{30}O_2$ + O_2 -----> CO_2 + H_2O

(c) H_2S + SO_2 -----> S + H_2O

(d) $KClO_3$ + heat ------> KCl + O_2

(e) $CaCO_3(s)$ --------> $CaO(s)$ + $CO_2(g)$

(f) $Al_4C_3(s)$ + $H_2O(l)$ -------> $CH_4(g)$ + $Al(OH)_3(s)$

(g) $Mg_3N_2(s)$ + $H_2O(l)$ -------> $NH_3(g)$ + $Mg(OH)_2(s)$

5. Balance these skeleton equations.

(a) $Al(s)$ + $Fe_2O_3(s)$ ------> $Al_2O_3(s)$ + $Fe(s)$

(b) $Ca(OH)_2(aq)$ + $HNO_3(aq)$ ------> $Ca(NO_3)_2(aq)$ + $H_2O(l)$

(c) $Cr_2(SO_4)_3(aq)$ + $NaOH(aq)$ ------> $Cr(OH)_3(s)$ + $Na_2SO_4(aq)$

(d) $Cu(s)$ + $AgNO_3(aq)$ -------> $Cu(NO_3)_2(aq)$ + $Ag(s)$

(e) $CH_4(g)$ + $O_2(g)$ ------> $CO_2(g)$ + $H_2O(g)$

(f) $C_2H_6(g)$ + $O_2(g)$ ------> $CO_2(g)$ + $H_2O(l)$

(g) $SiO_2(s)$ + $HF(g)$ ------> $SiF_4(g)$ + $H_2O(l)$

(h) $MgO(s)$ + $H_3PO_4(aq)$ -------> $Mg_3(PO_4)_2(s)$ + $H_2O(l)$

(i) $NaBr(aq)$ + $Cl_2(g)$ --------> $Br_2(l)$ + $NaCl(aq)$

(j) $Sb_2S_3(s)$ + $HCl(aq)$ ------> $H_3SbCl_6(aq)$ + $H_2S(g)$

(k) $Fe_3O_4(s)$ + $H_2(g)$ -------> $Fe(s)$ + $H_2O(l)$

(l) $HgO(s)$ -------> $Hg(l)$ + $O_2(g)$

6. Balance the following chemical equation (All reactants and products are given):

(a) C_3H_8 + O_2 -------> CO_2 + H_2O

(b) Al_2O_3 + HCl --------> $AlCl_3$ + H_2O

(c) F_2 + H_2O ----------> HF + O_2

(d) Fe_2O_3 + CO --------> Fe_3O_4 + CO_2

(e) PH_3 + O_2 -------> P_4O_{10} + H_2O

(f) CO_2 + Al -------> Al_2O_3 + C

(g) F_2 + C_3H_8O -----> HF + CF_4 + O_2

(h) $CaCN_2$ + H_2O ------> NH_3 + $CaCO_3$

(i) MnO_2 + HCl ------> $MnCl_2$ + Cl_2 + H_2O

(j) NH_3 + O_2 ------> NO + H_2O

(k) FeS + O_2 -----> Fe_2O_3 + SO_3

(l) Fe_2O_3 + H_2O ---------> $Fe(OH)_3$

(m) H_2S + SO_2 --------> S + H_2O

(n) $CuFeS_2$ + O_2 ------> Cu + FeO + SO_2

(o) ZnS + O_2 -----> ZnO + SO_2

28. Answers - Balancing More Complex Reactions

1. (a) $Ca(OH)_2$ + 2 HCl -----> $CaCl_2$ + 2 H_2O (metathesis)
   (b) 2 $AgNO_3$ + $CaCl_2$ -----> $Ca(NO_3)_2$ + 2 AgCl (metathesis)
   (c) 2 Fe_2O_3 + 3 C ------> 4 Fe + 3 CO_2 (single displacement)
   (d) P_4O_{10} + 6 H_2O -------> 4 H_3PO_4 (combination)
   (e) $Pb(NO_3)_2$ + Na_2SO_4 ------> $PbSO_4$ + 2 $NaNO_3$ (metathesis)
   (f) Fe_2O_3 + 3 H_2 ------> 2 Fe + 3 H_2O (single displacement)
   (g) 2 Al + 3 H_2SO_4 ------> $Al_2(SO_4)_3$ + 3 H_2 (single displacement)

2. (a) $Mg(OH)_2$ + 2 HBr ------> $MgBr_2$ + 2 H_2O (metathesis)
   (b) Al_2O_3 + 3 H_2SO_4 ------> $Al_2(SO_4)_3$ + 3 H_2O (metathesis)
   (c) 2 $KHCO_3$ + H_3PO_4 ------> K_2HPO_4 + 2 H_2O + 2 CO_2 (metathesis)(decomposition)
   (d) C_9H_{20} + 14 O_2 --------> 9 CO_2 + 10 H_2O (metathesis)(combustion)

3. (a) CaO + 2 HNO_3 ------> $Ca(NO_3)_2$ + H_2O (metathesis)
   (b) Na_2CO_3 + $Mg(NO_3)_2$ -----> $MgCO_3$ + 2 $NaNO_3$ (metathesis)
   (c) $(NH_4)_3PO_4$ + 3 NaOH ------> Na_3PO_4 + 3 NH_3 + 3 H_2O (metathesis) (decomposition)
   (d) 2 $LiHCO_3$ + H_2SO_4 ------> Li_2SO_4 + 2 H_2O + 2 CO_2 (metathesis)(decomposition)
   (e) 2 C_4H_{10} + 13 O_2 --------> 8 CO_2 + 10 H_2O (metathesis)(combustion)
   (f) CH_4 + 4 Cl_2 -----> CCl_4 + 4 HCl (metathesis)
   (g) 2 NaOH + H_2SO_4 -------> Na_2SO_4 + 2 H_2O (metathesis)
   (h) CH_4 + 2 O_2 ------> CO_2 + 2 H_2O (metathesis)(combustion)
   (i) 2 $Al(OH)_3$ + 3 H_2SO_4 ------> $Al_2(SO_4)_3$ + 6 H_2O (metathesis)
   (j) $Ca(NO_3)_2$(aq) + Na_2CO_3(aq) ------> $CaCO_3$(aq) + 2 $NaNO_3$(aq) (metathesis)

4. (a) Fe_2O_3 + 6 HNO_3 ------> 2 $Fe(NO_3)_3$ + 3 H_2O (metathesis)
   (b) 2 $C_{21}H_{30}O_2$ + 55 O_2 -----> 42 CO_2 + 30 H_2O (metathesis)
   (c) 2 H_2S + SO_2 -----> 3 S + 2 H_2O (metathesis)
   (d) 2 $KClO_3$ + heat ------> 2 KCl + 3 O_2 (decomposition)
   (e) $CaCO_3$(s) --------> CaO(s) + CO_2(g) (decomposition)
   (f) Al_4C_3(s) + 12 H_2O(l) -------> 3 CH_4(g) + 4 $Al(OH)_3$(s) (metathesis)
   (g) Mg_3N_2(s) + 6 H_2O(l) -------> 2 NH_3(g) + 3 $Mg(OH)_2$(s) (metathesis)

5. (a) 2 Al(s) + Fe_2O_3(s) ------> Al_2O_3(s) + 2 Fe(s)
   (b) $Ca(OH)_2$(aq) + 2 HNO_3(aq) ------> $Ca(NO_3)_2$(aq) + 2 H_2O(l)
   (c) $Cr_2(SO_4)_3$(aq) + 6 NaOH(aq) ------> 2 $Cr(OH)_3$(s) + 3 Na_2SO_4(aq)
   (d) Cu(s) + 2 $AgNO_3$(aq) -------> $Cu(NO_3)_2$(aq) + 2 Ag(s)
   (e) CH_4(g) + 2 O_2(g) ------> CO_2(g) + 2 H_2O(g)
   (f) 2 C_2H_6(g) + 7 O_2(g) ------> 4 CO_2(g) + 6 H_2O(l)
   (g) SiO_2(s) + 4 HF(g) ------> SiF_4(g) + 2 H_2O(l)
   (h) 3 MgO(s) + 2 H_3PO_4(aq) -------> $Mg_3(PO_4)_2$(s) + 3 H_2O(l)
   (i) 2 NaBr(aq) + Cl_2(g) --------> Br_2(l) + 2 NaCl(aq)
   (j) Sb_2S_3(s) + 12 HCl(aq) ------> 2 H_3SbCl_6(aq) + 4 H_2S(g)
   (k) Fe_3O_4(s) + 4 H_2(g) -------> 3 Fe(s) + 4 H_2O(l)

(l) 2 HgO(s) -------> 2 Hg(l) + O_2(g)

6. (a) C_3H_8 + 5 O_2 -------> 3 CO_2 + 4 H_2O
   (b) Al_2O_3 + 6 HCl --------> 2 $AlCl_3$ + 3 H_2O
   (c) 2 F_2 + 2 H_2O ----------> 4 HF + O_2
   (d) 3 Fe_2O_3 + CO --------> 2 Fe_3O_4 + CO_2
   (e) 4 PH_3 + 8 O_2 -------> P_4O_{10} + 6 H_2O
   (f) 3 CO_2 + 4 Al -------> 2 Al_2O_3 + 3 C
   (g) 20 F_2 + 2 C_3H_8O -----> 16 HF + 6 CF_4 + O_2
   (h) $CaCN_2$ + 3 H_2O ------> 2 NH_3 + $CaCO_3$
   (i) MnO_2 + 4 HCl ------> $MnCl_2$ + Cl_2 + 2 H_2O
   (j) 4 NH_3 + 5 O_2 ------> 4 NO + 6 H_2O
   (k) 4 FeS + 9 O_2 -----> 2 Fe_2O_3 + 4 SO_3
   (l) Fe_2O_3 + H_2O ---------> $Fe(OH)_3$
   (m) 2 H_2S + SO_2 --------> 3 S + 2 H_2O
   (n) 2 $CuFeS_2$ + 5 O_2 ------> 2 Cu + 2 FeO + 4 SO_2
   (o) 2 ZnS + 3 O_2 -----> 2 ZnO + 2 SO_2

29. Extra Balancing Practice Questions

1. Balance the following equations

a) KNO_3 ---------> KNO_2 + O_2

b) CaC_2 + O_2 ----------> Ca + CO_2

c) C_5H_{12} + O_2 ----------> CO_2 + H_2O

d) K_2SO_4 + $BaCl_2$ ----------> KCl + $BaSO_4$

e) KOH + H_2SO_4 ----------> K_2SO_4 + H_2O

f) $Ca(OH)_2$ + NH_4Cl ----------> NH_4OH + $CaCl_2$

g) C + SO_2 ----------> CS_2 + CO

h) V_2O_5 + Ca ----------> CaO + V

i) Na_2O_2 + H_2O ----------> NaOH + O_2

j) Fe_3O_2 + H_2 ----------> Fe + H_2O

k) Cu + H_2SO_4 ----------> $CuSO_4$ + H_2O + SO_2

l) Al + H_2SO_4 ----------> H_2 + $Al_2(SO_4)_3$

m) Si_4H_{10} + O_2 ----------> SiO_2 + H_2O

n) NH_3 + O_2 ----------> N_2H_4 + H_2O

o) $C_{15}H_{30}$ + O_2 ----------> CO_2 + H_2O

p) BN + F_2 ----------> BF_3 + N_2

q) $CaSO_4 \cdot 2\,H_2O$ + SO_3 ----------> $CaSO_4$ + H_2SO_4

r) $C_{12}H_{26}$ + O_2 ----------> CO_2 + H_2O

2. Balance the following equations

a) $C_7H_6O_3$ + O_2 --------------> CO_2 + H_2O

b) Na + ZnI_2 --------------> NaI + $NaZn_4$

c) $HBrO_3$ + HBr --------------> H_2O + Br_2

d) Al_4C_3 + H_2O --------------> $Al(OH)_3$ + CH_4

e) $Ca(NO_3)_2 \cdot 3H_2O$ + LaC_2 --------------> $Ca(NO_3)_2$ + $La(OH)_2$ + C_2H_2

f) CH_3NO_2 + Cl_2 --------------> CCl_3NO_2 + HCl

g) $Ca_3(PO_4)_2$ + SiO_2 + C --------------> $CaSiO_3$ + CO + P

h) Al_2C_6 + H_2O --------------> $Al(OH)_3$ + C_2H_2

i) NaF + CaO + H_2O --------------> CaF_2 + NaOH

j) LiH + $AlCl_3$ --------------> $LiAlH_4$ + LiCl

k) CaF_2 + + H_2SO_4 + SiO_2 --------------> $CaSO_4$ + SiF_4 + H_2O

l) $CaSi_2$ + $SbCl_3$ --------------> Si + Sb + H_2O

m) TiO_2 + B_4C + C --------------> TiB_2 + CO

n) NH_3 + O_2 --------------> NO + H_2O

o) NH_4Cl + CaO --------------> NH_3 + $CaCl_2$ + H_2O

p) NaPb + C_2H_5Cl --------------> $Pb(C_2H_5)_4$ + Pb + NaCl

q) Be_2C + H_2O --------------> $Be(OH)_2$ + CH_4

r) NpF_3 + O_2 --------------> NpF_4 + H_2O

s) NO_2 + H_2O --------------> HNO_3 + NO

t) $LiAlH_4$ + BF_3 --------------> LiF + AlF_3 + B_2H_6

30. Answers - Extra Balancing Practice Questions-Answers

1. Balance the following equations

a) 2 KNO_3 ---------> 2 KNO_2 + O_2

b) CaC_2 + 2 O_2 ----------> Ca + 2 CO_2

c) C_5H_{12} + 8 O_2 ----------> 5 CO_2 + 6 H_2O

d) K_2SO_4 + $BaCl_2$ ----------> 2 KCl + $BaSO_4$

e) 2 KOH + H_2SO_4 ----------> K_2SO_4 + 2 H_2O

f) $Ca(OH)_2$ + 2 NH_4Cl ----------> 2 NH_4OH + $CaCl_2$

g) 5 C + 2 SO_2 ----------> CS_2 + 4 CO

h) V_2O_5 + 5 Ca ----------> 5 CaO + 2 V

i) Na_2O_2 + H_2O ----------> 2 NaOH + O_2

j) Fe_3O_2 + 2 H_2 ----------> 3 Fe + 2 H_2O

k) Cu + 2 H_2SO_4 ----------> $CuSO_4$ + 2 H_2O + SO_2

l) 2 Al + 3 H_2SO_4 ----------> 3 H_2 + $Al_2(SO_4)_3$

m) 2 Si_4H_{10} + 13 O_2 ----------> 8 SiO_2 + 10 H_2O

n) 4 NH_3 + O_2 ----------> 2 N_2H_4 + 2 H_2O

o) 2 $C_{15}H_{30}$ + 45 O_2 ----------> 30 CO_2 + 30 H_2O

p) 2 BN + 3 F_2 ----------> 2 BF_3 + N_2

q) $CaSO_4 \cdot 2 H_2O$ + SO_3 ----------> $CaSO_4$ + 2 H_2SO_4

r) 2 $C_{12}H_{26}$ + 37 O_2 ----------> 24 CO_2 + 26 H_2O

2. Balance the following equations

a) $C_7H_6O_3$ + 7 O_2 --------------> 7 CO_2 + 3 H_2O

b) 9 Na + 4 ZnI_2 --------------> 8 NaI + $NaZn_4$

c) $HBrO_3$ + 5 HBr --------------> 3 H_2O + 3 Br_2

d) Al_4C_3 + 12 H_2O --------------> 4 $Al(OH)_3$ + 3 CH_4

e) 2 $Ca(NO_3)_2 \cdot 3H_2O$ + 3 LaC_2 --------------> 2 $Ca(NO_3)_2$ + 3 $La(OH)_2$ + 3 C_2H_2

f) CH_3NO_2 + 3 Cl_2 --------------> CCl_3NO_2 + 3 HCl

g) $Ca_3(PO_4)_2$ + 3 SiO_2 + 5 C --------------> 3 $CaSiO_3$ + 5 CO + 2 P

h) Al_2C_6 + 6 H_2O --------------> 2 $Al(OH)_3$ + 3 C_2H_2

i) 2 NaF + CaO + H_2O --------------> CaF_2 + 2 NaOH

j) 4 LiH + $AlCl_3$ --------------> $LiAlH_4$ + 3 LiCl

k) 2 CaF_2 + 2 H_2SO_4 + SiO_2 --------------> 2 $CaSO_4$ + SiF_4 + 2 H_2O

l) 3 $CaSi_2$ + 2 $SbCl_3$ --------------> 6 Si + 2 Sb + 3 H_2O

m) 2 TiO_2 + B_4C + 3C --------------> 2 TiB_2 + 4 CO

n) 4 NH_3 + 5 O_2 --------------> 4 NO + 6 H_2O

o) 2 NH_4Cl + CaO --------------> 2 NH_3 + $CaCl_2$ + H_2O

p) 4 NaPb + 4 C_2H_5Cl --------------> $Pb(C_2H_5)_4$ + 3 Pb + 4 NaCl

q) Be_2C + 4 H_2O --------------> 2 $Be(OH)_2$ + CH_4

r) 4 NpF_3 + O_2 --------------> 4 NpF_4 + 2 H_2O

s) 3 NO_2 + H_2O --------------> 2 HNO_3 + NO

t) 3 $LiAlH_4$ + 4 BF_3 --------------> 3 LiF + 3 AlF_3 + 2 B_2H_6

32. Translating English into Chemistry
Write each of the following as a balanced equation.

1. Iron can be produced from iron ore, Fe_2O_3, by reacting the ore with carbon monoxide, CO. Carbon dioxide is also produced.

2. Sodium hydroxide or caustic soda, NaOH, used in many household drain cleaners, can be prepared by the reaction of calcium hydroxide, $Ca(OH)_2$, with sodium carbonate, Na_2CO_3. Calcium carbonate, $CaCO_3$ is also formed in this reaction.

3. Lead(II) chloride reacts with sodium chromate to form a precipitate of lead(II) chromate and another product.

4. You may have seen the thick haze commonly found over highly industrial areas. One of the substances responsible for this is ammonium sulphate, $(NH_4)_2SO_4$, which forms in the air by the reaction between ammonia, NH_3, and sulphuric acid, H_2SO_4.

5. Magnesium hydroxide, $Mg(OH)_2$, commonly called milk of magnesia, is often used to neutralize stomach acid, HCl. Write the balanced equation for the reaction if one of the products is water.

6. Carbon monoxide burns in oxygen to produce carbon dioxide.

7. When potassium chlorate, $KClO_3$, is strongly heated, it decomposes into potassium chloride and oxygen.

8. When calcium is added to water, calcium hydroxide is formed along with a gas.

9. The process of photosynthesis in plants produces glucose, $C_6H_{12}O_6$, and oxygen, from the raw materials carbon dioxide and water.

10. Magnesium reacts with sulphuric acid, forming magnesium sulphate and releasing hydrogen gas.

11. Ammonia gas and hydrogen chloride gas react to form ammonium chloride, a white solid.

12. Sulphur dioxide, formed during the burning of sulphur containing coal, may be removed from smokestack gases by passing the gases over solid calcium oxide. Calcium sulphite is formed in this reaction.

13. If a bottle of hydrogen peroxide solution, H_2O_2, is left to stand at room temperature, oxygen gas is slowly released. After a period of time, the bottle contains only water.

14. In some water treatment plants, solutions of aluminum sulphate and calcium hydroxide are added to the water. A "sticky" precipitate of aluminum hydroxide forms. This sticky substance removed some of the small particles in the water as it settles to the bottom. There is another substance produced as well.

33. Answers - Translating English into Chemistry
Write each of the following as a balanced equation.

1) Fe_2O_3 + 3 CO ----> 2 Fe + 3 CO_2
2) $Ca(OH)_2$ + Na_2CO_3 -----> 2 NaOH + $CaCO_3$
3) $PbCl_2$ + Na_2CrO_4 -----> $PbCrO_4$ + 2 NaCl
4) 2 NH3 + H_2SO_4 ---------> $(NH_4)_2SO_4$
5) $Mg(OH)_2$ + HCl ----------> $MgCl_2$ + 2 H_2O
6) 2 CO + O_2 ----> 2 CO_2
7) 2 $KClO_3$ ----> 2 KCl + 3 O_2
8) Ca + 2 H_2O ------> $Ca(OH)_2$ + H_2
9) 6 CO_2 + 6 H_2O --------> $C_6H_{12}O_6$ + 6 O_2
10) Mg + H_2SO_4 -------> $MgSO_4$ + H_2
11) NH_3 + HCl ------> NH_4Cl
12) SO_2 + CaO -----> $CaSO_3$
13) 2 H_2O_2 -------> 2 H_2O + O_2
14) $Al_2(SO_4)_3$ + 3 $Ca(OH)_2$ ----> 2 $Al(OH)_3$ + 3 $CaSO_4$

35. Isotope Calculations

1. What are the names, symbols, electrical charges, and masses (expressed in amu) of the three subatomic particles?
2. Where is nearly all of the mass of an atom located? Explain your answer in terms of what contributes to this mass.
3. Define the terms atomic number and mass number.
4. How are isotopes of the same element alike? How do they differ?
5. The composition of ordinary neon is: neon-20, 90.92 %; neon-21, 0.26 %; neon-22, 8.82 %. Calculate the average atomic mass of neon.
6. Natural lithium comes in only two isotopes of Li-6 (7.42%) and Li-7 (92.58%). Determine the average atomic mass for Lithium.
7. Boron occurs as two natural isotopes of B-10 (19.78%) and B-11 (80.22%). Determine the average atomic mass for boron.
8. Calculate the relative atomic mass of gallium given that the relative abundance of its two isotopes are: 60.5% of Ga-69 and 39.5% of Ga-71
9. Oxygen occurs as one major isotope and two minor isotopes. O-16 (99.759%) , O-17 (0.037%) and O-18 (0.204%). Calculate the average atomic mass of oxygen.
10. Iron has four isotopes; Fe-54 (5.82%); Fe-56 (91.66%); Fe-57 (2.19%) and Fe-58 (0.33%). Determine the average atomic mass for natural iron.
11. Nickel has five naturally occurring isotopes. We will exclude all the special isotopes synthetically made in nuclear reactors. The isotopes are:
    Ni-58 67.88% Ni-60 26.23% Ni-61 1.19% Ni-62 3.66% Ni-64 1.08%
    Calculate the average atomic mass of nickel.
12. Iridium (a metal rather like platinum) occurs with only two isotopes of mass number 191 and 193. The atomic weight of iridium is 192.2. Deduce the relative abundance of the two isotopes of this element.
13. A recently discovered element has been given the symbol RU (recently unknown). It has an average atomic mass of 255.84 amu. There are only two isotopes of RU, these being RU-253 and RU-259. Determine the relative percentages of these two isotopes.
14. Natural Rb consists solely of the isotopes Rb-85 and Rb-87. From the atomic mass of Rb (85.4678) calculate the relative percentages of these two isotopes.
15. There are only two naturally occurring isotopes of strettonium (St). There are St-335 and St-338. (The first person to make a joke about Strettonium being a heavy element will be summarily flogged.) St-335 makes up 69.00% of all know Strettonium. Determine the average atomic mass of Strettonium.

36. Answers to Isotope Calculation

1.

Name	Symbol	Charge	Mass
proton	p^+	+1	1 a.m.u.
neutron	n^0	0	1 a.m.u.
electron	e^-	-1	1/1837 a.m.u.

2. The nucleus, consisting of all the protons and neutrons.

3. The atomic number is the number of protons in the nucleus of any atom. It also represents the number of electrons in orbit around a neutral atom. The mass number is a calculated SUM. It is the total of the protons and neutrons in the nucleus.

4. Isotopes have the same number of protons and electrons and behave chemically the exact same way. Isotopes do have different number sof neutrons in their nuclei.

5. AAM = (90.92% x 20 u) + (0.26% x 21 u) + (8.82% x 22 u)
   = (0.9092 x 20 u) + (0.0026 x 21 u) + (0.0882 x 22 u)
   = 18.184 u + 0.0546 u + 1.9404 u
   = 20.18 u

6. AAM = (7.42% x 6 u) + (92.58% x 7 u)
   = (0.0742 x 6 u) + (0.9258 x 7 u)
   = 0.4452 u + 6.4806 u
   = 6.93 u

7. AAM = (19.78% x 10 u) + (80.22% x 11 u)
   = (0.1978 x 10 u) + (0.8022 x 11 u)
   = 1.978 u + 8.8242 u
   = 10.80 u

8. AAM = (60.5% x 69 u) + (39.5% x 71 u)
   = (0.605 x 69 u) + (0.395 x 71 u)
   = 41.745 u + 28.045 u

= 69.79 u

9. * AAM = (99.75% x 16 u) + (0.037% x 17 u) + (0.204% x 18 u)
= (0.9975 x 16 u) + (0.00037 x 17 u) + (0.00204% x 18 u)
= 15.9616 u + 0.00629 u + 0.03672
= 16.01 u

10. AAM = (5.82% x 54 u)+ (91.66% x 56 u) + (2.19% x 57 u) + (0.33% x 58 u)
= (0.0582 x 54 u)+ (0.9166 x 56 u) + (0.0219 x 57 u) + (0.0033 x 58 u)
= 3.1428 u + 51.3296 u + 1.2483 u + 0.1914 u
= 55.91 u

11. AAM = (67.88% x 58 u) + (26.23% x 60 u) + (1.19% x 61 u) + (3.66% x 62 u) +(1.08% x 64 u)
= (0.6788 x 58 u) + (0.2623 x 60 u) + (0.0119 x 61 u) + (0.0366 x 62 u) +(0.0108 x 64 u)
= 39.3704 u + 15.738 u + 0.7259 u + 2.2692 + 0.6912 u
= 58.79 u

12. 192.2 u = (a X 191 u) + ((1-a) X 193 u)
192.2 = 191a + 193 - 193a ('u' removed for clarity)
192.2 -193 = 191a -193a
-0.8 = -2a
a = -0.8/-2
a = 0.4 Therefore the isotope associated with 'a' (Ir-191) is 40% of the total
Ir-191 = 40%, Ir-193 = 60%

13. 255.84 = (a X 253u) + ((1-a) X 259u)
255.84 = 253a + 259 -259a ('u' removed for clarity)
255.84 - 259 = 253a - 259a
-3.16 = -6a
a = -3.16/-6
a = 0.52666 Therefore the isotope linked with 'a' (RU-253) is52.67% of the total
RU-253 =52.67%, RU-259 = 47.33%

14. 85.4698 = (a X 85u) + ((1-a) X 87 u)
85.4698 = 85a + 87 - 87a
85.4698 -87 = 85a-87a
-1.5302 = -2a
a = -1.5302/-2
a = 0.7651 Therefore the isotope associated with 'a' (Rb-85) is 76.51% of the total
Rb-85 = 76.51%, Rb-87 = 23.49%

15. AAM = (69% x 335 u) + (31% x 338 u)
= (0.69 x 335 u) + (0.31 x 338 u)
= 231.15 u + 104.78 u
= 335.93 u

37. Avogadro's Number and Moles

1. What are the units of molar mass?

2. The mass of 2.5 X 10^4 grapes is 50 kilograms, and that of an equal number of oranges is 1.2 X 10^3 kg. What is the mass ratio of a single single grape to a single orange?

3. A mole of carbon atoms has a mass of 12 grams, and a mole of magnesium atoms, 24 grams. What is the mass ratio of a single carbon atom to a single magnesium atom?

4. Aluminum and oxygen combine in a mass ratio of 9.00 to 8.00. If a flashbulb contains 5.4 X 10-^{3} grams of aluminum, what mass of oxygen must be present for complete combustion of the aluminum?

5. If there are 'x' atoms in 5 grams of carbon, how many atoms are there in 5 grams of silicon?

6. If 10 grams of iron contain 'y' atoms, how many grams of aluminum will contain 'y' atoms.

7. If 8 grams of oxygen contain 3.01 X 10^{23} atoms, calculate the number of atoms present in 2 grams of oxygen.

8. Using Avogadro's number, calculate the number of atoms in 0.005 kilograms of carbon.

38. Answers to Avogadro's Number and Moles

1. g/mol

2. 24 grapes are equavalent to 1 orange

3. C : Mg → 1 : 2

4. mass of Oxygen = 4.8 X 10^{-3} g

5. x = 0.43

6. x = 4.83 g of Al will contain 'y' atoms

7. 7.53 X 10^{22} atoms of oxygen

8. 2.51 X 10^{23} atoms

Grams, Moles and Molecular Mass

1. What is the mass of 0.100 mol of each of the substances given below:
   (a) Sodium carbonate, Na_2CO_3
   (b) Ammonium tetraborate, $(NH_4)_2B_4O_7$
   (c) Calcium cyclamate, $Ca(C_6H_{12}NSO_3)_2$
2. How many moles of sodium nitrate are in 1.70 grams of sodium nitrate, $NaNO_3$, a substance used in fertilizers and to make gunpowder.
3. Ammonium sulphate, $(NH_4)_2SO_4$, is a fertilizer used to supply both nitrogen and sulphur. How many grams of ammonium sulphate are in 35.8 moles of $(NH_4)_2SO_4$.
4. A 0.500 mol sample of table sugar, $C_{12}H_{22}O_{11}$, weighs how many grams?
5. A solution of zinc chloride, $ZnCl_2$, in water is used to soak the ends of wooden fenceposts to preserve them from rotting while they are stuck in the ground. One ratio used is 840 grams $ZnCl_2$ to 4 L water. How many moles of $ZnCl_2$ are in 840 grams of $ZnCl_2$?
6. In the early 1970s, thallium sulphate, Tl_2SO_4, a powerful poison, was illegally used in poison baits to control predators such as coyotes on western rangelands. Hundreds of eagles died after taking these baits. A 1.00 kilogram can of Tl_2SO_4 contains how many moles of this compound?
7. Borazon, one crystalline form of boron nitride, BN, is very likely the hardest of all substances. If one sample contains 3.02×10^{23} atoms of boron, how many atoms and how many grams of nitrogen are also in this sample?
8. If iodine is not in a person's diet, a thyroid condition called goitre develops. Iodized salt is all that it takes to prevent this disfiguring condition. Calcium iodate, $Ca(IO_3)_2$, is added to table salt to make iodized salt. How many atoms of iodine are in 0.500 moles of $Ca(IO_3)_2$? How many grams of calcium iodate are needed to supply this much iodine?
9. Ammonium carbonate,$(NH_4)_2CO_3$, is used as a fertilizer and to manufacture explosives. How many atoms of nitrogen are in 0.665 moles of this substance? How many grams of ammonium nitrate supply this much nitrogen?
10. Sodium perborate, $NaBO_3$, is present in "oxygen bleach". It acts by releasing oxygen, which has bleaching ability. How many grams of sodium perborate are in 4.65 moles of $NaBO_3$?
11. Barium sulphate, $BaSO_4$, is given to patients as a thick slurry in flavoured water before X-rays are taken of the intestinal tract. The barium blocks the X-rays, and the tract therefore casts a shadow that is seen on the x-ray film. How many grams are in 0.568 mole of barium sulphate.
12. Calculate the number of grams in 0.586 mole of each of the following substances?
    (a) Water, H_2O.
    (b) Glucose, $C_6H_{12}O_6$, a sugar in grape juice and honey.
    (c) Iron, Fe.
    (d) Methane, CH_4.
13. Calculate the number of moles of each substance in 100.0 grams of each of the following samples:
    (a) Ammonia, NH_3
    (b) Cholesterol, $C_{27}H_{46}O$
    (c) Gold, Au
    (d) Ethyl alcohol, C_2H_6O
14. Why does 100.0 grams of ammonia, NH_3, have so many more moles than 100.0 grams of cholesterol, $C_{27}H_{46}O$?
15. A sample of a compound with a mass of 204 grams consists of 1.00×10^{23} molecules. What is its formula weight?

Answers - Grams, Moles and Molecular Mass

1. (a) 10.60 grams of Na_2CO_3
   (b) 19.13 grams of $(NH_4)_2B_4O_7$
   (c) 39.66 grams of $Ca(C_6H_{12}NSO_3)_2$

2. 0.02 moles of $NaNO_3$

3. 47.31 kg of $(NH_4)_2SO_4$

4. 171.17 grams of $C_{12}H_{22}O_{11}$

5. 6.16 moles of $ZnCl_2$

6. 1.98 moles of Tl_2SO_4

7. 7.02 grams of N

8. a) 6.02 X 1023 atoms of I in 0.5 mol of $Ca(IO_3)_2$
   b) 194.94 grams of $Ca(IO_3)_2$

9. a) 3.99×10^{23} molecules
   b) 63.91 grams of $(NH_4)_2CO_3$

10. 380.37 grams of $NaBO_3$

11. 132.57 grams of $BaSO_4$

12. (a) 10.56 grams of H_2O
    (b) 105.59 grams of $C_6H_{12}O_6$
    (c) 32.73 grams of Fe atoms
    (d) 9.41 grams of CH_4

13. (a) 5.87 moles of NH_3
    (b) 0.26 moles of $C_{27}H_{46}O$
    (c) 0.51 moles of Au
    (d) 2.17 moles of C_2H_6O

14. Cholesterol has a higher molecular mass than ammonia.

15. 1228.08 grams/mole

39. Atomic Weights & Molar Masses Calculations

1. State the full meaning of the following:

   a) Fe b) $CuCl_2$ c) 2 Ca d) 4 $Fe_2(SO_4)_3$

2. How many atoms of hydrogen are represented in each of the following molecules?

   a) $KHCO_3$ b) H_2SO_4 c) C_3H_8 d) $HC_2H_3O_2$ e) $(NH_4)_2SO_4$ f) $(CH_3)_3COH$

3. Asbestos, a known cancer-causing agent, has a typical formula, $Ca_3Mg_5(Si_4O_{11})_2(OH)_2$. How many atoms of each element are given in the formula?
4. How many atoms of each kind are represented in the following formulas?

   a) Na_3PO_4 b) $Ca(H_2PO_4)_2$ c) C_4H_{10}

   d) $Fe_3(AsO_4)_2$ e) $Cu(NO_3)_2$ f) $MgSO_4$•$7H_2O$

5. How many atoms of each element are represented in the formula of cobalt(II) chloride hexahydrate?

   $CoCl_2$•$6H_2O$

6. Calculate the molecular weight (mass) of H_3PO_4 and $HClO_4$.
7. Calculate the molecular masses of:

   a) SO_2 b) P_4O_{10} c) UF_6 d) NH_3 e) CCl_4

8. Determine the molecular mass of these compounds:

   a) methane, CH_4 b) potassium perchlorate, $KClO_4$

   c) phosphorus trichloride, PCl_3 d) sulphuric acid, H_2SO_4

   e) silicon dioxide, SiO_2 f) nitrogen(IV) oxide, NO_2

   g) nitrogen(V) oxide, N_2O_5 h) glucose, $C_6H_{12}O_6$

9. What is the molecular weight of each of these common chemicals compounds?

   a) sodium bicarbonate, $NaHCO_3$ b) laughing gas, N_2O

   c) Potassium permanganate, $KMnO_4$ d) limestone, $CaCO_3$

   e) Epsom salts, $MgSO_4$•$7H_2O$ f) ozone, O_3

40. Answers to Atomic Weights & Molar Masses Calculations

1. a) Fe 1 atom of iron
   b) $CuCl_2$ 1 molecule of $CuCl_2$
   c) 2 Ca 2 atoms of calcium
   d) 4 $Fe_2(SO_4)_3$ 4 molecules of $Fe_2(SO_4)_3$

2. a) $KHCO_3$ H = 1
   b) H_2SO_4 H = 2
   c) C_3H_8 H = 8
   d) $HC_2H_3O_2$ H = 4
   e) $(NH_4)_2SO_4$ H = 8
   f) $(CH_3)_3COH$ H = 10

3. Ca = 3; Si = 8; H =2; Mg = 5; O = 24

4. a) Na_3PO_4 Na = 3; P = 1; O = 4
   b) $Ca(H_2PO_4)_2$ Ca = 1; H = 4; P = 2; O = 8
   c) C_4H_{10} C= 4; H = 10
   d) $Fe_3(AsO_4)_2$ Fe = 3; As = 2; O= 8
   e) $Cu(NO_3)_2$ Cu = 1; N = 2; O =6
   f) $MgSO_4 \cdot 7H_2O$ Mg = 1; S = 1; H =14; O = 11

5. $CoCl_2 \cdot 6H_2O$ Co = 1; Cl = 2; H = 12; O = 6

6. M of H_3PO_4 = 98.00 grams/mole and the M of $HClO_4$ = 100.46 grams/mole

7. a) SO_2 M = 64.07 grams/mole
   b) P_4O_{10} M = 283.88 grams/mole
   c) UF_6 M = 352.03 grams/mole
   d) NH_3 M = 17.04 grams/mole
   e) CCl_4 M = 153.81 grams/mole

8. a) methane, CH_4 M = 16.05 grams/mole
   b) potassium perchlorate, $KClO_4$ M = 138.55 grams/mole
   c) phosphorus trichloride, PCl_3 M = 137.32 grams/mole
   d) sulphuric acid, H_2SO_4 M = 98.07 grams/mole
   e) silicon dioxide, SiO_2 M = 60.09 grams/mole
   f) nitrogen(IV) oxide, NO_2 M = 46.01 grams/mole
   g) nitrogen(V) oxide, N_2O_5 M = 108.02 grams/mole
   h) glucose, $C_6H_{12}O_6$ M = 180.18 grams/mole

9. a) sodium bicarbonate, $NaHCO_3$ M = 84.01 grams/mole
   b) laughing gas, N_2O M = 44.02 grams/mole
   c) Potassium permanganate, $KMnO_4$ M = 158.04 grams/mole
   d) limestone, $CaCO_3$ M = 100.09 grams/mole
   e) Epsom salts, $MgSO_4 \cdot 7H_2O$ M = 246.51 grams/mole
   f) ozone, O_3 M = 48.00 grams/mole

43. Stoichiometric Gram to Gram Calculations

1. The combustion of a sample of butane, C_4H_{10} (lighter fluid), produced 2.46 grams of water.

   $2\ C_4H_{10} + 13\ O_2 \text{ -------> } 8\ CO_2 + 10\ H_2O$

   (a) How many moles of water formed?

   (b) How many moles of butane burned?

   (c) How many grams of butane burned?

   (d) How much oxygen was used up in moles? In grams?

2. Terephthalic acid, an important raw material for making Dacron, a synthetic fibre, is made from para-xylene by the following reaction.

   $C_8H_{10} + 3\ O_2 \xrightarrow{\text{special conditions}} C_8H_6O_4 + 2\ H_2O$

   para-xylene → terephthalic acid

   How much terephthalic acid could be made from 154 grams of para-xylene in moles? In grams?

3. Adipic acid, a raw material for nylon, is made industrially by the oxidation of cyclohexane.

   $5\ O_2 + 2\ C_6H_{12} \xrightarrow{\text{special conditions}} 2\ C_6H_{10}O_4 + 2\ H_2O$

   cyclohexane → adipic acid

   (a) How many moles of oxygen would be needed to make 40.0 moles of adipic acid by this reaction?

   (b) If 164 grams of cyclohexane is used, what is the theoretical yield of adipic acid in moles? In grams?

4. Aluminum oxide, Al_2O_3, a buffing powder, is to be made by combining 5.00 grams of aluminum with oxygen, O_2. How much oxygen is needed in moles? In grams?

5. Calculate how many grams of iron can be made from 16.5 grams of Fe_2O_3 by the following equation.

   $Fe_2O_3 + 3\ H_2 \text{ -------------> } 2\ Fe + 3\ H_2O$

6. Iodine chloride, ICl, can be made by the following reaction between iodine, I_2, potassium iodate, KIO_3, and hydrochloric acid.

   $2\ I_2 + KIO_3 + 6\ HCl \text{ ---------> } 5\ ICl + KCl + 3\ H_2O$

   Calculate how many grams of iodine are needed to prepare 28.6 grams of ICl by this reaction.

7. The nitrite ion (NO_2^-) in potassium nitrite is changed to the nitrate ion by the action of potassium permanganate ($KMnO_4$) in sulphuric acid solution.

   $5\ KNO_2 + 2\ KMnO_4 + 3\ H_2SO_4 \text{ ------> } 5\ KNO_3 + 2\ MnSO_4 + K_2SO_4 + 3\ H_2O$

   How many moles and how many grams of $KMnO_4$ are needed to carry out this reaction on 11.4 grams of KNO_2?

8. The chief component of glass is silica for which the formula SiO_2 can be used. Silica is dissolved by hydrofluoric acid, HF, according to the following reaction that produces silicon tetrafluoride, SiF_4, a gas at room temperature.

   $SiO_2 + 4\ HF \text{ ------------> } SiF_4 + 2\ H_2O$

   How many grams and how many moles of SiF_4 can be produced from 63.4 grams of HF?

9. Copper(I) iodide, CuI, is not stable enough to last long in storage, so it is generally made just prior to use. In can be prepared from copper sulphate and hydriodic acid by the following reaction.

   $2\ CuSO_4 + 4\ HI \text{ -------------> } 2\ CuI + 2\ H_2SO_4 + I_2$

   If 10.4 grams of $CuSO_4$ is used, calculate the number of grams of HI needed and the number of grams of each of the products that are produced. Show that the mass data are in accordance with the law of conservation of mass in chemical reactions.

10. If 2.56 grams of chlorine, Cl_2, are to be used to prepare dichlorine heptoxide, Cl_2O_7, how many moles and how many grams of oxygen are needed?

11. Under the right conditions, ammonia can be converted to nitric oxide, NO by the following reaction.

    $4\ NH_3 + 5\ O_2 \text{ -----------> } 4\ NO + 6\ H_2O$

    How many moles and how many grams of oxygen are needed to react with 56.8 grams of ammonia by this reaction?

12. One way to prepare iodine is to mix sodium iodate, $NaIO_3$, with hydriodic acid, HI. The following reaction occurs.

    $NaIO_3 + 6\ HI \text{ ------------> } 3\ I_2 + NaI + 3\ H_2O$

    Calculate the number of moles and the number of grams of iodine that can be made this way from 16.4 grams of $NaIO_3$.

13. Nickel metal reacts with silver nitrate solution according to the following balanced equation.

    $Ni + 2\ AgNO_3 \text{ -----------> } 2\ Ag + Ni(NO_3)_2$

    If 15.32 grams of nickel reacts with an excess of silver nitrate solution, calculate the mass of silver produced.

14. How many grams of CO_2 are produced when 23 grams of C_2H_5OH are burned?

15. Given: $3\ Fe_2O_3 + CO \text{ -------------> } 2\ Fe_3O_4 + CO_2$

    How many grams of Fe_2O_3 can be converted to Fe_3O_4 by 14.0 grams of CO?

44. Answers - Stoichiometric Gram to Gram Calculations

1. **2** $C_4H_{10} + 13\ O_2 \text{ ----> } 8\ CO_2 + 10\ H_2O$

   a) 0.14 moles of water formed

   b) 0.03 moles of butane burned

c) 1.74 grams of butane were burned
d) 5.76 grams of oxygen

2. para-xylene terephthalic acid

$1\ C_8H_{10}$ + $3\ O_2$ -----> $1\ C_8H_6O_4$ + $2\ H_2O$
154 g ? g
154 g of para-xylene will produce 240.90 grams of terephthalic acid in this reaction.

3. cyclohexane adipic acid

$5\ O_2$ + $2\ C_6H_{12}$ ---> $2\ C_6H_{10}O_4$ + $2\ H_2$
a) 100 moles of oxygen are needed to create 40 moles of adipic acid

b) 164 grams of cyclohexane will produce 285.01 grams of adipic acid.

4. Create a balanced equation from the question information
$4\ Al$ + $3\ O_2$ ---> $2\ Al_2O_3$
5 g ? g
5 grams of aluminum requires 4.48 grams of oxygen in this reaction.

5. Fe_2O_3 + $3\ H_2$ ---> $2\ Fe$ + $3\ H_2O$
16.5 g ? g
16.5 grams of iron(III) oxide will produce 11.16 grams of metallic iron

6. $2\ I_2$ + KIO_3 + $6\ HCl$ ----> $5\ ICl$ + KCl + $3\ H_2O$
? g 28.6 g
28.6 grams of iodine monochloride can be created from 17.77 grams of molecular iodine

7. $5\ KNO_2$ + $2\ KMnO_4$ + $3\ H_2SO_4$ ---> $5\ KNO_3$ + $2\ MnSO_4$ + K_2SO_4 + $3\ H_2O$
11.4 g ? g
8.20 grams of potassium permanganate is required to react with the original 11.4 grams of potassium nitrite

8. SiO_2 + $4\ HF$ ---> SiF_4 + $2\ H_2O$
63.4 g ? g
63.4 grams of hydrogen fluoride will produce 82.23 grams of silicon tetrafluoride

9. $2\ CuSO_4$ + $4\ HI$ ---> $2\ CuI$ + $2\ H_2SO_4$ + I_2
10.4 g ? g ? g ? g ? g
17.91 g of HI are needed as a reactant
13.33 g of CuI are created as product
6.87 g of H_2SO_4 are created as product
8.88 grams of I_2 are produced

10. Create a balanced equation for this reaction
$2\ Cl_2$ + $7\ O_2$ ---> $2\ Cl_2O_7$
2.56 g ? g
When 2.56 g of chlorine gas are reacted according to this equation 4.48 grams of oxygen gas are required.

11. $4\ NH_3$ + $5\ O_2$ ---> $4\ NO$ + $6\ H_2O$
56.8 g ? g
56.8 grams of ammonia needs 133.44 grams of oxygen gas in this reaction

12. $NaIO_3$ + $6\ HI$ ----> $3\ I_2$ + NaI + $3\ H_2O$
16.4 g ? g
16.4 grams of sodium iodate will produce 60.91 grams of molecular iodine according to this reaction

13. Ni + $2\ AgNO_3$ ---> $2\ Ag$ + $Ni(NO_3)_2$
15.32 g ? g
This reaction produces 56.09 grams of silver metal for every 15.32 grams of nickel metal reacted

14. Create and balance a combustion equation for C_2H_5OH
C_2H_5OH + $3\ O_2$ ---> $2\ CO_2$ + $3\ H_2O$
23 g ? g
The combustion of 23 grams of C_2H_5OH produces 44.01 grams of carbon dioxide

15. $3\ Fe_2O_3$ + CO ---> $2\ Fe_3O_4$ + CO_2
? g 14.0 g

14.0 grams of carbon monoxide will convert 239.55 grams of iron(III) oxide into Fe_3O_4

46. Empirical Formulas

1. The molecular formulas of some substances are as follows. Write their empirical formulas.
   (a) Acetylene, C_2H_2 (used in oxyacetylene torches)
   (b) Glucose, $C_6H_{12}O_6$ (the chief sugar in blood)
   (c) Octane, C_8H_{18} (a component of gasoline)
   (d) Ammonium nitrate, NH_4NO_3 (a component of fertilizer)

2. A radioactive form of sodium pertechnetate is used as a brain-scanning agent in medical diagnosis. An analysis of a 0.9872 gram sample found 0.1220 grams of sodium and 0.5255 grams of technetium. The remainder is oxygen. Calculate the empirical formula of sodium pertechnetate. (Use the value of 98.907 as the atomic weight of Tc and arrange the atomic symbols in the formula in the order NaTcO.)

3. Potassium persulphate (Anthion) is used in photography to remove the last tracers of hypo from photographic papers and plates. A 0.8162 gram sample was found to contain 0.2361 grams of potassium and 0.1936 grams of sulphur; the rest was oxygen. The formula weight of this compound was measured to be 261. What are the empirical and molecular formulas of potassium persulphate? (Arrange the atomic symbols in the formulas in the order KSO.)

4. Adenosine triphosphate (ATP) is an important substance in all living cells. A sample with a mass of 0.8138 grams was analyzed and found to contain 0.1927 grams of carbon, 0.02590 grams of hydrogen, 0.1124 grams of nitrogen, and 0.1491 grams of phosphorus. The remainder was oxygen. Its formula weight was determined to be 507. Calculate the empirical and molecular formulas of adenosine triphosphate. (Arrange the atomic symbols in alphabetical order in the formula.)

5. Realgar (re-Al-gar) is a deep red pigment used in painting. A 0.6817 grams sample was found to contain 0.4774 grams of arsenic; the remainder was sulphur. The formula weight of realgar was found to be 428. What are the empirical and molecular formulas of this pigment? (Arrange the symbols in the order AsS.)
6. Isobutylene is a raw material for making synthetic rubber. A sample with a mass of 0.6481 grams was found to contain 0.5555 grams of carbon; the rest was hydrogen. Its formula weight was determined to be 56.12. What are the empirical and molecular formulas of isobutylene? (Place the atomic symbols in the formulas in the order CH.)

7. Cyanuric acid is used for such different purposes as making synthetic sponges and killing weeds. A sample with a mass of 0.5627 grams was found to contain 0.1570 grams of carbon, 0.01317 grams of hydrogen, and 0.1832 grams of nitrogen, with the balance being oxygen. Its formula weight was found to be 129. Calculate the empirical and molecular formulas of cyanuric acid, arranging the atomic symbols in alphabetical order.

8. C.I.Pigment Yellow 45 ("sideran yellow") is a pigment used in ceramics, glass, and enamel. When analyzed, a 2.164 grams sample of this substance was found to contain 0.5259 grams of Fe and 0.7345 grams of Cr. The remainder was oxygen. Calculate the empirical formula of this pigment.

9. The composition of nicotine is 74.0% C, 8.7% H, and 17.3% N. The molecular mass of nicotine is 162. What is its molecular formula?

10. One compound of mercury with a formula weight of 519 contains 77.26% Hg, 9.25% C, and 1.17% H, and the remainder is oxygen. Calculate its empirical and molecular formulas, arranging the atomic symbols in the order Hg, C, H, and O.

11. The chief compound in the mineral celestine consists of strontium, sulphur, and oxygen. The percentage composition is 47.70% Sr and 17.46% S; the remainder being oxygen. Its formula weight is 184. What are the empirical and molecular formulas of this compound? (Arrange the atomic symbols in the formulas in the order Sr, S, and O.)

12. One of the most deadly poisons, strychnine, has a formula weight of 334 and the composition 75.42% C, 6.63% H, 8.38% N; the rest is oxygen. Calculate the empirical and molecular formulas of strychnine, arranging the atomic symbols in alphabetical order.

13. A sample of a liquid consisting of only C, H and O and having a mass of 0.5438 grams was burned in pure oxygen and 1.039 grams of CO_2 and 0.6369 grams of H_2O were obtained. What is the empirical formula of the compound?

47. Answers - Empirical Formulas

1. (a) CH; (b) CH_2O; (c) C_4H_9; (d) NH_4NO_3

2. Total mass of sample = 0.9872 g
Mass of sodium = 0.1220 g
Mass of technetium = 0.5255 g
Mass of oxygen = 0.9872 g - (0.1220 g + 0.5255 g) = 0.3397 g

	Na	Tc	O
m	0.1220 g	0.5255 g	0.3397 g
M	22.99 g/mol	98.00 g/mol	16.00 g/mol
n	0.00531	0.00536	0.0212
	0.00531 / 0.00531 = 1	0.00536 / 0.00531 = 1	0.0212 / 0.00531 = 4

Therefore the compound is $NaTcO_4$

3. Total mass of sample = 0.8162 g
Mass of potassium = 0.2361 g
Mass of sulphur = 0.1936 g
Mass of oxygen = 0.8162 g - (0.2361 g + 0.1936 g) = 0.3865 g

	K	S	O
m	0.2361 g	0.1936 g	0.3865 g
M	39.10 g/mol	32.07 g/mol	16.00 g/mol
n	0.2361 mol		
	0.2361 mol / 0.1936 mol = 1	0.1936 mol / 0.1936 mol = 1	0.3865 mol / 0.1936 mol = 4

Therefore the empirical formula is KSO_4
The empirical mass is 135.17 g/mol.
The actual given mass is 261 g/mol. Therefore 261/135.17 = 2
The actual formula is twice the empirical or $K_2S_2O_8$

4. Total mass is 0.8138 g
Mass of C is 0.1927 g
Mass of H = 0.02590 g
Mass of N = 0.1124 g
Mass of P = 0.1491 g
Mass of O = 0.8138 g - (0.1927 g + 0.02590 g + 0.1124 g + 0.1491 g) = 0.3337 g

	C	H	N	O	P
m	0.1927 g	0.02590 g	0.1124 g	0.3337 g	0.1491 g
M	12.01 g/mol	1.01 g/mol	14.01 g/mol	16.00 g/mol	30.97 g/mol
n	0.0161 mol	0.0256 mol	0.0080 mol	0.0209 mol	0.0048 mol
	0.0161 mol / 0.0048 mol = 3.33	0.0256 mol / 0.0048 mol = 5.33	0.0080 mol / 0.0048 mol = 1.66	0.0209 mol / 0.0048 mol = 4.35	0.0048 mol / 0.0048 mol = 1
Multiply by 3 to clear the mole fractions					
X 3	9.99	15.99	4.98	13.05	3

Therefore the empirical formula is $C_{10}H_{16}N_5O_{13}P_3$

5. Total mass is 0.6817 g
Mass of arsenic = 0.4774 g
Mass of oxygen = 0.6817 g - 0.4774 g = 0.2043 g

	As	S
m	0.4774 g	0.2043 g
M	74.92 g/mol	32.07 g/mol
n	0.0064 mol	0.0064 mol

Therefore the empirical formula is As_1S_1
The empirical mass is 106.99 g/mol
The actual given mass is 428 g/mol . Therefore 428/106.99 = 4
The actual formula is As_4S_4

6. Total mass = 0.6481 g
Mass of carbon = 0.5555 g
Mass of oxygen = 0.6481 g - 0.5555 g = 0.0926 g

	C	O
m	0.5555 g	0.0926 g
M	12.01 g/mol	16.00 g/mol
n	0.046 mol	0.092 mol
	0.046 mol / 0.046 mol = 1	0.092 mol / 0.046 mol = 2

Therefore the empirical formula is CH_2
The empirical mass is 14.03 g/mol
The actual given mass is 56.12 g/mol. Therefore 56.12/14.03 = 4
The actual formula is 4 times larger therefore C_4H_8

7. Total mass of sample = 0.5627 g
Mass of carbon = 0.1570 g
Mass of hydrogen = 0.01317 g
Mass of nitrogen =
Mass of oxygen = 0.5627 g - (0.1570 g + 0.01317 g + 0.1832 g) = 0.20933 g

	C	H	N	O
m	0.1570 g	0.01317 g	0.1832 g	0.20933 g
M	12.01 g/mol	1.01 g/mol	14.01 g/mol	16.00 g/mol
n	0.013 mol / 0.013 mol = 1	0.013 mol / 0.013 mol = 1	0.013 mol / 0.013 mol = 1	0.013 mol / 0.013 mol = 1

Therefore the empirical formula is CHNO
The empirical mass is 43.03 g/mol
The actual given mass is 129. Since 129/43.03 = 3
The actual molecular formulas is 3 times larger or $C_3H_3N_3O_3$

8. Total mass is 2.164 g
Mass of iron = 0.5259 g
Mass of chromium = 0.7345 g
Mass of oxygen = 2.164 g - (0.5259 g + 0.7345 g) = 0.9036 g

	Fe	Cr	O
m	2.164 g	0.5259 g	0.9036 g
M	55.85 g/mol	52.00 g/mol	16.00 g/mol
n	0.009 / 0.009 = 1 mol	0.014 / 0.009 = 1.5 mol	0.056 / 0.009 = 6.2 mol
Multiply to clear the mole fractions			
X 2	2	3	12

Therefore the empirical formula is $Fe_2Cr_3O_{12}$

9. Carbon = 74.0%
Hydrogen = 8.7%
Nitrogen = 17.3%

	C	H	N
Assume 100 grams			
m	74.0 g	8.7 g	17.3 g
M	12.01 g/mol	1.01 g/mol	14.01 g/mol
n	5.862 / 1.236 = 4.74 mol	8.614 / 1.236 = 6.96 mol	1.236 / 1.236 = 1 mol
	5	7	1

The empirircal formula is $C_5H_7N_1$
The empirical mass is 81.13 g/mol
The actual given mass is 162 g/mol. Since 162/81.13 = 2 the actual formula is twice the empirical formula or $C_{10}H_{14}N_2$

10. Mercury = 77.26%
Carbon = 9.25%
Hydrogen = 1.17%
Oxygen = 100% - (77.26% + 9.25% + 1.17%) = 12.32%

	Hg	C	H	O
Assume 100 grams				
m	77.26	9.25	1.17	12.32
M	200.59 g/mol	12.01 g/mol	1.01 g/mol	16.00 g/mol
n	0.385 mol / 0.385 mol = 1	0.77 mol / 0.385 mol = 2	1.16 mol / 0.385 mol = 3	0.77 mol / 0.385 mol = 2

The empirical formula is $HgC_2H_3O_2$
The empirical mass is 259.64 g/mol.

The actual given mass is 519 g/mol. Since 519/259.64 = 2 the actual formula is twice the empirical formula. The actual formula is $Hg_2C_4H_6O_4$

11. Strontium = 47.70%
    Sulphur = 17.46%
    Oxygen = 100% - (47.79% + 17.46%) = 34.84%

	Sr	S	O
m	47.79	17.46	34.84
M	87.62	32.07	16.00
n	$\frac{0.544}{0.544}$ = 1	$\frac{0.544}{0.544}$ = 1	$\frac{2.178}{0.544}$ = 4

The empirical formula is $SrSO_4$
The empirical mass is 183.69 g/mol
The actual given mass is 180 g/mol therefore the empirical formula and actual formula are the same.

12. Carbon = 75.42%
    Hydrogen = 6.63%
    Nitrogen = 8.38%
    Oxygen = 100% - (75.42% + 6.63% + 8.38%) = 9.57%

	C	H	N	O
m	75.42	6.63	8.38	9.57
M	12.01	1.01	14.01	16.00
n	$\frac{6.28}{0.598}$ = 10.5	$\frac{6.56}{0.598}$ = 11	$\frac{0.5986}{0.598}$ =1	$\frac{0.598}{0.598}$ =1
X 2	21	22	2	2

The empirical formula is $C_{21}H_{22}N_2O_2$
The empirical mass is 334.45 g/mol
The actual given mass is 334 g/mol
The empirical formula and actual formula are the same

13. Mass of burnt sample = 0.5438 grams
    Mass of CO_2 produced = 1.039 grams
    Mass of H_2O produced = 0.6369 grams

Solution steps
Step #1 Find the grams of carbon that produced the carbon dioxide
Step #2 Find the grams of hydrogen that produced the water
Step #3 Subtract the mass of carbon and hydrogen from the sample mass to find the mass of oxygen.
Step #4 Do the empirical calculation now that all the masses are known.

Step #1 Find the grams of carbon in the original compound
(i) moles of CO_2

$$n = \frac{g}{M} = \frac{1.039 \text{ grams}}{44.01 \text{ g/mol}} = 0.0236 \text{ moles of } CO_2$$

(ii) From the balanced equation $C + ½ O_2 \rightarrow CO_2$
moles of carbon = the moles of carbon dioxide therefore
moles of C = 0.0236 moles of carbon

(iii) Find grams of carbon

m = n • M = 0.0236 mol • 12.01 g/mol = 0.2835 grams of C

Step #2 Find the grams of hydrogen in the original compound
(i) moles of H_2O
$n = \frac{g}{M} = \frac{0.6369 \text{ grams}}{18.02 \text{ g/mol}} = 0.03534$ moles of H_2O

(ii) From the balanced equation $2\ H + \frac{1}{2}\ O_2 \rightarrow H_2O$
moles of hydrogen = twice the moles of water therefore
moles of H = 0.07068 moles of hydrogen

(iii) Find grams of hydrogen
m = n • M = 0.07068 mol • 1.01 g/mol = 0.0707 grams of hydrogen

Step #3 The grams of oxygen in the compound is
Mass of oxygen = sample mass - (mass of carbon + mass of hydrogen)
= 0.5438 g - (0.2835 g + 0.0707 g)
= 0.1896 grams of oxygen

Step #4 Empirical calculation

	C	H	O
m	0.2835	0.0707	0.1896
M	12.01	1.01	16.00
n	$\frac{0.0236}{0.01185}$ = 2	$\frac{0.07068}{0.01185}$ = 6	$\frac{0.01185}{0.01185}$ = 1

The empirical formula for the sample is C_2H_6O

14. Mass of burnt sample = 3.00 grams
Mass of CO_2 produced = 2.87 grams
Mass of H_2O produced = 1.17 grams

Solution steps
Step #1 Find the grams of carbon that produced the carbon dioxide
Step #2 Find the grams of hydrogen that produced the water
Step #3 Subtract the mass of carbon and hydrogen from the sample mass to find the mass of oxygen.
Step #4 Do the empirical calculation now that all the masses are known.

Step #1 Find the grams of carbon in the original compound
(i) moles of CO_2
$n = \frac{g}{M} = \frac{2.87 \text{ grams}}{44.01 \text{ g/mol}} = 0.065$ moles of CO_2

(ii) From the balanced equation $C + \frac{1}{2}\ O_2 \rightarrow CO_2$
moles of carbon = the moles of carbon dioxide therefore
moles of C = 0.065 moles of carbon

(iii) Find grams of carbon
m = n • M = 0.065 mol • 12.01 g/mol = 0.7807 grams of C

Step #2 Find the grams of hydrogen in the original compound
(i) moles of H_2O
$n = \frac{g}{M} = \frac{1.17 \text{ grams}}{18.02 \text{ g/mol}} = 0.065$ moles of H_2O

(ii) From the balanced equation $2\ H + \frac{1}{2}\ O_2 \rightarrow H_2O$
moles of hydrogen = twice the moles of water therefore
moles of H = 0.13 moles of hydrogen

(iii) Find grams of hydrogen
m = n • M = 0.13 mol • 1.01 g/mol = 0.1313 grams of hydrogen

Step #3 The grams of oxygen in the compound is
Mass of oxygen = sample mass - (mass of carbon + mass of hydrogen)
= 3.00 g - (0.7807 g + 0.1313 g)

= 2.088 grams of oxygen

Step #4 Empirical calculation

	C	H	O
m	0.7807	0.1313	2.088
M	12.01	1.01	16.00
n	$\frac{0.065}{0.065}$ = 1	$\frac{0.13}{0.065}$ =2	$\frac{0.1305}{0.065}$ =2

The empirical formula is CH_2O_2

15. Every unit is in milligrams. Omit the milli and treat as gram amounts for easier math.
Mass of burnt sample = 6.853 grams
Mass of CO_2 produced = 20.08 grams
Mass of H_2O produced = 5.023 grams

Solution steps
Step #1 Find the grams of carbon that produced the carbon dioxide
Step #2 Find the grams of hydrogen that produced the water
Step #3 Subtract the mass of carbon and hydrogen from the sample mass to find the mass of oxygen.
Step #4 Do the empirical calculation now that all the masses are known.

Step #1 Find the grams of carbon in the original compound
(i) moles of CO_2

$n = \frac{g}{M} = \frac{20.08 \text{ grams}}{44.01 \text{ g/mol}} = 0.456$ moles of CO_2

(ii) From the balanced equation C + ½ O_2 --> CO_2
moles of carbon = the moles of carbon dioxide therefore
moles of C = 0.465 moles of carbon

(iii) Find grams of carbon
m = n • M = 0.465 mol • 12.01 g/mol = 5.477 grams of C

Step #2 Find the grams of hydrogen in the original compound
(i) moles of H_2O

$n = \frac{g}{M} = \frac{5.023 \text{ grams}}{18.02 \text{ g/mol}} = 0.2787$ moles of H_2O

(ii) From the balanced equation 2 H + ½ O_2 --> H_2O
moles of hydrogen = twice the moles of water therefore
moles of H = 0.5575 moles of hydrogen

(iii) Find grams of hydrogen
m = n • M = 0.5575 mol • 1.01 g/mol = 0.5631 grams of hydrogen

Step #3 The grams of oxygen in the compound is
Mass of oxygen = sample mass - (mass of carbon + mass of hydrogen)
= 6.853 g - (5.477 g + 0.5631 g)
= 0.813 grams of oxygen

Step #4 Empirical calculation

	C	H	O
m	5.477	0.5631	0.813
M	12.01	1.01	16.00
n	$\frac{0.456}{0.051}$ = 8.9	$\frac{0.5575}{0.051}$ 10.9	$\frac{0.051}{0.051}$ = 1

The empirical formula is $C_9H_{11}O$
The empirical mass is 135.2 g/mol.
The given mass of 270 is almost exactly twice the empirical formula therefore the actual formula is $C_{18}H_{22}O_2$

16. Every unit is in milligrams. Omit the milli and treat as gram amounts for easier math.
Mass of burnt sample = 5.676 grams
Mass of CO_2 produced = 17.536 grams
Mass of H_2O produced = 5.850 grams

Solution steps
Step #1 Find the grams of carbon that produced the carbon dioxide
Step #2 Find the grams of hydrogen that produced the water
Step #3 Subtract the mass of carbon and hydrogen from the sample mass to find the mass of oxygen.
Step #4 Do the empirical calculation now that all the masses are known.

Step #1 Find the grams of carbon in the original compound
(i) moles of CO_2

$$n = \frac{g}{M} = \frac{17.536 \text{ grams}}{44.01 \text{ g/mol}} = 0.3985 \text{ moles of } CO_2$$

(ii) From the balanced equation $C + ½ O_2 \text{-->} CO_2$
moles of carbon = the moles of carbon dioxide therefore
moles of C = 0.3985 moles of carbon

(iii) Find grams of carbon
m = n • M = 0.465 mol • 12.01 g/mol = 4.7860 grams of C

Step #2 Find the grams of hydrogen in the original compound
(i) moles of H_2O

$$n = \frac{g}{M} = \frac{5.850 \text{ grams}}{18.02 \text{ g/mol}} = 0.3246 \text{ moles of } H_2O$$

(ii) From the balanced equation $2 H + ½ O_2 \text{-->} H_2O$
moles of hydrogen = twice the moles of water therefore
moles of H = 0.6493 moles of hydrogen

(iii) Find grams of hydrogen
m = n • M = 0.6493 mol • 1.01 g/mol = 0.6558 grams of hydrogen

Step #3 The grams of oxygen in the compound is
Mass of oxygen = sample mass - (mass of carbon + mass of hydrogen)
= 5.676 g - (4.7860 g + 0.6558 g)
= 0.2342 grams of oxygen

Step #4 Empirical calculation

	C	H	O
m	4.7860	0.6558	0.2343
M	12.01	1.01	16.00
n	0.3985 0.0147 = 27.1	0.6493 0.0147 = 44.2	0.0147 0.0147 = 1

The empirical formula is $C_{27}H_{44}O$

17. Mass of burnt sample = 0.0050 grams
Mass of CO_2 produced = 0.01476 grams
Mass of H_2O produced = 0.0043 grams

Solution steps
Step #1 Find the grams of carbon that produced the carbon dioxide
Step #2 Find the grams of hydrogen that produced the water
Step #3 Subtract the mass of carbon and hydrogen from the sample mass to find the mass of oxygen.
Step #4 Do the empirical calculation now that all the masses are known.

Step #1 Find the grams of carbon in the original compound
(i) moles of CO_2

$$n = \frac{g}{M} = \frac{0.01476 \text{ grams}}{44.01 \text{ g/mol}} = 0.000334 \text{ moles of } CO_2$$

(ii) From the balanced equation $C + ½ O_2 \text{-->} CO_2$
moles of carbon = the moles of carbon dioxide therefore
moles of C = 0.000334 moles of carbon

(iii) Find grams of carbon
m = n • M = 0.465 mol • 12.01 g/mol = 0.0040 grams of C

Step #2 Find the grams of hydrogen in the original compound
(i) moles of H_2O

$$n = \frac{g}{M} = \frac{0.0043 \text{ grams}}{18.02 \text{ g/mol}} = 0.000239 \text{ moles of } H_2O$$

(ii) From the balanced equation $2\ H + ½ O_2 \text{-->} H_2O$
moles of hydrogen = twice the moles of water therefore
moles of H = 0.000478 moles of hydrogen

(iii) Find grams of hydrogen
m = n • M = 0.000478 mol • 1.01 g/mol = 0.000483 grams of hydrogen

Step #3 The grams of oxygen in the compound is
Mass of oxygen = sample mass - (mass of carbon + mass of hydrogen)
= 0.005 g - (0.0040 g + 0.000483 g)
= 0.000517 grams of oxygen

Step #4 Empirical calculation

	C	H	O
m	0.0040	0.000483	0.000517
M	12.01	1.01	16.00
n	0.000334 0.0000323 = 10.34	0.000478 0.0000323 = 14.8	0.0000323 0.0000323 = 1
X 2	21	30	2

The empirical formula is $C_{21}H_{30}O_2$

49. Limiting Reagents and Percentage Yield

1. Consider the reaction

   $I_2O_5(g) + 5\ CO(g)$ -------> $5\ CO_2(g) + I_2(g)$

   a) 80.0 grams of iodine(V) oxide, I_2O_5, reacts with 28.0 grams of carbon monoxide, CO. Determine the mass of iodine I_2, which could be produced?

   b) If, in the above situation, only 0.160 moles, of iodine, I_2 was produced.
   i) what mass of iodine was produced?
   ii) what percentage yield of iodine was produced.

2. Zinc and sulphur react to form zinc sulphide according to the equation.

   Zn + S ---------> ZnS

   If 25.0 g of zinc and 30.0 g of sulphur are mixed,
   a) Which chemical is the limiting reactant?
   b) How many grams of ZnS will be formed?
   c) How many grams of the excess reactant will remain after the reaction is over?

3. Which element is in excess when 3.00 grams of Mg is ignited in 2.20 grams of pure oxygen? What mass is in excess? What mass of MgO is formed?

4. How many grams of Al_2S_3 are formed when 5.00 grams of Al is heated with 10.0 grams S?

5. When MoO_3 and Zn are heated together they react

   $3\ Zn(s) + 2\ MoO_3(s)$ ----------> $Mo_2O_3(s) + 3\ ZnO(s)$

   What mass of ZnO is formed when 20.0 grams of MoO_3 is reacted with 10.0 grams of Zn?

6. Silver nitrate, $AgNO_3$, reacts with ferric chloride, $FeCl_3$, to give silver chloride, AgCl, and ferric nitrate, $Fe(NO_3)_3$. In a particular experiment, it was plannned to mix a solution containing 25.0 g of $AgNO_3$ with another solution containing 45.0 grams of $FeCl_3$.

   a) Write the chemical equation for the reaction.

   b) Which reactant is the limiting reactant?

   c) What is the maximum number of moles of AgCl that could be obtained from this mixture?

   d) What is the maximum number of grams of AgCl that could be obtained?

   e) How many grams of the reactant in excess will remain after the reaction is over?

7. Solid calcium carbonate, $CaCO_3$, is able to remove sulphur dioxide from waste gases by the reaction:

   $CaCO_3 + SO_2$ + other reactants ------> $CaSO_3$ + other products

   In a particular experiment, 255 g of $CaCO_3$ was exposed to 135 g of SO_2 in the presence of an excess amount of the other chemicals required for the reaction.

   a) What is the theoretical yield of $CaSO_3$?

   b) If only 198 g of $CaSO_3$ was isolated from the products, what was the precentage yield of $CaSO_3$ in this experiment?

8. A research supervisor told a chemist to make 100 g of chlorobenzene from the reaction of benzene with chlorine and to expect a yield no higher that 65%. What is the minimum quantity of benzene that can give 100 g of chlorobenzene if the yield is 65%? The equation for the reaction is:

   $C_6H_6 + Cl_2$ -----------> $C_6H_5Cl + HCl$
   benzene   chlorobenzene

9. Certain salts of benzoic acid have been used as food additives for decades. The potassium salt of benzoic acid, potassium benzoate, can be made by the action of potassium permanganate on toluene.

   $C_7H_8 + 2\ KMnO_4$ -------> $KC_7H_5O_2 + 2\ MnO_2 + KOH + H_2O$
   toluene   potassium benzoate

   If the yield of potassium benzoate cannot realistically be expected to be more than 68%, what is the minimum number of grams of toluene needed to achieve this yield while producing 10.0 g of $KC_7H_5O_2$?

10. Aluminum dissolves in an aqueous solution of NaOH according to the following reaction:

    $2\ NaOH + 2\ Al + 2\ H_2O$ -----> $2\ NaAlO_2 + 3\ H_2$

    If 84.1 g of NaOH and 51.0 g of Al react:
    i) Which is the limiting reagent?
    ii) How much of the other reagent remains?
    iii) What mass of hydrogen is produced?

11. Dimethylhydrazine, $(CH_3)_2NNH_2$, was used as a fuel for the Apollo Lunar Descent Module, with N_2O_4 being used as the oxidant. The products of the reaction are H_2O, N_2, and CO_2.

    i) Write a balanced chemical equation for the combustion reaction.

    ii) If 150 kg of $(CH_3)_2NNH_2$ react with 460 kg of N_2O_4, what is the theoretical yield of N_2?

    iii) If a 30 kg yield of N_2 gas represents a 68% yield, what mass of N_2O_4 would have been used up in the reaction?

12. Magnesium metal reacts quantitatively with oxygen to give magnesium oxide, MgO. If 5.00 g of Mg and 5.00 g of O_2 are allowed to react, what weight of MgO is formed, and what weight of which reactant is left in excess?

13. Adipic acid, $C_6H_{10}O_4$, is a raw material for the making of nylon and it can be prepared in the laboratory by the following reaction between cyclohexene, C_6H_{10}, and sodium dichromate, $Na_2Cr_2O_7$ in sulphuric acid.

$3\ C_6H_{10}(l) + 4\ Na_2Cr_2O_7(aq) + 16\ H_2SO_4(aq)$ --------->
$3\ C_6H_{10}O_4(aq) + 4\ Cr_2(SO_4)_3(aq) + 4\ Na_2SO_4(aq) + 16\ H_2O$

There are side reactions. These plus losses of product during its purification reduce the overall yield. A typical yield of purified adipic acid is 68.6%.

(a) To prepare 12.5 grams of adipic acid in 68.6% yield requires how many grams of cyclohexene?

(b) The only available supply of sodium dichromate is its dihydrate, $Na_2Cr_2O_7 \cdot 2H_2O$. (Since the reaction occurs in an aqueous medium, the water in the dihydrate causes no problems, but it does contribute to the mass of what is taken of this reactant). How many grams of this dihydrate are also required in the preparation of 12.5 grams of adipic acid in a yield of 68.6%?

50. Answers - Limiting Reagents and Percentage Yield

1. a) I_2O_5 + 5 CO ---> 5 CO_2 + I_2
80.0 g 28.0 g

a) Using CO as the limiting reagent, a reaction of 28.0 grams of CO will produce 50.76 grams of iodine.

b) If the actual yield is only 0.160 moles then the gram yield is 40.61 grams which is 80% of the theoretical yield.

2. Zn + S ----> ZnS
25.0 g 30.0 g ? g

a) Zn is L.R.
b) 37.03 g of ZnS
c) 17.96 grams of S are in excess

3. 2 Mg + O_2 -----> 2 MgO
3.00 g 2.20 g ? g

Mg is L.R.
4.84 grams of MgO will be produced.
O_2 in excess by 0.32 grams

4. 2 Al + 3 S -----> Al_2S_3
5.00 g 10.0 g ? g

Al is L.R.

14.27 grams of aluminum sulphide will be created

5. 3 Zn + 2 MoO_3 -----> Mo_2O_3 + 3 ZnO
10.0 g 20.0 g ? g

Zn is L.R.
12.12 grams of Zinc oxide.

6. a) 3 $AgNO_3$ + $FeCl_3$ ----> 3 AgCl + $Fe(NO_3)_3$
25.0 g 45.0 g ? g

$AgNO_3$ is L.R.
21.50 grams of AgCl
37.31 grams of $FeCl_3$ in excess

7. $CaCO_3$ + SO_2 + other reactants ---> $CaSO_3$ + other products
255 g 135 g

SO_2 is L.R.
253.49 grams of $CaSO_3$

$$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\% = \frac{198\ g}{253.49\ g} \times 100\ \% = 78.11\%$$

8. C_6H_6 + Cl_2 ------> C_6H_5Cl + HCl
? g 100 g

The final yield must be 100 g. The target amount is larger knowing that only 65% will be made.

target amount = $\frac{100\ g}{0.65}$ = 153.86 grams of C_6H_5Cl

Therefore the calculations are actually starting with 153.86 grams of the C_6H_5Cl and working back to C_6H_6 grams.
Making 100 grams of chlorobenzene knowing that there is only a 65% yield requires 107.02 grams of benzene.

9. C_7H_8 + 2 $KMnO_4$ -----> $KC_7H_5O_2$ + 2 MnO_2 + KOH + H_2O
10.0 grams

The target amount is larger than the amount needed since the yield is only 68% for this reaction.
The target amount is

target amount = $\frac{10.0\ grams}{0.68}$ = 14.71 grams is the target amount

8.29 grams of toluene

10. 2 NaOH + 2 Al + 2 H_2O ---> 2 $NaAlO_2$ + 3 H_2
84.1 g 51.0 g

Therefore of the 51.0 grams of NaOH available for the reaction there are still 8.4 grams left over after the reaction is complete.

11. $(CH_3)_2NNH_2$ + 2 N_2O_4 ------> 4 H_2O + 3 N_2 + 2 CO_2
150 kg 460 kg ? kg

If the 30 kg of nitrogen released represents only 68% of the nitrogen produced then the amount of oxidizer used was 96.59 kg.

12. 2 Mg + O_2 -----> 2 MgO
5.00 g 5.00 g ? g

The reaction of 5.00 grams of Mg with 5.00 grams of O_2 results in the production of 8.47 grams of MgO formed with 1.76 grams of O_2 in excess.

adipic acid

13. 3 C_6H_{10} + 4 $Na_2Cr_2O_7$ + 16 H_2SO_4 --> 3 $C_6H_{10}O_4$ + 4 $Cr_2(SO_4)_3$ + 4 Na_2SO_4 + 16 H_2O
12.5 grams
68.6% yield

a) In order to obtain 12.5 grams of adipic acid knowing that there is only a 68.6% yield the reaction requires 9.86 grams of cyclohexene starting reactant.

(b) The reaction reacquires 47.68 grams of $Na_2Cr_2O_7$•$2H_2O$

52. Impure Samples and Percentage Purity

1. An impure sample of Na_2SO_4 has a mass of 1.56 grams. This sample is dissolved and allowed to react with $BaCl_2$ solution. The precipitate has a mass of 2.15 grams. Calculate the percentage of Na_2SO_4 in the original sample.
2. An impure, 0.500 grams sample of NaCl was dissolved in 20.0 mL of water. The chloride ions were precipitated completely by addition of a $AgNO_3$ solution. The dried AgCl precipitate has a mass of 1.15 grams.

   a) How many moles of AgCl formed?

   b) How many moles of NaCl were in the sample?

   c) How many grams of NaCl were in the sample?

   d) What was the percentage of NaCl in the impure sample?
3. An impure sample of Na_2SO_4 has a mass of 1.65 grams and is dissolved in water. Addition of $BaCl_2$ solution produced a precipitate of barium sulphate with mass 2.32 grams. What is the percentage of Na_2SO_4 in the impure sample?
4. A sample known to contain only NaCl and KCl has a mass of 1.08 grams. The sample is dissolved and treated with $AgNO_3$ until precipitation is complete. The precipitate of AgCl has a mass of 2.32 grams. What is the percentage of NaCl in the mixture?
5. A mixture of Na_2SO_4 and K_2SO_4 having a total mass of 0.500 grams, was dissolved in water. Barium chloride was added as a precipitating agent. The dried $BaSO_4$ resulting from the reaction has a mass of 0.715 grams. What is the percentage of each component in the original mixture?

53. Answers - Impure Samples and Percentage Purity

1. Na_2SO_4 + $BaCl_2$ ------> 2 NaCl + $BaSO_4$
   2.15 g
   The percentage purity is 84.0%

2. NaCl + $AgNO_3$ ---> $NaNO_3$ + AgCl
   1.15 g
   Percentage Purity = 91.2%

3. Na_2SO_4 + $BaCl_2$ ------> 2 NaCl + $BaSO_4$
   2.32 g
   The percentage purity is 85.45%

4. Assume that the NaCl and KCl solids are equal in mass.
   NaCl % 37.96%
   KCl% = 62.04 %

5. Na_2SO_4 = 40% K_2SO_4 = 60%

55. Percentage Yield Problems

1. An organic chemist reacted 10 g CH_4 with excess Cl_2 and obtained 10 g of CH_3Cl.

   a) What should have been the theoretical yield.

   b) What was their percentage yield?

2. An inorganic chemist reacted 100 g of $PbCl_4$ with excess NH_4Cl, obtaining an 87% yield of ammonium chloroplumbate(IV), $(NH_4)_2PbCl_6$. How many grams did they obtain?

3. The synthesis of sulphanilamide, $NH_2C_6H_5SO_2NH_2$, requires six steps beginning with benzene, C_6H_6. If the average yield per step is 80%, how many grams of sulphanilamide will you obtain from 1 kg of benzene?

56. Answers - Percentage Yield Problems

1. a) $CH_4 + Cl_2$ ---> CH_3Cl + HCl
   10 g
   There should be 31.30 grams of chloromethane produced according to the equation.

   b) The percentage yield is 31.95%

2. $PbCl_4$ + 2 NH_4Cl ----> $(NH_4)_2PbCl_6$
   100 g x g
   132.24 grams is the theoretical yield but with an 87% actual yield they should expect 115.05 grams of product.

3. | | |
   |---|---|
   | Benzene | 1000 g |
   | First reaction product | 800 g |
   | Second reaction product | 640 g |
   | Third reaction product | 512 g |
   | Fourth reaciton product | 409.6 g |
   | Fifth reaction product | 327.68 g |
   | Final reaction product | 262.14 g |

   Each step is 80% of the previous amount

58. Find the information type Question

1) Lithium (from the Greek word *lithos* meaning stony) was discovered by Johann Arfwedson (Sweden in 1817 and named by J.J. Berzelius). Lithium, a white metal with a silvery lustre, is the lightest solid element known, having a specific gravity of 0.531. It is a member of the alkali metal family (Group IA) and the least active chemically. The metal melts at 180.5^{o}C and boils at 1336^{o}C. The electron configuration is $1s^2$, $2s^1$ with an atomic radius of 133 pm and a univalent cation radius of 60 pm. Find the following:

a) Mass of one mole of Li metal

b) Number of atoms in one mole of Li metal

c) Mass of a single atom of Li

d) Melting point of Li

e) Density of Li metal

f) Volume occupied by 16.75 g of Li

g) Number of moles of Li metal in 16.75 g

h) Number of atoms of Li in 525 g

i) Atomic radius

2) Lithium occurs in trace amounts in most rocks with the average content of the earth's crust being estimated at 0.006%. It is frequently a minor constituent of natural brines and spring waters. Lithium is mined from open pits. The primary source is spodumene (lithium aluminum silicate) $LiAl(SiO_3)_2$ or $LiAlSi_2O_6$. Extensive deposits of spudomene are found in Quebec. The commercial production of lithium in the world has been important only since 1930. Lithium never occurs in the free state. Forty-two percent of the grease used in the United States contains lithium soap. The wing skins on an aircraft operating at Mach 2 are constructed from a lithium-aluminum alloy. Find the following:

a) Mass of one mole of lithium aluminum silicate

b) Percent of lithium in spudomene

c) Percent aluminum in spudomene

d) Percent silicon in spudomene

e) Number of moles of $LiAl(SiO_3)_2$ in 137.25 g of the compound

f) Number of grams of Li that could be obtained from 350.75 g of lithium aluminum silicate

g) Number of grams of Li that could be obtained from 18.25 kg of $LiAl(SiO_3)_2$

3) The phenomenon known as "knocking" in an internal combustion engine depends markedly on the nature of the constituent hydrocarbons in gasoline. The knocking tendency of a fuel is expressed in terms of an octane number. The octane rating of a gasoline product may be greatly improved by the addition of small amounts of tetraethyllead (TEL), sometimes referred to as tetraethylplumbate or lead tetraethyl. This antiknock agent controls the concentration of free radicals and prevents premature explosions in the combustion chamber. Tetraethyllead is a colourless, oily liquid with a faint fruity odor whose vapours form explosive mixtures with air. It burns with an orange-coloured flame with a green margin. Tetraethyllead has a specific gravity of 1.653 and boils at 200^{o}C with decomposition. The vapors are very toxic and fatal lead poisoning by ingestion, vapor inhalation, or skin absorption may occur. Open-cup flash-point is 120^{o}C. The formula for tetraethyllead is given as: $(C_2H_5)_4Pb$

The structural formula is:

```
          C2H5
           |
C2H5 --Pb-- C2H5
           |
          C2H5
```

Find the following:

a) Mass of molecular mass of tetraethyl lead

b) Percent composition by mass

c) Number of atoms in 1 molecule of compound

d) Number of molecules in 1 mole of compound

e) Mass of 1 molecule of compound

f) Number of moles in 98.75 g of compound

g) Number of grams in 0.625 moles of the compound

60. Answers - Find the Information Type Question

1)

a) 6.94 g

b) 6.02×10^{23}

c) 1.15×10^{-23} g

d) 453.65 K

e) 0.531 g/cm^3

f) 31.54 cm^3

g) 2.41 moles

h) 4.55×10^{25} atoms

i) 0.133 nm

2)

a) 186.10 g

b) 3.73 %

c) 14.50 %

d) 30.19 %

e) 0.74 mole

f) 13.08 g

3)

a) 323.48 g/mol

b) 29.70 %C

c) 6.24 %H

d) 64.05 %Pb

e) 29

f) 6.02×10^{23}

g) 5.37×10^{-22} g

h) 0.31 mole

i) 202.18 g

61. Concentration Unit Calculations (Other than molarity)

1. Rubbing alcohol, $C_3H_7OH_{(l)}$ is sold as a 70.0% solution for external use only. What volume of pure $C_3H_7OH_{(l)}$ is present in a 500 mL bottle?

2. Suppose your company makes hydrogen peroxide solution with a generic label for drugstores in your area. What mass of pure hydrogen peroxide is needed to male 1000 bottles each containing 250 mL of 3.0% $H_2O_{2(aq)}$

3. The maximum acceptable concentration of fluoride ions in municipal water supplies is 1.5 ppm. What is the maximum mass of fluoride ions you would get from a 0.250 L glass of water?

4. What concentration ratio is often found on the labels of consumer products? Why do you think this unit is used instead of moles per litre?

5. Bags of a D5W intravenous sugar solution used in hospitals contains a 5.0%W/V dextrose-in-water solution.
   a) What mass of dextrose is present in a 500.0 mL bag?
   b) What is the concentration of D5W expressed in parts per million?

6. Bald eagle chicks living around Lake Superior were found to contain PCBs (polychlorinated biphenyls) at an average concemtration of 18.9 mg/kg. If a chick had a mass of 0.6 kg, what mass of PCB's would it contain?

7. If the average concentation of PCB's in the body tissue of a human is 4.00 ppm, what mass of PCBs is present in a 64 kg person?

8. Each 5 mL dose of a cough remedy contains 153 mg of ammonum carbonate, 267 mg of potassium bicarbonate, 22 mg of menthol, and 2.2 mg of camphor. What is the concentrations of each of these ingredients in grams per litre?

9. An Olympic bound athlete tested positive for the anabolic steriod 'nandrolone'. The athlete's urine test results showed one thousand times the maximum acceptable level of 2 mg/L. What was the test result concentation in parts per million?

10. What do all concentrations units have in common?

11. Partly skimmed milk contains 2.0 grams of milk fat (MF) per 100 mL of milk. What mass of milk fat is present in 250 mL (one glass) of milk?

12. A shopper has a choice of yogurt with three differenet concentrations of milk fat: 5.9% MF, 2.0% MF, and 1.2% MF. If the shopper wants to limit their milk fat intake to 3.0 grams per serving, calculate the mass of the largest serving they could have for each type of yogurt.

13. Water from a well is found to have a nitrate ion concentration of 55 ppm, a level considered unsafe for drinking. Calculate the mass of nitrate ions in 200 mL of the water.

14. The label on a bottle of "sports drink" indicated that the beverage contains water, glucose, citric acid, potassium citrate, sodium chloride, and potassium phosphate, as well as natural flavours and artificial colours. The label also indicates that the beverage contains 50 mg of sodium ions and 55 mg of potassium ions per 400 mL serving.
    a) Write chemical formulas for all of the compounds named on the label, and classify them as ionic or molecular. Further classify the moelcules compounds as acidic, basic or neutral.
    b) Which compound imparts a sweet taste to the beverage, and which imparts a tangy taste.
    c) Calculate the concentration in parts per million of the sodium and potassium ions in the beverage.

15. Laboratories order hydrochloric acid as a concentrations solution (eg. 36% W/V) What initial volume of concentrated laboratory hydrochloric acid should be diluted to prepare 5.00 L of a 0.12 mol/L solution for an experiment?

16. A 40% v/v solution of ethylene glycol in water gives an antifreeze that will protect a vehicle's cooling system to -24^oC. What volume of ethylene glycol has to be used to make 5.68 L of this solution?

17. How many grams of 4.00%(w/w) solution of KOH in water are needed to neutralize completely the acid in 10.0 mL of 0.256 M H_2SO_4?

62. Answers - Concentration Unit Calculations (Other than molarity)

1. $70\%\ v/v = \frac{70\ mL}{100\ mL} = \frac{x}{500\ mL}$ x = 350 mL of pure rubbing alcohol

2. 1000 bottles X 250 mL = 250 000 mL X 0.03% = 75,000 mL of pure H_2O_2

3. 1.5 ppm = $\frac{1.5 \text{ mg}}{1000 \text{ mL}} = \frac{x}{250 \text{ mL}}$ x = 0.375 mg of F^{-1} ions

4. W/V is the most common commercial unit. Weight is a more common layman's term than mass.

5. a) 5% w/v = $\frac{5 \text{ g}}{1000 \text{ mL}} = \frac{x}{500 \text{ mL}}$ x = 25 grams of sugar

b) $\frac{5 \text{ g}}{100 \text{ mL}} = \frac{5000 \text{ mg}}{0.1 \text{ L}}$ = 50,000 ppm

6. $\frac{18.9 \text{ mg}}{1 \text{ kg}} = \frac{x}{0.6 \text{ kg}}$ x = 11.34 mg of PCB

7. 4 ppm = $\frac{4 \text{ mg}}{1 \text{ kg}} = \frac{x}{64 \text{ kg}}$ x = 256 mg = 0.256 grams of PCB

8. $\frac{1000 \text{ mL}}{5 \text{ mL}}$ = 200

$(NH_4)_2CO_3$ = 153 mg X 200 = 30600 mg/L = 30.6 g/L
menthol = 22 mg X 200 = 4400 mg/L = 4.4 g/L
camphor = 2.2 mg X 200 = 440 mg/L = 0.44 g/L
K_2CO_3 = 267 mg 200 = 53400 mg/L = 53.4 g/L

9. $\frac{2 \text{ mg}}{\text{L}}$ = 1000 = 2000 ppm

10. They all are solute amounts divided by solvent amounts.

11. $\frac{2.0 \text{ g}}{100 \text{ mL}} = \frac{x}{250 \text{ mL}}$ x = 5.0 grams of MF

12. 5.9% w/v = $\frac{5.9 \text{ g}}{100 \text{ mL}} = \frac{3 \text{ g}}{x}$ x = 50.8 mL

2.0% w/v = $\frac{2.0 \text{ g}}{100 \text{ mL}} = \frac{3 \text{ g}}{x}$ x = 150 mL

1.2% w/v = $\frac{1.2 \text{ g}}{100 \text{ mL}} = \frac{3 \text{ g}}{x}$ x = 250 mL

13. 55 ppm = $\frac{55 \text{ mg}}{1000 \text{ mL}} = \frac{x}{200 \text{ mL}}$ x = 11 mg = 0.011 grams

14. a) water = H_2O; glucose = $C_6H_{12}O_6$; citric acid = $H_3C_6H_5O_7$;

potassium citrate = $K_3C_6H_5O_7$; sodium chloride = NaCl; potassium phosphate = K_3PO_4

b) sweet = glucose, tangy = citric acid

$Na^+ = \frac{50\ mg}{400\ mL} = \frac{50\ mg}{0.4\ L} = 125\ ppm$

$K^+ = \frac{55\ mg}{400\ mL} = \frac{55\ mg}{0.4\ L} = 137.5\ ppm$

15. $\frac{36\ g}{100\ mL}$ $M_{HCl} = 36.46\ g/mol$ $n = \frac{36\ g}{36.46\ g/mol} = 0.987$ moles of HCl

Therefore $\frac{0.987\ mol}{100\ mL} = \frac{9.87\ mol}{L}$

0.12 mol/L X 5 L = 0.60 moles

$\frac{0.987\ mol}{1000\ mL} = \frac{0.60\ mol}{x}$ x = 608 mL of stock HCl

16. $\frac{40\ mL}{100\ mL} = \frac{40\ mL}{0.1\ L} = \frac{x}{5.68\ L}$ x = 2272 mL = 2.27 L

17. $\frac{4\ g}{100\ g} = \frac{4\ g}{0.1\ L} = \frac{0.698\ mol}{0.1\ L} = \frac{0.7\ mol}{L}$ is the concentration of the KOH solution

Create the balanced equation

$2\ KOH + H_2SO_4 \rightarrow 2\ H_2O + K_2SO_4$

$\frac{0.80\ mol}{L}$ $\frac{0.256\ mol}{L}$

Solution Steps

Step #1 How many moles of sulphuric acid are thre in 10 mL

Step #2 How many moles of KOH are needed to neutralize this acid

Step #3 How many mL's of the KOH solution have this many moles

Step #1 Moles of Sulphuric acid

$\frac{0.256\ mol}{L} = \frac{0.256\ mol}{1000\ mL} = \frac{x}{10\ mL}$ x = 0.00256 mol of H_2SO_4

Step #2 Moles of KOH

$\frac{2\ KOH}{x} = \frac{H_2SO_4}{0.00256\ mol}$ x = 0.00512 moles of KOH

Step #3 mL's of KOH solution

$\frac{0.70\ mol}{L} = \frac{0.70\ mol}{1000\ mL} = \frac{0.00512\ mol}{x}$ x = 7.31 mLof KOH needed

To neutralize 10 mL of 0.256 mol/L sulphuric acid there must be 7.31 mL of 0.70 mol/L KOH

63. Stoichiometry Involving Solutions Worksheet

1. Calculate the number of mL of 2.00 M HNO_3 solution required to react with 216 grams of Ag according to the equation.

   3 Ag(s) + 4 HNO_3(aq) ---------> 3 $AgNO_3$(aq) + NO(g) + 2 H_2O(l)

2. Calculate in mL the volume of 0.500 M NaOH required to react with 3.0 grams of acetic acid. The equation is:

   NaOH(aq) + $HC_2H_3O_2$(aq) -------> $NaC_2H_3O_2$(aq) + H_2O(l)

3. Calculate the number of grams of AgCl formed when 0.200 L of 0.200 M $AgNO_3$ reacts with an excess of $CaCl_2$. The equation is:

   2 $AgNO_3$(aq) + $CaCl_2$(aq) -------> 2 AgCl(s) + $Ca(NO_3)_2$(aq)

4. Calculate the mass of AgCl formed when an excess of 0.100 M solution of NaCl is added to 0.100 L of 0.200 M $AgNO_3$.
5. Calculate:

   a) the mass of $BaSO_4$ formed when excess 0.200 M Na_2SO_4 solution is added to 0.500 L of 0.500 M $BaCl_2$ solution, and

   b) the minimum volume of the Na_2SO_4 solution needed to precipitate the Ba^{2+} ions from the $BaCl_2$ solution.
6. A sample of impure sodium chloride weighing 1.00 grams is dissolved in water and completely reacted with silver nitrate solution. The dried precipitate of AgCl has a mass of 1.48 grams . Calculate the percentage of NaCl in the original impure sample.
7. To neutralize the acid in 10.0 mL of 18.0 M H_2SO_4 that was accidentally spilled on a laboratory bench top, solid sodium bicarbonate was used. The container of sodium bicarbonate was known to weigh 155.0 g before this use and out of curiosity its mass was measured as 144.5 g afterwards. The reaction that neutralizes sulphuric acid this way is as follows.

   H_2SO_4 + 2 $NaHCO_3$ --------> Na_2SO_4 + 2 CO_2 + 2 H_2O

   Was sufficient sodium bicarbonate used? Calculate the limiting reactant and the maximum yield in grams of sodium sulphate.
8. Barium nitrate and potassium sulphate solutions react and form a precipitate. What is the precipitate? How many mL of 0.40 M $Ba(NO_3)_2$ solution are required to precipitate completely the sulphate ions in 25 mL of 0.80 M K_2SO_4 solution?
9. What mass of silver chloride can be precipitated from a silver nitrate solution by 200 mL of a solution of 0.50 M $CaCl_2$?

64. Answers - Stoichiometry Involving Solutions Worksheet

1. 3 Ag + 4 HNO_3 ----> 3 $AgNO_3$ + NO + 2 H_2O
   216 g 2 M
   The reaction of 216 g of Ag requires 1335 mL of 2 M nitric acid

2. NaOH + $HC_2H_3O_2$ -----> $NaC_2H_3O_2$ + H_2O
   0.500 M 3 g
   The reaction of 3.0 g of acetic acid requires 100 mL of 0.50 M sodium hydroxide

3. 2 $AgNO_3$ + $CaCl_2$ ----> 2 AgCl + $Ca(NO_3)_2$
   0.20 L ? g
   0.20 M
   The reaction of 200 mL of 0.20 M silver nitrate with excess calcium chloride will produce 5.73 grams of silver chloride.

4. $AgNO_3$ + NaCl ---> AgCl + $NaNO_3$
   0.2 M 0.1 M ? g
   0.1 L excess
   The reaction of 100 mL of 0.20 M silver nitrate with excess sodium chloride will produce 2.87 grams of silver chloride.

5. a) $BaCl_2$ + Na_2SO_4 ---> $BaSO_4$ + 2 NaCl
   0.5 M 0.2 M ? g
   0.5 L excess
   58.35 grams barium sulphate produced, 1250 mL of barium sulphate

6. NaCl + $AgNO_3$ ---> AgCl + $NaNO_3$
   ? g 1.48 g
   Percentage purity 58.44%

7. H_2SO_4 + 2 $NaHCO_3$ ---> Na_2SO_4 + 2 CO_2 + 2 H_2O
   There is 0.18 moles of sulphuric acid spilled. The sodium bicarbonate will only neutralize a portion of the acid. There is not enough sodium bicarbonate used to completely neutralize the spilled sulphuric acid. There will only be a maximum yield of 8.52 grams of sodium sulphate produced.

8. $Ba(NO_3)_2$ + K_2SO_4 -----> $BaSO_4$ + 2 KNO_3
   0.40 M 0.80 M
   ? mL 25 mL
   Ans = 50 mL

9. 2 $AgNO_3$ + $CaCl_2$ -----> 2 AgCl + $Ca(NO_3)_2$
   0.5 M ? g

200 mL

200 mL of 0.5 M $CaCl_2$ solution will react with silver nitrate and produce 28.66 grams of silver chloride

65. Dilutions of Stock Solutions

1. Many solutions are prepared in the laboratory from purchased concentrated solutions. What volume of concentrated 17.8 M stock sulphuric acid solution would a laboratory technician need to make 2.00 L of 0.200 M solution by dilution of the original, concentrated stock solution?
2. In a study of reaction rates, you need to dilute copper(II) sulfate solution. You take 5.00 mL of 0.050 M $CuSO_{4(aq)}$ and dilute this to a final volume of 100.0 mL
   a) What is the final concentration of the dilute solution?
   b) What mass of $CuSO_{4(s)}$ is present in 10.0 mL of the final dilute solution?
   c) Can this final dilute solution of 10 mL be prepared directly using the pure solid? Defend your answer.
3. A student tries a reaction and finds that the volume of solution that reacts is too small to be measured precisely. She takes a 10.0 mL volume of the solution by pipet, transfers it into a clean 250 mL volumetric flask containing some pure water, adds enough pure water to increase the volume to 250.0 mL, and mixes the solution thoroughly.
   a) Compare the concentration of the dilute solution to that of the original solution.
   b) Compare the volume that will react now to the volume that reacted initially.
   c) Predict the speed or rate of reaction using the diluted solution compared with the rate using the original solution. Explain your answer.
4. A 10.00 mL sample of a test solution is diluted in an environmental laboratory to a final volume of 250.0 mL. The concentration of the diluted solution is found to be 0.274 g/L. What was the concentration of the original test solution?
5. As part of a study of reaction rates, you are to prepare two aqueous solutions of cobalt(II) chloride.
   a) Calculate the mass of solid cobalt(II) chloride hexahydrate you need to prepare 100.0 mL of a 0.100 mole/L cobalt(II) chloride solution.
   b) Calculate how to dilute this solution to make 100.0 mL of 0.0100 mole/L cobalt(II) chloride solution.
   c) Write a list of materials, and a procedure for the preparation of the two solutions. Be sure to include all necessary safety procautions.
6. In chemical analysis we often dilute stock solution to produce a required standard solution.
   a) What volume of a 0.400 M stock solution is required to produce 100.0 mL of a 0.100 mole/L solution.
   b) Write a complete procedure for the preparation of this standard solution, including specific quantities and equipment.
7. By the additions of water, 30.0 mL of 6.0 M H_2SO_4 is diluted to 150.0 mL. What is the concentration of H_2SO_4 after dilution?
   a) 1.2 M b) 1.5 M c) 3.0 M d) 4.8 M e) 6.0 M
8. By the addition of water, 40.0 mL of 8.0 M H_2SO_4 is diluted to 160.0 mL. What is the molarity after dilution?
   a) 0.50 M b) 1.0 M c) 1.6 M d) 2.0 M e) 4.0 M
9. A volume, V, of concentrated hydrochloric acid, 18.0 M, is diluted by the addition of 555 mL of water so that the final concentration of acid is 2.40 molar. What is V? Take volumes as being additive.
   a) 74 mL b) 85 mL c) 133 mL d) 240 mL e) 4163 mL
10. By the additions of water, 75.0 mL of 6.0 M H_2SO_4 is diluted to 150.0 mL. What is the concentration of H_2SO_4 after dilution?
    a) 1.2 M b) 1.5 M c) 3.0 M d) 4.8 M e) 6.0 M
11. What volume of 6.00 mol/L nitric acid, HNO_3(aq), solution is needed to make 4.2 L of 0.15 mol/L HNO_3 solution?
    a) 1.05 L b) 168 mL c) 105 mL d) 214 mL
12. What volume of water must be added to 800 L of 0.130 mol/L solution to dilute it to 0.100 mol/L?
    a) 1840 L b) 1040 L c) 560 L d) 240 L e) 24 L

66. Answers to Dilutions of Stock Solutions

1. Use the dilution equation: $M_c \bullet V_c = M_d \bullet V_d$

$$V_c = \frac{M_d \bullet V_d}{M_c} = \frac{0.2\text{ M} \bullet 2.00\text{ L}}{17.8\text{ M}} = 0.022\text{ L} = 22\text{ mL}$$

2. a) Use the dilution equation: $M_c \bullet V_c = M_d \bullet V_d$

$$M_d = \frac{M_c \bullet V_c}{V_d} = \frac{0.05\text{ M} \bullet 5\text{ mL}}{100\text{ mL}} = 0.0025\text{ M}$$

b) $\frac{0.0025\text{ M}}{1000\text{ mL}} = \frac{x}{10\text{ mL}}$ x = 0.000025 mol of $CuSO_4$

m = n • M = 0.000025 mol • 159.62 g/mol = 0.00399 grams = 4 mg

c) The amount required is to small to measure on a laboratory scale. Microgram scales are available but the cost is prohibitively high.

3. a) The concentration of the dilte solution is only 4% that of the original solution.

   b) The volume has increased by a factor of 25 times.

   c) The speed should be 25 times slower.

4. $M = \frac{0.274\ g}{L}$

   $M_c = \frac{M_d \bullet V_d}{V_c} = \frac{0.274\ g/L \bullet 250\ mL}{10\ mL} = 6.85\ \frac{g}{L}$

5. a) $\frac{0.100\ mol}{1000\ mL} = \frac{x}{100\ mL}$ x = 0.01 moles needed

   m = n • M = 0.01 mol • 237.95 g/mol = 2.38 grams of $CoCl_2 \bullet 6H_2O$

   b) $M_c \bullet V_c = M_d \bullet V_d$

   $V_c = \frac{M_d \bullet V_d}{M_c} = \frac{0.01\ M \times 100\ mL}{0.1\ M} = 10$ mL of concentrate needed

   c) To a clean 100 mL volumetric flask add 50 mL of distilled H_2O. To this add 2.35 grams of cobalt(II) chloride hexahydrate. Swirl to dissolve. Top up to 100 mL mark with distilled water. This the stock solution at 0.1 M. Using a 10 mL volumetric pipette remove 10 mL of 0.1 M solution and place it in another clean 100 mL columetric flask. Add distilled water to this second flask until it reaches the 100 mL volumetric flask mark. This is the second solution.

   Apparatus - 2 100 mL volumetric flask, 2.38 g of $CoCl_2 \bullet 6H_2O$
   Safety - DO NOT PIPETTE BY MOUTH

6. a) $M_c \bullet V_c = M_d \bullet V_d$

   $V_c = \frac{M_d \bullet V_d}{M_c} = \frac{0.01\ M \times 100\ mL}{0.4\ M} = 25.0$ mL of concentrate needed

   Obtain the bottle of 0.4 M stock solution. Pour some into a clear dry beaker. (Never pipette directly from the stock bottle) Using a 25.0 mL volumetric flask, pipette 25.0 mL of stock solution from the beaker. Transfer this to a clear dry 100 mL volumetric flask. Add water to this flask until the water reaches the 100 mL volumetric mark.
   Apparatus - 1 - 25 mL volumetric pipette
   1 - 100 mL volumetric flask
   1 - stock solution
   1 - beaker (50 mL size recommended)

7. $M_c \bullet V_c = M_d \bullet V_d$ $V_d = \frac{M_c \bullet V_c}{M_d} = \frac{6.0\ M \bullet 30.0\ mL}{150.0\ mL} = 1.2\ M$
   answer a)

8. $M_c \bullet V_c = M_d \bullet V_d$ $V_d = \frac{M_c \bullet V_c}{M_d} = \frac{8.0\ M \bullet 40.0\ mL}{160.0\ mL} = 2.0\ M$
   answer d)

9. $M_c \bullet V_c = M_d \bullet V_d$ $(V + 555\ mL) = \frac{18.0\ M \bullet V\ mL}{2.4\ M\ mL}$
   V = 85 mL
   answer b)

10. $M_c \bullet V_c = M_d \bullet V_d$ $M_d = \frac{M_c \bullet V_c}{V_d} = \frac{6.0\ M \bullet 75.0\ mL}{150\ mL} = 3\ M$
    answer c)

11. $V_c = \frac{M_d \bullet V_d}{M_c} = \frac{0.15\ M \bullet 4.2\ L}{6.0\ M} = 0.105\ L = 105\ mL$
    answer c)

12. $M_c \bullet V_c = M_d \bullet V_d$ $(V + 800\ L) = \underline{0.130\ M \bullet 800\ L}$

0.100 M

V = 240 L

answer d)

67. pH Calculations

1. What is the pH of a 0.0010 M HCl solution?

   a) 0.0 b) 1.0 c) 2.0 d) 3.0 e) 4.0

2. What is the molar concnetration in a solution of pH 5.50?

   a) 5.50 M b) $3.2 X 10^{-5}$ M c) $5.0 X 10^{-5}$ M
   d) $3.2 X 10^{-6}$ M e) $3.2 X 10^{-1}$ M

3. What hydrogen ion concentration corresponds to a pH of 8.64?

   a) 0.94 M b) $4.4 X 10^{-6}$ M c) $2.3 X 10^{-6}$ M
   d) $4.4 X 10^{-9}$ M e) $2.3 X 10^{-9}$ M

4. What is the hydrogen ion concentration in a solution of pH 5.76?

   a) $1.74 X 10^{-6}$ M b) $5.76 X 10^{-6}$ M c) $2.40 X 10^{-6}$ M
   d) $5.76 X 10^{-5}$ M e) $7.64 X 10^{-5}$ M

5. What is the $[H^+]$ in a 0.15 molar solution of acetic acid in water at 25°C? Acetic acid is 1.3% dissociated.

   a) $1.10 X 10^{-2}$ M b) $1.95 X 10^{-3}$ M c) $1.20 X 10^{-4}$ M
   d) $1.80 X 10^{-5}$ M e) $2.75 X 10^{-6}$ M

6. What is the H+ ion concentrtaion of an aqueous solution that has a pH of 11?

   a) $1.0 X 10^{-11}$ M b) $1.00 X 10^{-3}$ M c) $3.0 X 10^{-1}$ M d) $11 X 10^{-1}$ M

7. If an aqueous solution has a $[OH^{-1}] = 3.0 X 10^{-11}$, the solution would be

   a) an acidic solution b) a basic solution c) a neutral solution d) a salty solution

8. The pH of a solution in which the hydroxide ion concentration is $2.00 X 10^{-3}$ mol/L is

   a) 1.70 b) 2.70 c) 11.0 d) 11.3

9. The pH of a solution is 5. The hydrogen ion and hydroxide ion concentrations are:

   a) $[H^{+1}] = 1.0 X 10^{-9}$ M; $[OH^{-1}] = 1.0 X 10^{-5}$ M
   b) $[H^{+1}] = 1.0 X 10^{-5}$ M; $[OH^{-1}] = 1.0 X 10^{-5}$ M
   c) $[H^{+1}] = 1.0 X 10^{-5}$ M; $[OH^{-1}] = 1.0 X 10^{-9}$ M
   d) $[H^{+1}] = 1.0 X 10^{-7}$ M; $[OH^{-1}] = 1.0 X 10^{-9}$ M

10. The pOH of 0.00010 M nitric acid solution is

    a) $1.0 X 10^{-10}$ b) $1.0 X 10^{-4}$ c) 10 d) 4.0

11. How are acidic, basic, and neutral solutions in water defined;

    a) in terms of $[H^{+1}]$ and $[OH^{-1}]$

    b) in terms of pH

12. A sodium hydroxide solution is prepared by dissolving 6.0 g of NaOH in 1.00 L of water. What is the pOH and pH of this solution?

13. A solution was made by dissolving 0.837 grams of $Ba(OH)_2$ in 100 mL of water. If $Ba(OH)_2$ is fully dissociated into ions what is the pOH and pH of the resulting solution?

14. What is the pH and pOH of a solution made by adding 400 mL of distilled water to 10 mL of 0.010 M HNO_3? You may assume that volumes are additive.

15. What is the $[OH^{-1}]$ and pH of these solutions:

    a) 5.6 mg of KOH dissolved in 100 mL of solution.

    b) 74 mg of $Ca(OH)_2$ dissoved in 2.0 litres of solution.

68. Answers - pH Calculations

1. $[H^+] = 0.0010$ M pH = $-\log[H^+]$ = $-\log(0.0010)$ = 3.00
   answer d)

2. pH = 5.50 $[H^+] = 10^{-5.50}$ = $3.16 X 10^{-6}$ M
   answer d)

3. pH = 8.64 $[H^+] = 10^{-8.64}$ = $2.29 X 10^{-9}$ M
   answer e)

4. pH = 5.76 $[H^+] = 10^{-5.76}$ = $1.74 X 10^{-6}$ M
   answer a)

5. 0.15 <u>mol</u> • 0.013 = $1.95 X 10^{-3}$ M

L

CH_3COOH ------> CH_3COO^{-1} + H^{+1}

0.15 M 1.95×10^{-3} M 1.95×10^{-3} M

answer b)

6. pH = 11 $[H^+] = 10^{-11} = 1.00 \times 10^{-11}$ M
answer a)

7. $[OH^-] = 3.0 \times 10^{-11}$ M pOH = 10.52 therefore pH = 3.48
answer a)

8. $[OH^-] = 2.0 \times 10^{-3}$ M pOH = 2.70 therefore pH = 11.30
answer d)

9. pH = 5 therefore pOH = 9
$[H^+] = 10^{-5} = 1.00 \times 10^{-5}$ M $[OH^-] = 10^{-9} = 1.00 \times 10^{-9}$ M
answer c)

10. $[H^+]$ = 0.00010 M pH = -log$[H^+]$ = -log(0.00010) = 4.00
therefore pOH = 14 -4 = 10
answer c)

11. a) acidic $[H^{+1}] > [OH^{-1}]$
basic $[H^{+1}] < [OH^{-1}]$
neutral $[H^{+1}] = [OH^{-1}]$

b) acidic pH > pOH
basic pH < pOH
neutral pH = pOH

12. M_{NaOH} = 40.00 g/mol
$n = \frac{m}{M} = \frac{6.0\ g}{40.00\ g/mol}$ = 0.15 moles
M = 0.15 mol/L Since NaOH is a strong base allof it will dissolve therefore there will be 0.15 M OH^- ions. pOH = -log(0.15) = 0.82 and pH = 13.1

13. $M_{Ba(OH)2}$ = 171.35 g/mol
$n = \frac{m}{M} = \frac{0.837\ g}{171.35\ g/mol}$ = 0.005 moles
$M = \frac{0.005\ mol}{0.1\ L}$ = 0.05 M $Ba(OH)_2$ = Ba^{+2} + 2 OH^{-1}
0.05 M   0.05 M   0.10 M
pOH = -log(0.1) = 1 and pH =13

14. $0.010\ M = \frac{0.010\ mol}{1000\ mL} = \frac{x}{100\ mL}$ x = 0.001 moles of nitric acid
$M = \frac{0.001\ mol}{0.5\ L}$ = 0.002 M Since nitric acid is a strong acid there is complete ionization.
pH = -log(0.002) = 2.7 and pOH = 11.3

15. a) 5.6 mg of KOH in 100 mL M_{KOH} = 56.11 g/mol
$n = \frac{m}{M} = \frac{0.0056\ g}{56.11\ g/mol} = 1.0 \times 10^{-3}$ M

Since KOH is a strong base it will ionize completely.
pOH = -log(1.0×10^{-3}) = 3 and pH = 11

b) 74 mg of $Ca(OH)_2$ in 2 L $M_{Ca(OH)2}$ = 74.10 g/mol

$n = \frac{m}{M} = \frac{0.074\ g}{74.11\ g/mol}$ = 0.001 moles

M = $\frac{0.001 \text{ moles}}{2 \text{ L}}$ = 0.0005 M

Since $Ca(OH)_2$ is a strong base there will be complete dissolution.

$Ca(OH)_2$ ----> Ca^{+2} + 2 OH^{-1}
0.0005 M 0.0005 M 0.0010 M

pOH = -log(0.0010) = 3 therefore the pH = 11

69. Acids & Bases Worksheet

1. Explain the meaning of the terms "strong" and "weak" when applied to acids and bases.
2. Give illustrations of a strong acid, a strong base, a weak acid and a weak base.
3. Phosphoric acid is the acitve ingredient in many commerical rust-removing solutions. Calculate the volume of concentrated phosphoric aicd (14.6 M) that must be diluted to prepare 500 mL of a 1.25 M solution?
4. How did Arrhenius define and acid and a base?
5. Pure $HClO_4$ is molecular. Write an equation for its disoolution in water.
6. What is the difference between a strong electrolyte and a weak electrolyte.
7. If asubstance is a weak electrolyte, what does this mean in terms of the tendency of the ions to react to form the molecular compound? How does this compare with strong electrolytes?
8. Nitrous acid, HNO_2, is a weak acid. Write an equation showing its reaction with water.
9. Hydrazine is a toxic substance that can be formed when household ammonia is mixed with a bleach such as Clorox™. Its formula is N_2H_4 and it is a weak base. Write a chemical equation showing its reaction with water.
10. $HClO_3$ is a strong acid. Write an equation for its reaction with water.
11. Formic acid, $HCHO_2$, is the substance that is responsible for the painful bites of fire ants. It is a weak electrolyte and reacts with water in the same manner as acetic acid. Write a chemical equation that shows its ionization in water.
12. Write the formula for the conjugate bases for each of these acids:
    a) HCl; b) CH_4; c) HSO_3^{-1}; d) H_2SO_4; e) NH_3; f) $HClO_4$
13. Show how each of these acids react with water and forms a conjugate acid-base pair:
    a) HCl; b) HNO_3; c) H_2SO_4; d) $HClO_4$; e) H_2S; f) H_3PO_4
14. Calculate the molarity of a solution that contains 10 grams of HCl in 100 mL of solution.
15. A solution contains 0.1 mole of $HC_2H_3O_2$ dissolved in 0.5 L of solution. Calculate the molarity of the solution.
16. 500 mL of a solution contain 0.1 mole of $HC_2H_3O_2$. The solution is diluted with water to the 1 L mark. Calculate the molarity of the resulting solution.
17. A 250 mL solution of H_2SO_4 has a strength of 0.2 M. The solution is diluted with water to the 1 L mark. What is the molarity of the solution so formed?
18. If 0.3 mole of acetic acid is present in 150 mL of solution, calculate the molarity of the acid solution.
19. How many moles of acetic acid are required to make 125 ml of a 0.5 M solution.
20. To what volume must 125 mL of a 2 M solution of HCl be diluted to make the solution 0.05M?
21. What is the concentration of a solution formed by diluting 300 mL of a solution containing 0.1 mole of HCl to 6 L?
22. Give directions for preparing 2.0 L of 0.250 mol/L HCl using 11.7 M HCl.
23. Give directions for preparing 5.00 L of 0.15 mol/L H_2SO_4 using 18.0 M H_2SO_4.
24. What volume of 2.00 mol/L HNO_3 is needed to yield 10.00 grams of HNO_3?

70. Answers - Acids & Bases Worksheet

1. Strong electrolytes ionize 100% when they dissolve. Weak electrolytes do not ionize as much.

2. Strong acid - HCl Strong base = NaOH
   Weak acid - CH_3COOH Weak base - hydrazine

3. 42.81 mL

4. An acid is a compound that donates H^+. A base is a compound that donates OH^-.

5. $HClO_4$ + H_2O ------> H_3O^{+1} + ClO_4^{-1}

6. A strong electrolyte produces lots of ions when it dissolves (ie 100%) but a weak electroyle does not dissolve very well and therefore places on a

small amount of ions into the water.

7. The fact that they don't dissolve into ions means that they prefer to stay in a molecular state . Therefore their tendency is strongly molecular. Strong electrolytes on the other hand prefer to be ions and rapidly and radily become ions in solution.

8. HNO_2 + H_2O -----> H_3O^{+1} + NO_2^{-1}

9. Because strong acis are 100% dissociated

10. $HClO_3$ + H_2O ------> H_3O^{+1} + ClO_3^{-1}

11. $HCHO_2$ + H_2O ------> H_3O^{+1} + CHO_2^{-1}

12. a) HCl; conjugate base is Cl^{-1}
b) CH_4; conjugate base is CH_3^{-1}
c) HSO_3^{-1}; conjugate base is SO_3^{-2}
d) H_2SO_4; conjugate base is HSO_4^{-1}
e) NH_3; conjugate base is NH_2^{-1}
f) $HClO_4$ conjugate base is ClO_4^{-1}

13. a) HCl + H_2O ------> H_3O^{+1} + Cl^{-1}
b) HNO_3 + H_2O ------> H_3O^{+1} + NO_3^{-1}
c) H_2SO_4 + H_2O ------> H_3O^{+1} + HSO_4^{-1}
followed by HSO_4^{-1} + H_2O ------> H_3O^{+1} + SO_4^{-2}

d) $HClO_4$ + H_2O ------> H_3O^{+1} + ClO_4^{-1}
e) H_2S + H_2O ------> H_3O^{+1} + HS^{-1}
followed by HS^{-1} + H_2O ------> H_3O^{+1} + S^{-2}
f) H_3PO_4 + H_2O ------> H_3O^{+1} + $H_2PO_4^{-1}$
followed by $H_2PO_4^{-1}$ + H_2O ------> H_3O^{+1} + HPO_4^{-2}
followed by HPO_4^{-2} + H_2O ------> H_3O^{+1} + PO_4^{-3}

14. 10 grams of HCl in 100 mL of water
M_{HCl} = 36.46 g/mol

$$\text{moles of HCl} = \frac{10\text{ g}}{36.46\text{ g/mol}} = 0.274 \text{ moles of HCl}$$

$$M = \frac{\text{moles}}{L} = \frac{0.274\text{ moles}}{100\text{ mL}} = \frac{0.274\text{ moles}}{0.1\text{ L}} = \frac{2.74\text{ mol}}{L} = 2.74\text{ M}$$

15. 0.1 moles of vinegar dissolved in 0.5 L of water

$$M = \frac{\text{mol}}{L} = \frac{0.1\text{ mol}}{0.5\text{ L}} = \frac{0.2\text{ mol}}{L} = 0.2\text{ M}$$

16. 500 mL of a solution contains 0.1 moles of vinegar and then diluted to 1 L.

$$M = \frac{\text{mol}}{L} = \frac{0.1\text{ mol}}{1\text{ L}} = 0.1\text{ M}$$

17. 250 mL of a sulphuric solution at 0.2 M. Diluted to 1 L

Number of moles in the solution before dilution

$$0.2\text{ M} = \frac{0.2\text{ moles}}{1000\text{ mL}} = \frac{x}{250\text{ mL}} \qquad x = 0.05\text{ moles}$$

Molarity of new solution after dilution

$$M = \frac{\text{mol}}{L} = \frac{0.05\text{ moles}}{1\text{ L}} = 0.05\text{ M}$$

18. 0.3 moles of acetic acid in 150 mL of solution

$$M = \frac{mol}{L} = \frac{0.3\ moles}{1\ L} = \frac{0.3\ moles}{0.15\ L} = 2\ M$$

19. $$M = \frac{0.5\ mol}{L} = \frac{0.5\ mol}{1000\ mL} = \frac{x}{125\ mL} \qquad x = 0.0625\ mol$$

20. New volume if 125 mL of 2 M Hcl is to be diluted to 0.05 M

Find the number of moles present

$$2\ M = \frac{2\ mol}{L} = \frac{2\ mol}{1000\ mL} = \frac{x}{125\ mL} \qquad x = 0.250\ mol$$

Find the new volume

$$0.05\ M = \frac{0.05\ mol}{L} = \frac{0.250\ mol}{x} \qquad x = 5\ L$$

21. 300 mL of 0.1 M is diluted to 6 L

Find the number of moles present

$$0.1\ M = \frac{0.1\ mol}{1000\ mL} = \frac{x}{300\ mL} \qquad x = 0.03\ mol$$

Find the new molarity after dilution

$$M = \frac{mole}{L} = \frac{0.03\ mol}{6\ L} = 0.005\ M$$

22. Create 2.0 L of 0.250 M HCl solution using 11.7 M concentrate.

Find the needed moles

$$0.250\ M = \frac{0.250\ mol}{L} = \frac{x}{2\ L} \qquad x = 0.50\ \text{moles needed}$$

Find how much concentrate will supply this number of moles

$$11.7\ M = \frac{11.7\ mol}{1000\ mL} = \frac{0.50\ mol}{x} \qquad x = 42.74\ mL$$

Solution creation
To a large 6 L container, add 3 L of distilled or deionized water.
Add 42.74 mL of the 11.7 M HCl concentrate
Top up the 6 L container to the 6 L mark

23. Create 5.00 L of 0.150 M H_2SO_4 solution using 18.0 M concentrate.

Find the needed moles

$$0.150\ M = \frac{0.150\ mol}{L} = \frac{x}{5\ L} \qquad x = 0.75\ \text{moles needed}$$

Find how much concentrate will supply this number of moles

$$18.0\ M = \frac{18.0\ mol}{1000\ mL} = \frac{0.75\ mol}{x} \qquad x = 41.67\ mL$$

Solution creation
To a large 5 L container, add 2.5 L of distilled or deionized water.
Add 41.67 mL of the 18.0 M H_2SO_4 concentrate
Top up the 5 L container to the 5 L mark

24. What volume of 2.0 M HNO_3 yields 10.00 grams

M_{HNO3} = 63.02 g/mol

$$n = \frac{m}{M} = \frac{10.00\ g}{63.02\ g/mol} = 0.16\ mol\ of\ HNO_3$$

$$2.0\ M = \frac{2.0\ mol}{1000\ mL} = \frac{0.16\ mol}{x} \qquad x = 80\ mL\ of\ 2.0\ M\ HNO_3$$

71. Molecular, Ionic and Net Ionic Equations

1. Strontium compounds are often used in flares because their flame colour is bright red. One industrial process to produce low-solubility strontium compounds (that are less affected by getting wet) involves the reaction of aqueous solutions of strontium nitrate adn sodium carbonate. Write the balanced molecular equation, the total ionic equation and the net ionic equation for this reaction.
2. Placing aluminum foil in any solution containing aqueous coper(II) ions will result in a reaction. The reaction is slow to begin with, then proceeds rapidly.

   a) Referring to a solubility table, name at least four ionic compounds that could be dissolved in water to make a solution containing aqueous copper(II) ions.

   b) Write a balanced chemical equation for the reaction of aluminum with one of the compounds you suggested in a).

   c) Write the total ionic equation for the reactions.

   d) Write the total net ionic equation for the reactions.
3. One industrial method of producing bromine is to react seawater, containing a low concentration of sodium bromide, with chlorine gas. The chlorine gas is bubbled through the seawater in a specially designed vessel. Write the net ionic equation for this reaciton.
4. In a hard-water analyses, sodium oxalate solution reacts with calcium hydrogen carbonate (in the hard water) to precipitate a calcium compound. Write the net ionic equation for this reaction.
5. In a laboratory test of the metal activiity series, a student places a strip of lead metal into aqueous silver nitrate. Write the net ionic equation for this reaction.
6. Some natural waters contain iron ions that affect the tste of teh water and cause rust stains. Aeration converts any iron(II) ions into iron(III) ions. A basic solution (contains hydroxide ions) is added to produce a precipitate.

   a) Write the net ionic equation for the reaction of aqueous iron(II) ions and aqueous hydroxide ions.

   b) What separation method is most likely to be used during this water treatment process?
7. A common method for the disposal of soluble lead water is to precipitate the lead as the low-solubility lead(II) silicate. Write the net ionic equation for the reaction of aqueous lead(II) nitrate and aqueous sodium silicate.
8. In a water treatment plant, sodium phosphate is added to remove calcium ions from the water. Write the net ionic equation for the reaction of aqueous calcium chloride and aqueous sodium phosphate.
9. As part of a recycling process, silver metal is recovered from a silver nitrate solution by reacting it with copper metal. Write the net ionic equation for this reaction.
10. Predict which of the following combinations of aqueous chemicals produce a precipitate. Write a net ionic equation (including any states of matter) for the formation of any precipitate.

    a) lead(II) nitrate and calcium chloride

    b) ammonium sulphide and zinc bromide

    c) potassium iodide and sodium nitrate

    d) silver sulphate and amonium acetate

    e) barium nitrate and ammonium phosphate

    f) sodium hydroxide and calcium nitrate
11. Equal volume of 1.0 M solutions of each of the following pairs of solutions are mixed. Predict which combinations will form a precipitate and write net ionic equation for the predicted reactions.

    a) $CuSO_{4(aq)}$ and $NaOH_{(aq)}$

    b) $H_2SO_{4(aq)}$ and $NaOH_{(aq)}$

    c) $Na_3PO_{4(aq)}$ and $CaCl_{2(aq)}$

    d) $AgNO_{3(aq)}$ and $KCl_{(aq)}$

    e) $MgSO_{4(aq)}$ and $LiBr_{(aq)}$

    f) $CuNO_{3(aq)}$ and $NaCl_{(aq)}$
12. A lab techniciam uses 1.0 M $Na_2CO_{3(aq)}$ to precipitate metal ions from waste solutions. the resulting filtered solids can be disposed of more easily than large volumes of solution. Write net ionic equations for the reaction between $Na_2CO_{3(aq)}$ and each of the following waste solutions.

    a) $Zn(NO_3)_{2(aq)}$

    b) $Pb(NO_3)_{2(aq)}$

    c) $Fe(NO_3)_{3(aq)}$

    d) $CuSO_{4(aq)}$

    e) $AgNO_{3(aq)}$

    f) $NiCl_{2(aq)}$

    g) Defend the technicians choice of $Na_2CO_{3(aq)}$ as the excess reagent.
13. The purification of water can involve several precipitation reactions. Write balanced net ionic equation to represent the reactions described below.

    a) aqueous aluminum sulfate reacts with aqueous calcium hydroxide

    b) aqueous sodium phosphate reacts with dissolved calcium bicarbonate

    c) dissolved magnesium bicarbonate reacts with aqueous calcium hydroxide

d) aqueous calcium hydroxide reacts with dissolved iron(III) sulfate

14. What two conditiodn must be fulfilled by a balanced ionic equation?

15. Write ionic and net ionic equations for these reactions.
    a) $(NH_4)_2CO_{3(aq)}$ + $MgCl_{2(aq)}$ ----> 2 $NH_4Cl_{(aq)}$ + $MgCO_{3(s)}$
    b) $CuCl_{2(aq)}$ + 2 $NaOH_{(aq)}$ -----> $Cu(OH)_{2(s)}$ + 2 $NaCl_{(aq)}$
    c) 3 $FeSO_{4(aq)}$ + 2 $Na_3PO_{4(aq)}$ ------> $Fe_3(PO_4)_{2(s)}$ + 3 $Na_2SO_{4(aq)}$
    d) 2 $AgC_2H_3O_{2(aq)}$ + $NiCl_{2(aq)}$ ----> 2 $AgCl_{(s)}$ + $Ni(C_2H_3O_2)_{2(aq)}$

16. Write ionic and net ionic equations for these reactions.
    a) $CuSO_{4(aq)}$ + $BaCl_{2(aq)}$ ------> $CuCl_{2(aq)}$ + $BaSO_{4(s)}$
    b) $Fe(NO_3)_{3(aq)}$ + $LiOH_{(aq)}$ ------> $LiNO_{3(aq)}$ + $Fe(OH)_{3(s)}$
    c) $Na_3PO_{4(aq)}$ + $CaCl_{2(aq)}$ ---------> $Ca_3(PO_4)_{2(s)}$ + $NaCl_{(aq)}$
    d) $Na_2S_{(aq)}$ + $AgC_2H_3O_{2(aq)}$ -------> $NaC_2H_3O_{2(aq)}$ + $Ag_2S_{(s)}$

17. Aqueous solutions of sodium sulphide, Na_2S, and copper nitrate, $Cu(NO_3)_2$, are mixed. A precipitate of copper sulphide, CuS, forms at once. left behind is a solution of sodium nitrate, $NaNO_3$. Write the net ionic equation for this reaction.

18. Silver bromide is the chief light-sensitive substance used in the manufacture of photographic film. It can be repared ny mixing solutions of $AgNO_3$ and NaBr. Write molecular, ionic and net ionic equations for this reaction.

19. Trisodium phosphate (TSP), Na_3PO_4, is a useful cleaning agent, but it must be handled with care because its solutions are quite caustic. If a solution of Na_3PO_4 is added to one containing a calcium salt such as $CaCl_2$, a precipitate of calcium phosphate is formed. Write molecular, ionic and net ionic equations for this reaction.

20. Milk of magnesia is a suspension of solid magnesium hydroxide, $Mg(OH)_2$, in water. This solid can be made by adding a solution of sodium hydroxide, NaOH, to a solution of magnesium chloride, $MgCl_2$, which causes $Mg(OH)_2$ to precipitate and leaves sodium chloride in solution. Write molecular, ionic and net ionic equations for this reaction.

21. Write molecular, ionic and net ionic equations for any reactions that occur between the following pairs of compounds. If no reaction occurs, write 'N.R.'
    a) $CuCl_{2(aq)}$ and $(NH_4)_2CO_{3(aq)}$
    b) $HCl_{(aq)}$ and $MgCO_{3(aq)}$
    c) $ZnCl_{2(aq)}$ and $AgC_2H_3O_{2(aq)}$
    d) $MnO_{(s)}$ and $H_2SO_{4(aq)}$
    e) $FeS_{(s)}$ and $HCl_{(aq)}$

72. Answers - Molecular, Ionic and Net Ionic Equations

1. molecular: $Sr(NO_3)_{2(aq)}$ + $Na_2CO_{3(aq)}$ ----> $SrCO_{3(ppt)}$ + 2 $NaNO_{3(aq)}$
   ionic: $Sr^{+2}_{(aq)}$ + 2 $NO_3^{-1}{}_{(aq)}$ + 2 Na^{+1} + $CO_3^{-2}{}_{(aq)}$ ----> $SrCO_{3(ppt)}$ + 2 $Na^{+1}_{(aq)}$ + 2 $NO_3^{-1}{}_{(aq)}$
   net ionic: $Sr^{+2}_{(aq)}$ + $CO_3^{-2}{}_{(aq)}$ ----> $SrCO_{3(ppt)}$

2. a) $Cu(C_2H_3O_2)_2$, $CuBr_2$, $CuCl_2$, $CuSO_4$

   b) 3 $Cu(C_2H_3O_2)_2$ + 2 $Al_{(s)}$ -------> 2 $Al(C_2H_3O_2)_3$ + 3 $Cu_{(s)}$
   3 $CuBr_2$ + 2 $Al_{(s)}$ -------> 2 $AlBr_3$ + 3 $Cu_{(s)}$
   3 $CuCl_2$ + 2 $Al_{(s)}$ -------> 2 $AlCl_3$ + 3 $Cu_{(s)}$
   3 $CuSO_4$ + 2 $Al_{(s)}$ -------> $Al_2(SO_4)_3$ + 3 $Cu_{(s)}$

   c) 3 $Cu^{+2}_{(aq)}$ + 6 $C_2H_3O_2^{-1}{}_{(aq)}$ + 2 $Al_{(s)}$ -------> 2 $Al^{+3}_{(aq)}$ + 6 $C_2H_3O_2^{-1}{}_{(aq)}$ + 3 $Cu_{(s)}$
   3 $Cu^{+2}_{(aq)}$ + 6 $Br^{-1}_{(aq)}$ + 2 $Al_{(s)}$ -------> 2 $Al^{+3}_{(aq)}$ + 6 $Br^{-1}_{(aq)}$ + 3 $Cu_{(s)}$
   3 $Cu^{+2}_{(aq)}$ + 6 $Cl^{-1}_{(aq)}$ + 2 $Al_{(s)}$ -------> 2 $Al^{+3}_{(aq)}$ + 6 $Cl^{-1}_{(aq)}$ + 3 $Cu_{(s)}$
   3 $Cu^{+2}_{(aq)}$ + 3 $SO_4^{-2}{}_{(aq)}$ + 2 $Al_{(s)}$ -------> 2 $Al^{+3}_{(aq)}$ + 3 $SO_4^{-2}{}_{(aq)}$ + 3 $Cu_{(s)}$

   d) All four reactions are identical
   3 $Cu^{+2}_{(aq)}$ + 2 $Al_{(s)}$ -------> 2 $Al^{+3}_{(aq)}$ + 3 $Cu_{(s)}$

3. molecular: 2 $NaBr_{(aq)}$ + $Cl_{2(aq)}$ ----> 2 $NaCl_{(aq)}$ + $Br_{2(g)}$
   ionic: 2 $Na^{+1}_{(aq)}$ + 2 $Br^{-1}_{(aq)}$ + $Cl_{2(aq)}$ ----> 2 $Na^{+1}_{(aq)}$ + 2 $Cl^{-1}_{(aq)}$ + $Br_2(g)$
   net ionic: 2 $Br^{-1}_{(aq)}$ + $Cl_{2(aq)}$ ----> 2 $Cl^{-1}_{(aq)}$ + $Br_2(g)$

4. molecular: $Na_2C_2O_{4(aq)}$ + $Ca(HCO_3)_{2(aq)}$ ----> $CaC_2O_{4(ppt)}$ + 2 $NaHCO_{3(aq)}$
   ionic: 2 $Na^{+1}_{(aq)}$ + $C_2O_4^{-2}{}_{(aq)}$ + $Ca^{+2}_{(aq)}$ + 2 $HCO_3^{-1}{}_{(aq)}$ --> $CaC_2O_{4(ppt)}$ + 2 $Na^{+1}_{(aq)}$ + 2 $HCO_3^{-1}{}_{(aq)}$
   net ionic: $Ca^{+2}_{(aq)}$ + $C_2O_4^{-2}{}_{(aq)}$ ----> $CaC_2O_{4(ppt)}$

5. molecular: $Pb_{(s)}$ + 2 $AgNO_{3(aq)}$ ------> 2 $Ag_{(s)}$ + $Pb(NO_3)_{2(aq)}$
   ionic: $Pb_{(s)}$ + 2 $Ag^{+1}_{(aq)}$ + 2 $NO_3^{-1}{}_{(aq)}$ ------> 2 $Ag_{(s)}$ + $Pb^{+2}_{(aq)}$ + 2 $NO_3^{-1}{}_{(aq)}$

net ionic: $Pb_{(s)} + 2\,Ag^{+1}_{(aq)}$ ------> $2\,Ag_{(s)} + Pb^{+2}_{(aq)}$

6.

a) $Fe^{+3}_{(aq)} + OH^{-1}_{(aq)}$ ----> $Fe(OH)_{3(ppt}$

b) filtration will remove the solid gel like $Fe(OH)_3$

7. molecular: $Pb(NO_3)_{2(aq)} + Na_2SiO_{3(aq)}$ ----> $PbSiO_{3(ppt)} + 2\,NaNO_{3(aq)}$
ionic: $Pb^{+2}_{(aq)} + 2\,NO_3^{-1}_{(aq)} + 2\,Na^{+1}_{(aq)} + SiO_3^{-2}_{(aq)}$ ----> $PbSiO_{3(ppt)} + 2\,Na^{+1}_{(aq)} + 2\,NO_3^{-1}_{(aq)}$
net ionic: $Pb^{+2}_{(aq)} + SiO_3^{-2}_{(aq)}$ ----> $PbSiO_{3(ppt)}$

8. molecular: $3\,CaCl_{2(aq)} + 2\,Na_3PO_{4(aq)}$ -----> $Ca_3(PO_4)_{2(ppt)} + 6\,NaCl_{(aq)}$
ionic: $3\,Ca^{+2}_{(aq)} + 6\,Cl^{-1}_{(aq)} + 6\,Na^{+1}_{(aq)} + 3\,PO_4^{-3}_{(aq)}$ -----> $Ca_3(PO_4)_{2(ppt)} + 6\,Na^{+1}_{(aq)} + 6\,Cl^{-1}_{(aq)}$
net ionic: $3\,Ca^{+2}_{(aq)} + 3\,PO_4^{-3}_{(aq)}$ -----> $Ca_3(PO_4)_{2(ppt)}$

9. molecular: $2\,AgNO_{3(aq)} + Cu_{(s)}$ ----> $2\,Ag_{(s)} + Cu(NO_3)_{2(aq)}$
ionic: $2\,Ag^{+1}_{(aq)} + NO_3^{-1}_{(aq)} + Cu_{(s)}$ ----> $2\,Ag_{(s)} + Cu^{+2}_{(aq)} + 2\,NO_3^{-1}_{(aq)}$
net ionic: $2\,Ag^{+1}_{(aq)} + Cu_{(s)}$ ----> $2\,Ag_{(s)} + Cu^{+2}_{(aq)}$

10.

a) $Pb^{+2}_{(aq)} + 2\,Cl^{-1}_{(aq)}$ ---> $PbCl_{2(ppt)}$

b) $Zn^{+2}_{(aq)} + S^{-2}_{(aq)}$ ---> $ZnS_{(ppt)}$

c) No precipitate forms as both products are soluble.

d) $Ag^{+1}_{(aq)} + CH_3COO^{-1}_{(aq)}$ --------> $AgCH_3COO_{(ppt)}$

e) $3\,Ba^{+2}_{(aq)} + 2\,PO_4^{-3}_{(aq)}$ ------> $Ba_3(PO_4)_{2(ppt)}$

11. a) $Cu^{+2}_{(aq)} + OH^{-1}_{(aq)}$ -------> $Cu(OH)_{2(ppt)}$
b) $H^{+1}_{(aq)} + OH^{-1}_{(aq)}$ ---> $H_2O_{(l)}$
c) $3\,Ca^{+2}_{(aq)} + 2\,PO_4^{-3}_{(aq)}$ ------> $Ca_3(PO_4)_{2(ppt)}$
d) $Ag^{+1}_{(aq)} + Cl^{-1}_{(aq)}$ --------> $AgCl_{(ppt)}$
e) No reaction
f) No reaction

12. a) $Zn^{+2}_{(aq)} + CO_3^{-2}_{(aq)}$ ------> $ZnCO_{3(ppt)}$
b) $Pb^{+2}_{(aq)} + CO_3^{-2}_{(aq)}$ ------> $PbCO_{3(ppt)}$
c) $2\,Fe^{+3}_{(aq)} + 3\,CO_3^{-2}_{(aq)}$ ------> $Fe_2(CO_3)_{3(ppt)}$
d) $Cu^{+2}_{(aq)} + CO_3^{-2}_{(aq)}$ ------> $CuCO_{3(ppt)}$
e) $2\,Ag^{+1}_{(aq)} + CO_3^{-2}_{(aq)}$ ------> $Ag_2CO_{3(ppt)}$
f) $Ni^{+2}_{(aq)} + CO_3^{-2}_{(aq)}$ ------> $NiCO_{3(ppt)}$
g) The carbonate ion seems to react with most heavy metals to produce insoluble precipitates.

13. a) molecular: $Al_2(SO_4)_{3(aq)} + 3\,Ca(OH)_{2(aq)}$ ----> $2\,Al(OH)_{3(ppt)} + 2\,CaSO_{4(aq)}$
ionic: $2\,Al^{+3}_{(aq)} + 3\,SO_4^{-2}_{(aq)} + 3\,Ca^{+2}_{(aq)} + 6\,OH^{-1}_{(aq)}$ ----> $2\,Al(OH)_{3(ppt)} + 2\,Ca^{+2}_{(aq)} + 2\,SO_4^{-2}_{(aq)}$
net ionic: $2\,Al^{+3}_{(aq)} + 6\,OH^{-1}_{(aq)}$ ----> $2\,Al(OH)_{3(ppt)}$

b) molecular: $2\,Na_3PO_{4(aq)} + Ca(HCO_3)_{2(aq)}$ -----> $6\,NaHCO_{3(aq)} + Ca_3(PO_4)_{2(ppt)}$
ionic: $6\,Na^{+1}_{(aq)} + 2\,PO_4^{-3}_{(aq)} + Ca^{+2}_{(aq)} + 2\,HCO_3^{-1}_{(aq)}$ ---> $6\,Na^{+1}_{(aq)} + 6\,HCO_3^{-1}_{(aq)} + Ca_3(PO_4)_{2(ppt)}$
net ionic: $3\,Ca^{+2}_{(aq)} + 2\,PO_4^{-3}_{(aq)}$ -----> $Ca_3(PO_4)_{2(ppt)}$

d) molecular: $3\,Ca(OH)_{2(aq)} + Fe_2(SO_4)_{3(aq)}$ ------> $2\,Fe(OH)_{3(ppt)} + 3\,CaSO_{4(aq)}$
ionic: $3\,Ca^{+2}_{(aq)} + 6\,OH^{-1}_{(aq)} + 2\,Fe^{+3} + 3\,SO_4^{-2}_{(aq)}$ ------> $2\,Fe(OH)_{3(ppt)} + 3\,Ca^{+2}_{(aq)} + 3\,SO_4^{-2}_{(aq)}$
net ionic: $Fe^{+3}_{(aq)} + 3\,OH^{-1}_{(aq)}$ ------> $Fe(OH)_{3(ppt)}$

14. i) the atoms must balance on either side of the arrow.
ii) the overall charge must also balance on either side of the arrow

15. a) molecular: $(NH_4)_2CO_{3(aq)} + MgCl_{2(aq)}$ ----> $2\,NH_4Cl_{(aq)} + MgCO_{3(s)}$

ionic: $2\ NH_{4\,(aq)}^{+1} + CO_{3\,(aq)}^{-2} + Mg^{+2}_{(aq)} + 2\ Cl^{-1}_{(aq)} \longrightarrow 2\ NH_{4\,(aq)}^{+1} + 2\ Cl^{-1}_{(aq)} + MgCO_{3(s)}$
net ionic: $Mg^{+2}_{(aq)} + CO_{3\,(aq)}^{-2} \longrightarrow MgCO_{3(s)}$

b) molecular: $CuCl_{2(aq)} + 2\ NaOH_{(aq)} \longrightarrow Cu(OH)_{2(s)} + 2\ NaCl_{(aq)}$
ionic: $Cu^{+2}_{(aq)} + 2Cl^{-1}_{(aq)} + 2\ Na^{+1}(aq) + 2\ OH^{-1}_{(aq)} \longrightarrow Cu(OH)_{2(s)} + 2\ Na^{+1}_{(aq)} + 2\ Cl^{-1}_{(aq)}$
net ionic: $Cu^{+2}_{(aq)} + 2\ OH^{-1}_{(aq)} \longrightarrow Cu(OH)_{2(s)}$

c) molecular: $3\ FeSO_{4(aq)} + 2\ Na_3PO_{4(aq)} \longrightarrow Fe_3(PO_4)_{2(s)} + 3\ Na_2SO_{4(aq)}$
ionic: $3\ Fe^{+2}_{(aq)} + 3\ SO_{4\,(aq)}^{-2} + 6\ Na^{+1}_{(aq)} + 2\ PO_{4\,(aq)}^{-3} \longrightarrow Fe_3(PO_4)_{2(s)} + 6\ Na^{+1}_{(aq)} + 3\ SO_{4\,(aq)}^{-2}$
net ionic: $3\ Fe^{+2}_{(aq)} + 2\ PO_{4\,(aq)}^{-3} \longrightarrow Fe_3(PO_4)_{2(ppt)}$

d) molecular: $2\ AgC_2H_3O_{2(aq)} + NiCl_{2(aq)} \longrightarrow 2\ AgCl_{(s)} + Ni(C_2H_3O_2)_{2(aq)}$
ionic: $2\ Ag^{+1}_{(aq)} + 2\ C_2H_3O_{2\,(aq)}^{-1} + Ni^{+2}_{(aq)} + 2\ Cl^{-1}_{(aq)} \longrightarrow 2\ AgCl_{(s)} + Ni^{+2}_{(aq)} + 2\ C_2H_3O_{2\,(aq)}^{-1}$
net ionic: $2\ Ag^{+1}_{(aq)} + 2\ Cl^{-1}_{(aq)} \longrightarrow 2\ AgCl_{(ppt)}$

16. a) molecular: $CuSO_{4(aq)} + BaCl_{2(aq)} \longrightarrow CuCl_{2(aq)} + BaSO_{4(s)}$
ionic: $Cu^{+2}_{(aq)} + SO_{4\,(aq)}^{-2} + Ba^{+2}_{(aq)} + 2\ Cl^{-1}_{(aq)} \longrightarrow Cu^{+2}_{(aq)} + 2\ Cl^{-1}_{(aq)} + BaSO_{4(s)}$
net ionic: $Ba^{+2}_{(aq)} + SO_{4\,(aq)}^{-2} \longrightarrow BaSO_{4(s)}$

b) molecular: $Fe(NO_3)_{3(aq)} + 3\ LiOH_{(aq)} \longrightarrow 3\ LiNO_{3(aq)} + Fe(OH)_{3(s)}$
ionic: $Fe^{+3}_{(aq)} + 3\ NO_{3\,(aq)}^{-1} + 3\ Li^{+1}_{(aq)} + 3\ OH^{-1}_{(aq)} \longrightarrow 3\ Li^{+1}_{(aq)} + 3\ NO_{3\,(aq)}^{-1} + Fe(OH)_{3(s)}$
net ionic: $Fe^{+3}_{(aq)} + 3\ OH^{-1}_{(aq)} \longrightarrow Fe(OH)_{3(s)}$

c) molecular: $2\ Na_3PO_{4(aq)} + 3\ CaCl_{2(aq)} \longrightarrow Ca_3(PO_4)_{2(s)} + 3\ NaCl_{(aq)}$
ionic: $6\ Na^{+1}_{(aq)} + 2\ PO_{4\,(aq)}^{-3} + 3\ Ca^{+2}_{(aq)} + 6\ Cl^{-1}_{(aq)} \longrightarrow Ca_3(PO_4)_{2(s)} + 6\ Na^{+1}_{(aq)} + 6\ Cl^{-1}_{(aq)}$
net ionic: $3\ Ca^{+2}_{(aq)} + 2\ PO_{4\,(aq)}^{-3} \longrightarrow Ca_3(PO_4)_{2(s)}$

d) molecular: $Na_2S_{(aq)} + 2\ AgC_2H_3O_{2(aq)} \longrightarrow 2\ NaC_2H_3O_{2(aq)} + Ag_2S_{(s)}$
ionic: $2\ Na^{+1}_{(aq)} + S^{-2}_{(aq)} + 2\ Ag^{+1}_{(aq)} + 2\ C_2H_3O_{2\,(aq)}^{-1} \longrightarrow 2\ Na^{+1}_{(aq)} + 2\ C_2H_3O_{2\,(aq)}^{-1} + Ag_2S_{(s)}$
net ionic: $2\ Ag^{+1}_{(aq)} + S^{-2}_{(aq)} \longrightarrow Ag_2S_{(s)}$

17. molecular: $Na_2S_{(aq)} + Cu(NO_3)_{2(aq)} \longrightarrow CuS(s) + 2\ NaNO_{3(aq)}$
ionic: $2\ Na^{+1}_{(aq)} + S^{-2}_{(aq)} + Cu^{+2}_{(aq)} + 2\ NO_{3\,(aq)}^{-1} \longrightarrow CuS(s) + 2\ Na^{+1}_{(aq)} + 2\ NO_{3\,(aq)}^{-1}$
net ionic: $Cu^{+2}_{(aq)} + S^{-2}_{(aq)} \longrightarrow CuS(s)$

18. molecular: $NaBr_{(aq)} + AgNO_{3(aq)} \longrightarrow AgBr_{(ppt)} + NaNO_{3(aq)}$
ionic: $Na^{+1}_{(aq)} + Br^{-1}_{(aq)} + Ag^{+1}_{(aq)} + NO_{3\,(aq)}^{-1} \longrightarrow AgBr_{(ppt)} + Na^{+1}_{(aq)} + NO_{3\,(aq)}^{-1}$
net ionic: $Ag^{+1}_{(aq)} + Br^{-1}_{(aq)} \longrightarrow AgBr_{(ppt)}$

19. molecular: $2\ Na_3PO_{4(aq)} + 3\ CaCl_{2(aq)} \longrightarrow 6\ NaCl_{(aq)} + Ca_3(PO_4)_{2(ppt)}$
ionic: $6\ Na^{+1}_{(aq)} + 2\ PO_{4\,(aq)}^{-3} + 3\ Ca^{+2}_{(aq)} + 6\ Cl^{-1}_{(aq)} \longrightarrow 6\ Na^{+1}_{(aq)} + 6Cl^{-1}_{(aq)} + Ca_3(PO_4)_{2(ppt)}$
net ionic: $3\ Ca^{+2}_{(aq)} + 2\ PO_{4\,(aq)}^{-3} \longrightarrow Ca_3(PO_4)_{2(ppt)}$

20. molecular: $2\ NaOH_{(aq)} + MgCl_{2(aq)} \longrightarrow Mg(OH)_{2(s)} + 2\ NaCl_{(aq)}$
ionic: $2\ Na^{+1}_{(aq)} + 2\ OH^{-1}_{(aq)} + Mg^{+2}_{(aq)} + Cl^{-1}_{(aq)} \longrightarrow Mg(OH)_{2(s)} + 2\ Na^{+1}_{(aq)} + 2\ Cl^{-1}_{(aq)}$
net ionic: $Mg^{+2}_{(aq)} + 2\ OH^{-1}_{(aq)} \longrightarrow Mg(OH)_{2(s)}$

21. a) molecular: $CuCl_{2(aq)} + (NH_4)_2CO_{3(aq)} \longrightarrow CuCO_{3(s)} + 2\ NH_4Cl_{(aq)}$
ionic: $Cu^{+2}_{(aq)} + 2\ Cl^{-1}_{(aq)} + 2\ NH_{4\,(aq)}^{+1} + CO_{3\,(aq)}^{-2} \longrightarrow CuCO_{3(s)} + 2\ NH_{4\,(aq)}^{+1} + 2\ Cl^{-1}_{(aq)}$
net ionic: $Cu^{+2}_{(aq)} + CO_{3\,(aq)}^{-2} \longrightarrow CuCO_{3(s)}$

b) molecular: $2\ HCl_{(aq)} + MgCO_{3(aq)} \longrightarrow MgCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$
ionic: $2\ H^{+1}_{(aq)} + 2\ Cl^{-1}_{(aq)} + Mg^{+2}_{(aq)} + CO_{3\,(aq)}^{-2} \longrightarrow Mg^{+2}_{(aq)} + 2\ Cl^{-1}_{(aq)} + H_2O_{(l)} + CO_{2(g)}$
net ionic: $2\ H^{+1}_{(aq)} + CO_{3\,(aq)}^{-2} \longrightarrow H_2O_{(l)} + CO_{2(g)}$

c) molecular: $ZnCl_{2(aq)} + 2\ AgC_2H_3O_{2(aq)} \longrightarrow 2\ AgCl_{(s)} + Zn(C_2H_3O_2)_{2(aq)}$
ionic: $Zn^{+1}_{(aq)} + 2\ Cl^{-1}_{(aq)} + 2\ Ag^{+1}_{(aq)} + 2\ C_2H_3O_{2\,(aq)}^{-1} \longrightarrow 2\ AgCl_{(s)} + Zn^{+2}_{(aq)} + 2\ C_2H_3O_{2\,(aq)}^{-1}$
net ionic: $Ag^{+1}_{(aq)} + Cl^{-1}_{(aq)} \longrightarrow AgCl_{(s)}$

d) molecular: $MnO_{(s)} + H_2SO_{4(aq)} \longrightarrow MnSO_{4(aq)} + H_2O_{(l)}$
ionic: $MnO_{(s)} + 2\ H^{+1}_{(aq)} + SO_{4\,(aq)}^{-2} \longrightarrow Mn^{+2}_{(aq)} + SO_{4\,(aq)}^{-2} + H_2O_{(l)}$
net ionic: $MnO_{(s)} + 2\ H^{+1}_{(aq)} \longrightarrow H_2O_{(l)} + Mn^{+2}_{(aq)}$

e) molecular: $FeS_{(s)} + 2\ HCl_{(aq)} \longrightarrow FeCl_{2(aq)} + H_2S_{(g)}$
ionic: $FeS_{(s)} + 2\ H^{+1}_{(aq)} + 2\ Cl^{-1}_{(aq)} \longrightarrow Fe^{+2}_{(aq)} + 2\ Cl^{-1}_{(aq)} + H_2S_{(g)}$
net ionic: $FeS_{(s)} + 2\ H^{+1}_{(aq)} \longrightarrow Fe^{+2}_{(aq)} + H_2S_{(g)}$

73. Titrations and Chemical Analysis

1. In a titration, 24.0 mL of 0.100 M NaOH was needed to react with 20.00 mL of HCl solution. What is the molarity of the acid?
2. A 10.00 mL sample of vinegar, containing acetic acid, $HC_2H_3O_{2(aq)}$, was titrated using 0.500 M NaOH solution. The titration required 13.40 mL of the base.

   a) What was the molar concentration of acetic acid in the vinegar?

   b) What was the W/V percent concentration of the acetic acid in the vinegar?
3. Lactic acid, $HC_3H_5O_3$, is a monoprotic acid that is formed when milk sours. A 20.0 mL sample of a solution of lactic acid required 18.35 mL of 0.160 M NaOH to reach an end point in a titration. How many moles of lactic acid were in the sample?
4. A 1.500 grams sample of a mixture of limestone, $CaCO_3$, and rock was pulversized and then treated with 50.0 mL of 0.200 M HCl. The mixture was warmed to expel the last traces of CO_2 and the unreacted HCl was then titrated with 0.500 M NaOH. The volume of base required was 3.46 mL.

   a) How many moles of NaOH were used in the titration?

   b) How many moles of HCl remained after reaction with the $CaCO_3$?

   c) How many moles of $CaCO_3$ had reacted?

   d) What was the original W/W percentage by weight of $CaCO_3$ in the original limestone sample?
5. Aspirin is a monoprotic acid called acetylsalicylic acid. This formula is $HC_9H_7O_4$. A certain pain reliever was analyzed for aspirin by dissolving a 250 mg tablet in water and titrating it with 0.0300 M KOH solution. The titration required 29.40 mL of base. What is the percentage by weight of aspirin in the pill?
6. A student prepared a solution of hydrochloric acid that was approximately 0.1 M and wished to determine its precise concentration. A 25.00 mL portion of the HCl solution was transferred to a flask, and after a few drops of indicator solution were added, the HCl soltuion was titrated with 0.0775 M NaOH solution. The titration required exactly 37.46 mL of the standard NaOH solutoin. What was the exact molarity of the HCl solution?
7. A solution of ammonia in water was analyzed by titrating the ammonia with hydrochloric acid. The net ionic reaction is:

   $NH_{3(aq)}$ + $H_3O^{+1}{}_{(aq)}$ -----> $NH_4^{+1}{}_{(aq)}$ + $H2O_{(l)}$

   In the analysis, a 5.00 grams sample of the ammonia solution was placed in a flask and titrated with 1.00 M HCl, using an appropriate indicator. The titration required 29.86 mL of the HCl solution. What is the W/V percent composition of the NH_3 in the ammonia solution?
8. In a titration, a sample of H_2SO_4 solution having a volume of 15.00 mL required 36.42 mL of 0.147 M NaOH solution for complete neutralization. What is the molarity of the H_2SO_4 solution?
9. "Stomach acid" is hydrochloric acid. A sample of gastric juices having a volume of 5.00 mL required 11.00 mL of 0.0100 M KOH solution for neutralization in a titration. What was the molar concentration of HCl in this fluid? What was the W/V percent composition of HCl in the gastric fluid?
10. A certain toilet bowl cleaner uses $NaHSO_4$ as its active ingredient. In an analysis, 0.500 grams of the cleaner was dissolved in 30.0 mL of distilled water and required 24.60 mL of 0.105 M NaOH for complete neutralization in a titration. The net ionic equation for the reaction is:

    $HSO_4^{-1}{}_{(aq)}$ + $OH^{-1}{}_{(aq)}$ ------> $H_2O_{(l)}$ + $SO_4^{-2}{}_{(aq)}$
11. How many grams of $Ca(OH)_2$ would be needed to completely neutralize 42.6 grams of H_3PO_4?
12. A solid sample weighing 0.950 grams contained strontium chloride and some inert impurities. It was dissolved in water and treated with 25.00 mL of 0.25 M AgNO3 solution to give a precipitate of silver chloride. The excess silver ions in the solution were titrated with 8.00 mL of 0.210 potassium thiocyanate (KSCN) according to the following equation:

    $Ag^{+1}{}_{(aq)}$ + $SCN^{-1}{}_{(aq)}$ --------> $AgSCN_{(s)}$

    What percentage of strontium chloride was present in the original sample?

74. Answers - Titrations and Chemical Analysis

1. The molarity of the hydrochloric acid is 0.12 M
2. a) The molarity of the hydrochloric acid is 0.67 M

   b) Therefore the solution is 4.02 % W/V
3. The molarity of the lactic acid is 0.15 M
4. a) first reaction $CaCO_3$ + 2 HCl ----> $CaCl_2$ + H_2O + CO_2

   1.50 g 50 mL

   0.2 M

   The first reaction is used to react all the $CaCO_3$ present in the sample.

   second reaction HCl + NaOH ---> NaCl + H_2O

   The second reaction removes the excess hydrochloric acid.

   moles of base = 0.0017 moles

There are 0.0017 moles of base used.

b) Since the NaOH reacts with the HCl on a 1:1 basis then there must have been 0.0017 moles of excess acid as well.

c) The amount of acid added in the original amount is 0.01 moles of HCl

The amount used in the reaction = 0.01 mol - 0.0017 mol of excess = 0.0083 moles of HCl

There was 0.0083 moles of HCl used in the reaction with the calcium carbonate.

d) The original reaction was:
$CaCO_3$ + 2 HCl ----> $CaCl_2$ + H_2O + CO_2
0.0083 mol
Therefore the W/W percentage is 27.69%

5. $HC_9H_7O_4$ + KOH ----> $KC_9H_7O_4$ + H_2O
0.250 g 0.03 M
impure 29.40 mL

The 0.159 grams of aspirin in a 0.250 grams tablet represents a 63.6% W/W concentration

6. The molarity of the hydrochloric acid is 0.116 M

7. NH_3 + H_3O^+ -----> NH_4^+ + H_2O
5.0 g 1.00 M
29.86 mL

The W/V concentration of the NH_3 solution is 0.10 W/V

8. H_2SO_4 + 2 NaOH -----> Na_2SO_4 + 2 H_2O
15.00 mL 0.147 M
36.42 mL

The molarity of the H_2SO_4 is 0.17 M

9. HCl + KOH ---> KCl + H_2O
5.00 mL 0.01 M
11.00 mL

The stomach acid sample has a 0.0008 W/V concentration.

10. 2 $NaHSO_4$ + 2 NaOH ---> 2 H_2O + Na_2SO_4
0.500 g 0.105 M
24.60 mL

The toilet cleaner is not pure and has a 62.44% W/W concentration.

11. 3 $Ca(OH)_2$ + 2 H_3PO_4 ---> $Ca_3(PO_4)_2$ + 6 H_2O
? g 42.6 g

The neutralization of 42.6 grams of phosphoric acid requires 48.17 grams of calcium hydroxide.

12. The reactions involved are:

$SrCl_2$ + 2 $AgNO_3$ ---> $Sr(NO_3)_2$ + 2 AgCl
0.95 g 0.25 M
25 mL
and
Ag^+ + SCN^- -----> AgSCN
0.21 M

8.00 mL

The original sample containing strontium chloride was 38% pure.

75. Reactions in Solution

1. Ammonium sulphate is a "high-nitrogen" fertilizer. It is manufactured by reacting sulphuric acid with ammonia. In a laboratory study of this process, 50.0 mL of sulphuric acid reacts with 24.4 mL of a 2.20 M ammonia solution (ammonium hydroxide) to yield the product ammonium sulphate in solution. Calculate the molar concentration of the sulphuric acid used.

2. Slaked lime is sometimes used in water treatment plants to clarify water for residential use. The lime is added to an aluminum sulphate solution in the water. Fine particles in the water stick to the floc precipitate produced, and settle out with it. Calculate the volume of 0.0250 M calcium hydroxide solution that can be completely reacted with 25.0 mL of 0.25 M aluminum sulphate solution.

3. In designing a solution stoichiometry experiment for her class to perform, a chemistry teacher wants 75.0 mL of 0.200 M iron(III) chloride solution to react completely with an excess of 0.250 M sodium carbonate solution.
   a) What is the minimum volume of this sodium carbonate solution needed?

   b) What would be a reasonable volume of this sodium carbonate solution to use in this experiment? Provide your reasoning.

4. A student wishes to precipitate all the lead(II) ions from 2.0 L of solution containing, among other substances, 0.34 M $Pb(NO_3)_{2(aq)}$. The purpose of this reaction is to make the filtrate solution non-toxic. If the student intends to precipitate lead(II) sulphate, suggest and calculate an appropriate solute, and calculate the required mass of this solute.

5. Copper(II) ions can be precipitated from waste solution by adding aqueous sodium carbonate.
   a) What is the minimum volume of 1.25 M Na_2CO_3(aq) needed to precipitate all the copper(II) ions in 4.54 L of 0.0875 M $CuSO_{4(aq)}$ solution?

   b) Suggest a suitable volume to use for this reaction.

6. A 24.89 piece of zinc is placed into a beaker containing 350 mL of hydrochloric acid. The next day the remaining zinc is removed, dried, weighed, and found to have a mass of 21.62 grams. Determine the concentration of zinc chloride in the beaker.

7. How many millilitres of 0.300 M $NiCl_{2(aq)}$ solution are required to completely react with 25.0 mL of 0.100 M $Na_2CO_{3(aq)}$ solution? How many grams of $NiCO_{3(s)}$ will be formed?

8. How many millilitres of 0.400 M $CaCl_{2(aq)}$ would be needed to react completely with 35.0 mL of 0.600 M $AgNO_{3(aq)}$ solution?

9. Suppose that 30.0 mL of 0.400 M NaCl(aq) is added to 30.0 mL of 0.300 M $AgNO_{3(aq)}$.
   a) How many moles and grams of AgCl(s) would precipitate?
   b) What would be the concentrations of each of the remaining ions in the solution after reaction?

76. Answers - Reactions in Solution

1. H_2SO_4 + 2 NH_3 ---> $(NH_4)_2SO_4$
   50.0 mL 2.20 M
   24.4 mL
   The molarity of the sulphuric acid solution is 0.54 M

2. 3 $Ca(OH)_2$ + $Al_2(SO_4)_3$ ----> 3 $CaSO_4$ + 2 $Al(OH)_3$
   0.025 M 0.125 M
   25.0 mL
   The reaction of 25 mL of 0.125 M aluminum sulphate with 0.025 M calcium hydroxide will require 375 mL of the calcium hydroxide solution.

3. a) 2 $FeCl_3$ + 3 Na_2CO_3 ----> $Fe_2(CO_3)_3$ + 6 NaCl
   0.2 M 0.25 M
   75.0 mL
   The reaction of 75.0 mL of the 0.2 M ferric chloride acid will require 90 mL of the 0.25 M sodium carbonate solution.
   A reasonable volume of this solution would be 100 mL since it garantees an excess but not by an excessive amount.

4. $Pb(NO_3)_2$ $0.34\text{ M} = \frac{0.34\text{ mol}}{1\text{ L}} = \frac{x}{2\text{ L}}$ x = 0.68 moles of lead(II) nitrate
   0.34 M
   2.0 L
   Therefore is is more economical to use the aluminum sulphate since only 78.70 g of alumnium sulphate is needed compared to the 118.50 g of potassium sulphate and 96.59 g of sodium sulphate.

5. a) $CuSO_4$ + Na_2CO_3 ----> $CuCO_3$ + Na_2SO_4
0.0875 M   1.25 M
4.54 L

The reaction of 4.54 L of 0.875 M copper(II) sulphate solution will require 317.8 mL of 1.25 M sodium carbonate solution. A reasonable volume of this solution would be 320 mL since it garantees an excess but not by an excessive amount.

6. The resulting solution will be 0.14 M $ZnCl_2$

7. $NiCl_2$ + Na_2CO_3 ---> $NiCO_3$ + 2 NaCl
0.300 M   0.1 M
25.0 mL

The reaction of 25.0 mL of 0.1 M sodium carbonate will require 8.33 mL of nickleous chloride and will produce 0.30 grams of nickleous carbonate.

8. $CaCl_2$ + 2 $AgNO_3$ ----> $Ca(NO_3)_2$ + 2 AgCl
0.4 M   0.6 M
35.0 mL

The reaction of 35 mL of 0.6 M silver nitrate will require 26.25 mL of the 0.4 M calcium chloride solution.

9. a) NaCl + $AgNO_3$ -----> AgCl + $NaNO_3$
0.4 M   0.3 M
30 mL   30 mL

1.29 grams of AgCl created

b) NaCl + $AgNO_3$ -----> AgCl + $NaNO_3$
0.012 mol   0.009 mol

Use ICE, Initial [], Changein [], and End []

Na^{+1} + Cl^{-1} + Ag^{+1} + NO_3^{-1} -----> $AgCl_{(ppt)}$ + Na^{+1} + NO_3^{-1}

	Na^{+1}	Cl^{-1}	Ag^{+1}	NO_3^{-1}
I	0.012	0.012	0.009	0.009
C	0	-0.009	-0.009	0
E	0.012	0.003	0	0.009

The volume will be 60 mL or 0.06 L therefore
$[Na^{+1}]$ = 0.2 M; $[Ag^{+1}]$ = 0; $[Cl^{-1}]$ = 0.05 M; $[NO_3^{-1}]$ = 0.15 M

77. Boyle's Law

1. State the pressure-volume law both in words and in the form of an equation.

2. To compress nitrogen at 1 atm from 750 mL to 500 mL, what must the new pressure be if the temperature is kept constant?

3. If oxygen at 128 kPa is allowed to expand at constant temperature until its pressure is 101.3 kPa, how much larger will the volume become?

4. A sample of nitrogen at 101.3 kPa with a volume of 100 mL is carefully compressed at constant temperature in successive changes in pressure, equalling 5 kPa at a time, until the final pressure is 133.3 kPa. Calculate each new volume and prepare a plot of P versus V, showing P on the horizontal axis.

5. A sample of nitrogen at 20°C was compressed from 300 mL to 0.360 mL and its new pressure was found to be 400.0 Pa. What was the original pressure in kPa?

6. The pressure on 6.0 L of a gas is 200 kPa. What will be the volume if the pressure is doubled, keeping the temperature constant?

7. What would be the new volume if the pressure on 600 mL is increased from 90 kPa to 150 kPa?

8. A student collects 25 mL of gas at 96 kPa. What volume would this gas occupy at 101.325 kPa. There is no change in temperature or mass.

9. A gas measuring 525 mL is collected at 104.66 kPa. What volume does this gas occupy at 99.33 kPa?

10. A mass of gas occupies 1 L at 1 atm. At what pressure does this gas occupy
    a) 2 litres,
    b) 0.5 litres?

11. From the data in the following table calculate the missing quantity (assuming constant temperature).
    a) V_1 = 22.4 L; P_1= 1 atm; P_2 = ? atm; V_2 = 2.8 L
    b) V_1 = 60 mL; P_1 = ? kPa; P_2 = 101.3 kPa; V_2 = 16 mL
    c) V_1 = ? m^3; P_1 = 40 Pa; P_2 = 100 kPa; V_2 = 1.0 L
    d) V_1 = 2.50 L; P_1 = 7.5 atm; P_2 = ? atm; V_2 = 100 mL

78. Answers - Boyle's Law

1. $P_1V_1=P_2V_2$ The pressure times volume in the fist scenario must be equal to the pressure times volume in the second scenario.

2. V_1 = 750 mL V_2 = 500 mL
   P_1 = 1 atm P_2 = ?

   $$P_2 = \frac{P_1 \bullet V_1}{V_2} = \frac{750\text{ mL} \bullet 1\text{ atm}}{500\text{ mL}} = 1.5\text{ atm}$$

   The new pressure must be 1.5 atmospheres.

3. Assume the initial volume is 1 L. The resulting pressure will be a multiple of this.
   V_1 = 1 L V_2 = ?
   P_1 = 128 kPa P_2 = 101.3 kPa

   $$V_2 = \frac{P_1 \bullet V_1}{P_2} = \frac{128\text{ kPa} \bullet 1\text{ L}}{101.3\text{ kPa}} = 1.264$$

   The volume will increase to 1.264 times larger than the original volume

4. Use $V_2 = \frac{P_1 \bullet V_1}{P_2}$

   Starting at a P_1 of 101.3 kPa find the V_2
   Increment by P_1 by 5 kPa until 133.3 kPa is reached

P_1	V_1
101.3 kPa	100 mL
106.3 kPa	95.3 mL

111.3 kPa	91.02 mL
116.3 kPa	87.10 mL
121.3 kPa	83.51 mL
126.3 kPa	80.21 mL
131.3 kPa	77.16 mL
133.3 kPa	76.00 mL

5. V_1 = 300 mL V_2 = 0.360 mL
P_1 = ? P_2 = 400 Pa

$$P_1 = \frac{P_2 \bullet V_2}{V_1} = \frac{400\ \text{Pa} \bullet 0.360\ \text{mL}}{300\ \text{mL}} = 0.48\ \text{Pa} = 4.8 \times 10^{-4}\ \text{kPa}$$

6. V_1 = 6.0 L V_2 = ?
P_1 = 200 kPa P_2 = 400 kPa

$$V_2 = \frac{P_1 \bullet V_1}{P_2} = \frac{200\ \text{kPa} \bullet 6.0\ \text{L}}{400\ \text{kPa}} = 3.0\ \text{L}$$

7. V_1 = 600 mL V_2 = ?
P_1 = 90 kPa P_2 = 150 kPa

$$V_2 = \frac{P_1 \bullet V_1}{P_2} = \frac{90\ \text{kPa} \bullet 600\ \text{mL}}{150\ \text{kPa}} = 360\ \text{mL}$$

8. V_1 = 25 mL V_2 = ?
P_1 = 96 kPa P_2 = 101.325 kPa

$$V_2 = \frac{P_1 \bullet V_1}{P_2} = \frac{96\ \text{kPa} \bullet 25\ \text{mL}}{101.325\ \text{kPa}} = 23.69\ \text{mL}$$

9. V_1 = 525 mL V_2 = ?
P_1 = 104.66 kPa P_2 = 99.33 kPa

$$V_2 = \frac{P_1 \bullet V_1}{P_2} = \frac{104.66\ \text{kPa} \bullet 525\ \text{mL}}{99.33\ \text{kPa}} = 553.17\ \text{mL}$$

10. a) V_1 = 1 L V_2 = 2 L
P_1 = 1 atm P_2 = ?

$$P_2 = \frac{V_1 \bullet P_1}{V_2} = \frac{1\ \text{L} \bullet 1\ \text{atm}}{2\ \text{L}} = 0.5\ \text{atm}$$

b) V_1 = 1 L V_2 =0.5 L
P_1 = 1 atm P_2 = ?

$$P_2 = \frac{V_1 \bullet P_1}{V_2} = \frac{1\ \text{L} \bullet 1\ \text{atm}}{0.5\ \text{L}} = 2\ \text{atm}$$

11. a) $$P2 = \frac{V1 \bullet P1}{V2} = \frac{22.4\ \text{L} \bullet 1\ \text{atm}}{2.8\ \text{L}} = 8\ \text{atm}$$

b) $$P1 = \frac{P2 \bullet V2}{V1} = \frac{101.3\ \text{kPa} \bullet 16\ \text{mL}}{60\ \text{mL}} = 27.0\ \text{kPa}$$

c) $$V1 = \frac{P2 \bullet V2}{P1} = \frac{100\ \text{kPa} \bullet 1.0\ \text{L}}{40\ \text{Pa}} = \frac{100\ 000\ \text{Pa} \bullet 1.0\ \text{L}}{40\ \text{Pa}} = 2500\ \text{L} = 2500\ \text{dm3} = 2.5\ \text{m3}$$

d) P2 = V1 • P1 = 2.50 L • 7.5 atm = 2.50 L • 7.5 atm = 187.5 atm

V2	100 mL	0.1 L

79. Charles Law

1. Give the temperature-volume law both in words and in the form of an equation.
2. How is the volume of a gas affected by a decrease in temperature?
3. What would be the new volume if the temperature on 450 mL of gas is changed from 45°C to -5°C?
4. A sample of gas whose volume at 27°C is 0.127 L, is heated at constant pressure until its volume becomes 317 mL. What is the final temperature of the gas in Celsius and kelvin?
5. To make 300 mL of oxygen at 20.0°C change its volume to 250 mL, what must be done to the sample if its pressure and mass are to be held constant?
6. To what temperature must an ideal gas at 27°C be cooled to reduce its volume by 1/3?
7. From the data in the following questions calculate the missing quantity.
   a) V_1 = 22.4 L; T_1 = 0°C; T_2 = 91°C; V_2 = ? L
   b) V_1 = 125 mL; T_1 = ? ; T_2 = 25°C; V_2 = 100 mL
   c) V_1 = ? L; T_1 = 400 K; T_2 = 175 K; V_2 = 6.20 L
   d) V_1 = 250 mL; T_1 = 298 K; T_2 = ? K; V_2 = 273 mL
8. A 50 cm^3 sample of a gas in a syringe at 15°C is heated to 50°C and the syringe's piston is allowed to move outward against a constant atmospheric pressure. Calculate the new volume of the hot gas.
9. What is the final volume if 3.4 L of nitrogen gas at 400 K is cooled to 200 K and kept at the same pressure?
10. Determine the final volume of 20 L of a gas whose temperature changes from -73°C to 327°C if the pressure remains constant.
11. A partially filled plastic balloon contains 3.4×10^3 m^3 of helium gas at 5°C. The noon day sun heats this gas to 37°C. What is the volume of the balloon if atmospheric pressure remains constant?

80. Answers - Charles Law

1. $\frac{V1}{T1} = \frac{V2}{T2}$ or $V1 \bullet T2 = V2 \bullet T1$

The volume of a gas is directly proportional to it's Kelvin temperature.

2. Gas volume decreases as the temperature decreases. Gas volume will increase as the temperature increases.

3. V1 = 450 mL V2 = ?
T1 = 45oC = 318.15 K T2 = -5oC = 268.15 K

$$V2 = \frac{V1 \bullet T2}{T1} = \frac{450\ mL \bullet 268.15\ K}{318.15\ K} = 379.28\ mL$$

4. V1 = 127 mL V2 = 317 mL
T1 = 27oC = 300.15 K T2 = ?

$$T2 = \frac{V2 \bullet T1}{V1} = \frac{317\ mL \bullet 300.15\ K}{127\ mL} = 749.19\ K = 476.04oC$$

5. V1 = 300 mL V2 = 250 mL
T1 = 20oC = 293.15 K T2 = ?

$$T2 = \frac{V2 \bullet T1}{V1} = \frac{250\ mL \bullet 293.15\ K}{300\ mL} = 244.29\ K = -28.86oC$$

6. V1 = 1 L V2 = 2/3 L
T1 = 27oC = 300.15 K T2 = ?

$$T2 = \frac{V2 \bullet T1}{V1} = \frac{2/3\ L \bullet 300.15\ K}{1\ L} = 200.1\ K = -73.05oC$$

7. a) $V2 = \frac{V1 \bullet T2}{T1} = \frac{364.15\ K \bullet 22.4\ L}{273.15\ K} = 29.86\ L$

b) $T1 = \frac{V1 \bullet T2}{V2} = \frac{298.15\ K \bullet 125\ mL}{100\ mL} = 372.69\ K = 99.54oC$

c) $V1 = \frac{V2 \bullet T1}{T2} = \frac{400\ K \bullet 6.20\ L}{175\ K} = 14.17\ L$

d) $T2 = \frac{V2 \bullet T1}{V1} = \frac{273\ mL \bullet 298.15\ K}{250\ mL} = 325.42\ K$

8. $V2 = \frac{V1 \bullet T2}{T1} = \frac{50\ cm3 \bullet 323.15\ K}{288.15\ K} = 56.07\ cm3$

9. $V2 = \frac{V1 \bullet T2}{T1} = \frac{3.4\ L \bullet 200\ K}{400\ K} = 1.7\ L$

10. $V2 = \frac{V1 \bullet T2}{T1} = \frac{20\ L \bullet 600.15\ K}{200.15\ K} = 60\ L$

11. $V2 = \frac{V1 \bullet T2}{T1} = \frac{3.4\ X\ 103\ m3 \bullet 310.15\ K}{278.15\ K} = 3.791\ X\ 103\ m3$

81. Avogadro's Law of Combining Volumes

Standard Temperature & Pressure: 22.4 L at 0^oC and 1 atmosphere pressure
Standard Ambient Temperature & Pressure: 24.8 L at 20^oC and 1 atmosphere pressure

1. A sample of carbon dioxide gas has a volume of 55.0 mL at 45^oC and 85.0 kPa. Determine the volume at STP and SATP.
2. What pressure will 37.18 grams of CO_2 gas exert on a container at standard temperature?
3. Find the mass of 543 mL of acetylene gas, C_2H_2, collected at a pressure of 85.0 kPa and standard temperature.
4. What is the density of CO_2 gas measured at 5^oC and 200 kPa?
5. A sample of cooking gas, taken from a cylinder, was collected and its density measured at 27^oC and 100 kPa. The density at those conditions was 1.768 g/L. What was the molar mass of the cooking gas?
6. At STP, how many molecules of hydrogen are in 22.4 L?
7. Given 4.80 g of O_2 gas and 2.80 g of N_2 gas. Calculate for each of these samples:
   (a) the number of moles
   (b) the number of molecules
   (c) the number of atoms
   (d) the volume of each at STP and SATP

82. Answers - Avogadro's Law of Combining Volumes

1. @ STP V_1 = 55.0 mL V_2 = ?
   P_1 = 85.0 kPa P_2 = 101.325 kPa
   $T_1 = 45^oC$ = 318.15 K $T_2 = 0^oC$ = 273.15 K

   $$V_2 = \frac{V_1 \bullet P_1 \bullet T_2}{P_2 \bullet T_1} = \frac{55.0\text{ mL} \bullet 85.0\text{ kPa} \bullet 273.15\text{ K}}{101.325\text{ kPa} \bullet 318.15\text{ K}} = 39.61\text{ mL at STP}$$

   @ SATP V_1 = 55.0 mL V_2 = ?
   P_1 = 85.0 kPa P_2 = 100 kPa
   $T_1 = 45^oC$ = 318.15 K $T_2 = 25^oC$ = 298.15 K

   $$V_2 = \frac{V_1 \bullet P_1 \bullet T_2}{P_2 \bullet T_1} = \frac{55.0\text{ mL} \bullet 85.0\text{ kPa} \bullet 298.15\text{ K}}{100\text{ kPa} \bullet 318.15\text{ K}} = 42.51\text{ mL at SATP}$$

2. Pressure of 37.18 of CO_2 at standard temperatures

   Solution steps
   Step #1 Find the number of moles of carbon dioxide present
   Step #2 Using the STP definition find the value of pressure
   Step #3 Convert to all other standard pressures values

   Step #1 Moles of CO_2 present
   $$n = \frac{m}{M} = \frac{37.18\text{ g}}{44.01\text{ g/mol}} = 0.845\text{ moles of } CO_2$$

   Step #2 Pressure at STP
   @ STP $\frac{1\text{ mole}}{} = \frac{1\text{ atm}}{}$
   therefore 0.845 mol x x = 0.845 atm

   Step #3 Convert to all other pressure units

   $$\frac{1\text{ atm}}{0.845\text{ atm}} = \frac{101.325\text{ kPa}}{x} = \frac{760\text{ Torr}}{y} \qquad x = 85.60\text{ kPa} \quad y = 642.05\text{ Torr}$$

3. @ STP V_1 = 543 mL V_2 = ?
   P_1 = 85.0 kPa P_2 = 101.325 kPa
   $T_1 = 0^oC$ = 273.15 K $T_2 = 0^oC$ = 273.15 K

   $$V_2 = \frac{V_1 \bullet P_1}{P_2} = \frac{543\text{ mL} \bullet 85.0\text{ kPa}}{101.325\text{ kPa}} = 0.456\text{ L at STP}$$

   $$\text{@ STP} \quad \frac{1\text{ mol}}{x} = \frac{22.4\text{ L}}{0.456\text{ L}} \qquad x = 0.02\text{ mol of gas present}$$

   m = n • M = 0.02 mol • 26.04 g/mol = 0.52 grams C_2H_2 = 2 C = 2 • 12.01 = 24.02 g/mol

$2\ H = 2 \bullet 1.01 = \underline{2.02}$ g/mol
26.04 g/mol

4. 1 mole of any gas at STP = 22.4 L

@ STP $V_1 = 22.4$ L; $V_2 = ?$
$P_1 = 101.325$ kPa; $P_2 = 200$ kPa
$T_1 = 0^{o}C = 273.15$ K; $T_2 = 5^{o}C = 278.15$ K

$$V_2 = \frac{V_1 \bullet P_1}{P_2} = \frac{22\ 4\ L \bullet 101.325\ kPa \bullet 278.15\ K}{101.325\ kPa \bullet 273.15\ K} = 11.56\ L \text{ at STP}$$

$$D = \frac{m}{V} = \frac{44.01\ g}{11.56\ L} = 3.81\ g/L$$

5. The gas has a density of 1.768 g/L
Therefore two pieces of information are given: m = 1.768 g and $V_1 = 1$ L

@ STP $V_1 = 1$ L; $V_2 = ?$
$P_1 = 100$ kPa; $P_2 = 101.325$ kPa
$T_1 = 27^{o}C = 300.15$ K; $T_2 = 0^{o}C = 273.15$ K

$$V_2 = \frac{V_1 \bullet P_1 \bullet T_2}{P_2 \bullet T_1} = \frac{1\ L \bullet 100\ kPa \bullet 273.15\ K}{101.325\ kPa \bullet 300.15\ K} = 0.90\ L$$

Therefore @ STP $\frac{1\ mole}{x} = \frac{22.4\ L}{0.90\ L}$ x = 0.04 mol

Therefore M = g/mol = 1.76 g/0.04 mol = 44.01 g/mol

6. At STP 22.4 L = 1 mole and 1 moles has 6.02×10^{23} molecules

7.

		O_2	N_2
	m	4.80 g	2.80 g
	M	32.00 g/mol	28.02 g/mol
a)	n	0.15 moles	0.10 moles
b)	molecules	9.03×10^{22} molecules	6.02×10^{22} molecules
c)	atoms	1.806×10^{23} atoms	1.204×10^{23} atoms
d)	STP	3.36 L	2.24 L
	SATP	3.72 L	2.48 L

83. Combined Gas Law

1. Helium in a 100 mL container at a pressure of 66.6 kPa is transferred to a container with a volume of 250 mL. What is the new pressure if no change in temperature occurs? What is the new pressure if the temperature changes from 20°C to 15°C?
2. What will have to happen to the temperature of a sample of methane if 1000 mL at 98.6 kPa and 25°C is given a pressure of 108.5 kPa and a volume of 900 mL?
3. A gas has a volume of 225 mL at 75°C and 175 kPa. What will be its volume at a temperature of 20°C and a pressure of 1.0 X 10^5 kPa?
4. A gas is heated to 80°C and a pressure of 180 kPa. If the container expands to hold a volume of 800 mL, what was the volume of the gas, (in litres), at a temperature of 50°C and 120 kPa pressure?
5. A 200 mL sample of gas is collected at 50 kPa and a temperature of 271°C. What volume would this gas occupy at 100 kPa and a temperautre of -14°C?
6. Correct the following volumes at STP and at SATP:
   (a) 24.6 L at 25°C and 104 kPa (b) 150000 mm^3 at 100°C and 75.00 kPa
   (c) 0.045 L at -45.0°C and 140.0 kPa (d) 0.5 L at 115°C and 148000 Pa
7. A certain sample of gas has a volume of 0.452 L measured at 87°C and 0.620 atm. What is its volume at 1 atm and 0°C?
8. Natural gas is usually stored in large underground reservoirs or in above ground tanks. Suppose that a supply of natural gas is stored in an underground reservoir of volume 8.0 X 10^5 m^3 at a pressure of 360 kPa and a temperature of 16°C. How many above ground tanks of volume 2.7 X 10^4 m^3 at a temperature of 6°C could be filled with the gas at a pressure of 120 kPa?
9. The human lung has an average temperature of 37°C. If one inhales Alaskan air at 1 atm and -28.9°C and then holds it, to what pressure will the air in the lungs rise? (The bursting strength of the human lung is over 2 atm. Will they burst?)
10. A cylindrical coffee can is welded shut at 20°C at sea level. Its height is 20 cm and its radius is 15 cm. If the bursting strength of it's "tin" plate is 3.75 atm, to what temperature may it be ehated before bursting?

84. Answers - Combined Gas Law

1. no temperature change

   P_1 = 66.6 kPa P_2 = ?
   V_1 = 100 mL V_2 = 250 mL

   $P_2 = \frac{P_1 \bullet V_1}{V_2}$

   $= \frac{66.6 \text{ kPa} \bullet 100 \text{ mL}}{250 \text{ mL}}$

   = 26.64 kPa without a temperature change

   with a temperature change

   P_1 = 66.6 kPa P_2 = ?
   V_1 = 100 mL V_2 = 250 mL
   T_1 = 20°C = 293.15 K T_2 = 288.15 K

   $P_2 = \frac{P_1 \bullet V_1 \bullet T_2}{V_2 \bullet T_1}$

   $= \frac{66.6 \text{ kPa} \bullet 100 \text{ mL}}{250 \text{ mL}}$

   =26.19 kPa with a temperature change

2. P_1 = 98.6 kPa P_2 = 108.5 kPa
   V_1 = 1000 mL V_2 = 900 mL
   T_1 = 25°C = 298.15 K T_2 = ?

   $T_2 = \frac{P_2 \bullet V_2 \bullet T_1}{P_1 \bullet V_1} = \frac{108.5 \text{ kPa} \bullet 900 \text{ mL} \bullet 298.15 \text{ K}}{98.6 \text{ kPa} \bullet 1000 \text{ mL}}$ = 295.28 K = 22.13°C

   The methane gas sample temperature will fall to 22.13°C

3. P_1 = 175 kPa P_2 = 100 000 kPa
   V_1 = 225 mL V_2 = ?
   T_1 = 75°C = 348.15 K T_2 = 20°C = 293.15 K

   $V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1} = \frac{175 \text{ kPa} \bullet 225 \text{ mL} \bullet 293.15 \text{ K}}{100\,000 \text{ kPa} \bullet 348.15 \text{ kPa}}$ = 0.33 mL

   The gas sample volume will decrease to 0.33 mL

4. P_1 = 180 kPa P_2 = 120 kPa
   V_1 = 800 mL V_2 = ?
   T_1 = 80°C = 353.15 K T_2 = 50°C = 323.15 K

   $V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1} = \frac{180 \text{ kPa} \bullet 800 \text{ mL} \bullet 323.15 \text{ K}}{120 \text{ kPa} \bullet 353.15 \text{ kPa}}$ = 1098.06 mL

   The gas sample volume will increase to 1098.06 mL

5. P_1 = 50 kPa P_2 = 100 kPa
   V_1 = 200 mL V_2 = ?

$T_1 = 544.15\ K$ $T_2 = -14^oC = 259.15\ K$

$$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1} = \frac{50\ kPa \bullet 200\ mL \bullet 259.15\ K}{100\ kPa \bullet 544.15\ kPa} = 47.62\ mL$$

The gas sample volume will decrease to 47.62 mL

STP | SATP

6. (a)

STP:

$P_1 = 104\ kPa$ $P_2 = 101.325\ kPa$
$V_1 = 24.6\ L$ $V_2 = ?$
$T_1 = 25^oC = 298.15\ K$ $T_2 = 0^oC = 273.15\ K$

$$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1}$$

$$= \frac{104\ kPa \bullet 24.6\ L \bullet 273.15\ K}{101.325\ kPa \bullet 298.15\ K}$$

= 23.13 L at STP

SATP:

$P_1 = 104\ kPa$ $P_2 = 101.325\ kPa$
$V_1 = 24.6\ L$ $V_2 = ?$
$T_1 = 25^oC = 298.15\ K$ $T_2 = 20^oC = 293.15\ K$

$$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1}$$

$$= \frac{104\ kPa \bullet 24.6\ L \bullet 293.15\ K}{101.325\ kPa \bullet 298.15\ K}$$

= 24.83 L at SATP

6. (b)

STP:

$P_1 = 75.00\ kPa$ $P_2 = 101.325\ kPa$
$V_1 = 150\ 000\ mm^3$ $V_2 = ?$
$T_1 = 100^oC = 373.15\ K$ $T_2 = 0^oC = 273.15\ K$

$$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1}$$

$$= \frac{75.0\ kPa \bullet 150\ 000\ mm^3 \bullet 273.15\ K}{101.325\ kPa \bullet 373.15\ K}$$

= 81274.38 mm^3 at STP

SATP:

$P_1 = 75.00\ kPa$ $P_2 = 101.325\ kPa$
$V_1 = 150\ 000\ mm^3$ $V_2 = ?$
$T_1 = 100^oC = 373.15\ K$ $T_2 = 20^oC = 293.15\ K$

$$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1}$$

$$= \frac{75.0\ kPa \bullet 150\ 000\ mm^3 \bullet 293.15\ K}{101.325\ kPa \bullet 373.15\ K}$$

= 87225.28 mm^3 at SATP

6. (c)

STP:

$P_1 = 140.0\ kPa$ $P_2 = 101.325\ kPa$
$V_1 = 0.045\ L$ $V_2 = ?$
$T_1 = -45^oC = 228.15\ K$ $T_2 = 0^oC = 273.15\ K$

$$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1}$$

$$= \frac{140.0\ kPa \bullet 0.045\ L \bullet 273.15\ K}{101.325\ kPa \bullet 228.15\ K}$$

= 0.074 L at STP

SATP:

$P_1 = 140.0\ kPa$ $P_2 = 101.325\ kPa$
$V_1 = 0.045\ L$ $V_2 = ?$
$T_1 = -45^oC = 228.15\ K$ $T_2 = 20^oC = 293.15\ K$

$$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1}$$

$$= \frac{140.0\ kPa \bullet 0.045\ L \bullet 293.15\ K}{101.325\ kPa \bullet 228.15\ K}$$

= 0.08 L at SATP

6. (d)

STP:

$P_1 = 148.0\ kPa$ $P_2 = 101.325\ kPa$
$V_1 = 0.5\ L$ $V_2 = ?$
$T_1 = 115^oC = 388.15\ K$ $T_2 = 0^oC = 273.15\ K$

$$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1}$$

$$= \frac{148.0\ kPa \bullet 0.5\ L \bullet 273.15\ K}{101.325\ kPa \bullet 388.15\ K}$$

= 0.51 L at STP

SATP:

$P_1 = 148.0\ kPa$ $P_2 = 101.325\ kPa$
$V_1 = 0.5\ L$ $V_2 = ?$
$T_1 = 115^oC = 388.15\ K$ $T_2 = 20^oC = 293.15\ K$

$$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1}$$

$$= \frac{148.0\ kPa \bullet 0.5\ L \bullet 293.15\ K}{101.325\ kPa \bullet 388.15\ K}$$

and 0.55 at SATP

7. $P_1 = 0.620\ atm$ $P_2 = 1\ atm$
$V_1 = 0.452\ L$ $V_2 = ?$
$T_1 = 87^oC = 360.15\ K$ $T_2 = 0^oC = 273.15\ K$

$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1} = \frac{0.620 \text{ atm} \bullet 0.452 \text{ L} \bullet 273.15 \text{ K}}{120 \text{ kPa} \bullet 289.15 \text{ K}} = 0.21 \text{ L}$

8. We need to take the gas from the underground set of conditions and convert it into the set of conditions found above ground in the tanks.

$P_1 = 360$ kPa $\quad P_2 = 120$ kPa
$V_1 = 8.0 \text{ X } 10^5 \text{ m}^3 \quad V_2 = ?$
$T_1 = 16^oC \quad T_2 = 6^oC$
$= 289.15$ K $\quad = 279.15$ K

$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1} = \frac{360 \text{ kPa} \bullet 8.0 \text{ X } 10^5 \text{ m}^3 \bullet 279.15 \text{ K}}{120 \text{ kPa} \bullet 289.15 \text{ K}} = 2316998.1 \text{ m}^3$

Since each tank can hold $2.7 \text{ X } 10^4 \text{ m}^3$ then then number of tanks will be:
Number of tanks = total volume = $\frac{2316998.1 \text{ m}^3}{2.7 \text{ X } 10^4 \text{ m}^3}$ = 85.8 tanks or 85 full tanks

9. Once the lungs are full they can't expand due to the ribs therefore we'll assume that the volume of the lungs before and after are the same.

$P_1 = 1$ atm $\quad P_2 = ?$
$T_1 = -28^oC \quad T_2 = 37^oC$
$= 244.15$ K $\quad = 310.15$ K

$P_2 = \frac{P_1 \bullet T_2}{T_1} = \frac{1 \text{ atm} \bullet 310.15 \text{ K}}{244.15 \text{ K}} = 1.27 \text{ atm}$

No, the lungs are not in danger of bursting, the total pressure only gets to 1.27 atm

10. The measurements of the can are misleading since the can is meant to stay intact until the moment of bursting. The volume should be the same before and after.

$P_1 = 1$ atm $\quad P_2 = 3.75$ atm
$T_1 = -20^oC \quad T_2 = ?$
$= 293.15$ K

$T_2 = \frac{P_2 \bullet T_1}{P_1} = \frac{3.75 \text{ atm} \bullet 293.15 \text{ K}}{1 \text{ atm}} = 1099.31 \text{ K} = 826.16^oC$

86. Partial Pressure

1. A gas mixture consists of 60.0% Ar, 30.0% Ne, and 10.0% Kr by volume. If the pressure of this gas mixture is 80.0 kPa, what is the partial pressure of each of the gases?

2. The total pressure of a mixture of H_2, He, and Ar is 99.3 kPa. The partial pressure of the He is 42.7 kPa, and the partial pressure of Ar is 54.7 kPa. What is the partial pressure of hydrogen?

3. A cylinder contains 40 g of He, 56 g of N_2, and 40 g of Ar.

   (a) How many moles of each gas are in the mixture?
   b) If the total pressure of the mixture is 10 atm, what is the partial pressure of He?

4. What is the partial pressure of each gas in a mixture which contains 40 g of He, 56 g of N_2, and 16 g of O_2, if the total pressure of the mixture is 5 atmospheres?

5. The composition of dry air by volume is 78.1% N_2, 20.9% O_2, and 1% other gases. Calculate the partial pressures, in atmospheres and kPa, in a tank of dry air compressed to 10.0 atmospheres.

87. Answers - Partial Pressure

1. Ar = 60%   Ne = 30% Kr = 10%   PT = 80.0 kPa

   Therefore PAr = 60% • 80.0 kPa = 48.0 kPa
   PNe = 30% • 80.0 kPa = 24.0 kPa
   PKr = 10% • 80.0 kPa = 8.0 kPa

2. PT = PH2 + PHe + PAr
   Therefore
   PH2 = PT - (PHe + PAr)
   = 99.3 kPa - (42.7 kPa + 54.7 kPa)
   = 1.9 kPa

3.

	He	N_2	O_2
m	40 g	56 g	40 g
M	4	28	32
n	10	2	1
mole fraction	10/13	2/13	1/13
mole fraction	0.7692	0.1539	0.0769
Pressure	76.92 atm	15.39 atm	7.69 atm

   (a) He= 10 moles; N2 = 2 moles; Ar = 1 mole
   (b) 7.69 atm

4.

	He	N_2	O_2
m	40 g	56 g	16 g
M	4	28	32
n	10	2	0.5
mole fraction	10/12.5	2/12.5	0.5/12.5
%	0.80	0.16	0.04
Pressure	4 atm	0.8 atm	0.2 atm

   He = 4 atm; N2 = 0.8 atm and O2 = 0.2 atm

5. N2 = 7.81 atm X 101.325 kPa/atm = 791.35 kPa
   O2 = 2.09 atm X 101.325 kPa/atm = 211.77 kPa
   other = 0.01 atm X 101.325 kPa/atm = 10.13 kPa
   N2 = 7.81 atm; O2 = 2.09 atm and other gases = 0.1 atm

88. Vapor Pressure

1. When nitrogen is prepared and collected over water at 30°C and a total pressure of 98.4 kPa, what is its partial pressure in atm?
2. If you were to prepare oxygen and collect it over water at 10°C and a total pressure of 100.1 kPa, what is its partial pressure in atm, kPa and torr?
3. A sample of carbon monoxide was prepared and collected over water at a temperature of 20°C and a total pressure of 99.8 kPa. It occupied a volume of 275 mL. Calculate the partial pressure of this gas in the sample in kPa and its dry volume in mL under a pressure of 101.3 kPa.
4. A sample of hydrogen was prepared and collected over water at a temperature of 25°C and a total pressure of 98.1 kPa. It occupied a volume of 295 mL. Calculate its partial pressure, in atm, and what its dry volume would be in mL under a pressure of 101.3 kPa.
5. What volume of "wet" methane would you have to collect at 20°C and 98.6 kPa to be sure the sample contained 240 mL of dry methane at the same pressure?
6. What volume of "wet" oxygen would you have to collect if you needed the equivalent of 260 mL of dry oxygen at 101.3 kPa and the atmosphereic pressure in the lab that day was 99.4 kPa? The oxygen is to be collected over water at a temperature of 15.0°C.
7. Exactly 100 mL of oxygen are collected over water at 25°C and 106.66 kPa. What is the pressure being exerted by the pure oxygen at 25°C.
8. In an experiment, a student collects 107 mL of hydrogen over water at a pressure of 104.8 kPa and a temperature of 31°C. What volume would this hydrogen occupy at SATP?
9. If 80.0 mL of oxygen are collected over water at 20°C and 95.0 kPa. What volume would the dry oxygen occupy at STP?
10. If 450 mL of hydrogen at STP occupy 511 mL when collected over water at 18°C, what is the atmospheric pressure?
11. In an experiment a student collects 58 mL of oxygen gas by the downward displacement of water at 18°C and 105 kPa pressure. What would the mass of the dry oxygen be?

89. Answers - Vapor Pressure

1. $P_T = P_{N2} + P_{H2O@30^oC}$
   Therefore
   $P_{N2} = P_T - P_{H2O@30^oC}$
   = 98.4 kPa - 4.2455 kPa
   = 94.15 kPa = 0.929 atm

2. $P_T = P_{O2} + P_{H2O@10^oC}$
   Therefore
   $P_{O2} = P_T - P_{H2O@10^oC}$
   = 100.1 kPa - 1.2281 kPa
   = 98.87 kPa = 741.59 Torr = 0.976 atm

3. $P_T = P_{CO2} + P_{H2O@20^oC}$
   Therefore
   $P_{CO2} = P_T - P_{H2O@20^oC}$
   = 99.8 kPa - 2.3388 kPa
   = 97.46 kPa

   P_1 = 97.46 kPa P_2 = 101.3 kPa
   V_1 = 275 mL V_2 = x

   $$V_2 = \frac{P_1 \bullet V_1}{P_2} = \frac{97.46 \text{ kPa} \bullet 275 \text{ mL}}{101.3 \text{ kPa}} = 264.58 \text{ mL}$$

4. $P_T = P_{H2} + P_{H2O@25^oC}$
   Therefore
   $P_{H2} = P_T - P_{H2O@25^oC}$
   = 98.1 kPa - 3.1691 kPa
   = 94.93 kPa

   P_1 = 94.93 kPa P_2 = 101.3 kPa
   V_1 = 295 mL V_2 = ?

   $$V_2 = \frac{P_1 \bullet V_1}{P_2} = \frac{94.93 \text{ kPa} \bullet 295 \text{ mL}}{101.3 \text{ kPa}} = 276.45 \text{ mL}$$

5. V_1 = 240 mL V_2 = x
   P_1 = 98.6 + 2.3388 kPa P_2 = 98.6 kPa

   $$V_2 = \frac{P_1 \bullet V_1}{P_2} = \frac{(98.6 + 2.3388 \text{ kPa}) \bullet 240 \text{ mL}}{98.6 \text{ kPa}} = 245.89 \text{ mL}$$

6. V_1 = 260 mL V_2 = x
   P_1 = 101.3 kPa P_2 = 99.4 - 1.7056 kPa = 97.69 kPa

$V_2 = \frac{P_1 \bullet V_1}{P_2} = \frac{101.3 \text{ kPa} \bullet 260 \text{ mL}}{97.69 \text{ kPa}} = 269.60 \text{ mL}$

7. $P_T = P_{O2} + P_{H2O@25^\circ C}$

Therefore

$P_{O2} = P_T - P_{H2O@25^\circ C}$

$= 106.66 \text{ kPa} - 3.1691 \text{ kPa}$

$= 103.49 \text{ kPa}$

8. $V_1 = 107$ mL $V_2 = x$

$P_1 = 104.8 - 4.2545 = 100.5545$ kPa $P_2 = 100$ kPa

$T_1 = 30^\circ C = 303.15$ K $T_2 = 298.15$ K

$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1} = \frac{100.5545 \text{ kPa} \bullet 107 \text{ mL} \bullet 298.15 \text{ K}}{100 \text{ kPa} \bullet 303.15 \text{ K}} = 105.82 \text{ mL}$

9. $V_1 = 80$ mL $V_2 = x$

$P_1 = 95.0 - 2.3388 = 92.6612$ kPa $P_2 = 101.325$ kPa

$T_1 = 20^\circ C = 293.15$ K $T_2 = 273.15$ K

$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1} = \frac{92.6612 \text{ kPa} \bullet 80 \text{ mL} \bullet 273.15 \text{ K}}{101.325 \text{ kPa} \bullet 293.15 \text{ K}} = 68.17 \text{ mL}$

10. $V_1 = 450$ mL $V_2 = 511$ mL

$P_1 = 101.325$ kPa $P_2 = ?$

$T_1 = 273.15$ K $T_2 = 293.15$ K

$P_2 = \frac{P_1 \bullet V_1 \bullet T_2}{V_2 \bullet T_1} = \frac{101.325 \text{ kPa} \bullet 450 \text{ mL} \bullet 293.15 \text{ K}}{511 \text{ mL} \bullet 273.15 \text{ K}} = 95.7628 \text{ kPa}$

$P_T = P_{H2} + P_{H2O@20^\circ C}$

$= 95.7628 + 2.3388 \text{ kPa} = 98.1016 \text{ kPa}$

11. $V_1 = 58$ mL $V_2 = x$

$P_1 = 105.0 - 2.3388 = 102.6612$ kPa $P_2 = 101.325$ kPa

$T_1 = 20^\circ C = 293.15$ K $T_2 = 25^\circ C = 298.15$ K

$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1} = \frac{102.6612 \text{ kPa} \bullet 58 \text{ mL} \bullet 298.15 \text{ K}}{100 \text{ kPa} \bullet 293.15 \text{ K}} = 60.56 \text{ mL} = 0.06056 \text{ L}$

@SATP $\frac{1 \text{ mol}}{x} = \frac{24.8 \text{ L}}{0.06056 \text{ L}}$ $x = 0.0024$ mol

$m = n \bullet M = 0.0024 \text{ mol} \bullet 32.00 \text{ g/mol} = 0.078 \text{ grams}$

90. Ideal Gas Law

1. Using the information from STP or SATP conditions determine the value of the ideal gas constant.
2. A sample of 1.00 moles of oxygen at 50°C and 98.6 kPa occupies what volume?
3. A sample of 4.25 moles of hydrogen at 20.0°C occupies a volume of 25.0 L. Under what pressure is this sample?
4. If a steel cylinder with a volume of 1.50 L contains 10.0 moles of oxygen, under what pressure is the oxygen if the temperature is 27.0°C?
5. When the pressure in a certain gas cylinder with a volume of 4.50 L reaches 500 atm, the cylinder is likely to explode. If this cylinder contains 40.0 moles of argon at 25.0°C, is it on the verge of exploding? Calculate the pressure in atmospheres.
6. At 22.0°C and a pressure of 100.6 kPa, a gas was found to have a density of 1.14 g/L. Calculate its molecular mass.
7. A gas was found to have a density of 1.76 mg/mL at 24.0°C and a pressure of 98.8 kPa. What is its molecular mass?
8. How many millilitres of nitrogen, N_2, would have to be collected at 99.19 kPa and 28°C to have a sample containing 0.015 moles of N_2?
9. The density of a certain gas at 27.0°C and 98.66 kPa is 2.53 g/L. Calculate its molecular mass.
10. What volume is occupied by 0.25 grams of O_2 measured at 25.0°C and 100.66 kPa?
11. What is the molecular mass of a gas if 2.82 grams of the gas occupies 3.16 litres at STP?
12. A balloon is to be filled with 30.0 kg of helium gas. What volume can be filled to a pressure of 1.15 atm if the temperature is 20.0°C?
13. In a gas thermometer, the pressure needed to fix the volume of 0.20 g of helium at 0.50 L is 113.30 kPa. What is the temperature?
14. A gaseous compound has the empirical formula CHCl. At 100°C, its density at 99.97 kPa is 3.12×10^{-3} g cm^{-3}. What is the molecular formula of this compound?
15. The pressure exerted on a diver by the water increases by about 100 kPa for every 10 m of depth. A scuba diver uses air at the rate of 8 L/min at a depth of 10 m where the pressure is 200 kPa (100 kPa due to the atmosphere and 100 kPa due to the water pressure) and the temperature 8°C. If the diver's 10 L air tank is filled to a ressure of 2.1×10^4 kPa at a dockside temperature of 32°C, how long can the diver remain safely submerged?
16. You want to send chlorine gas, Cl_2, safely from Vancouver to Kingston. Chlorine gas is very poisonous and corrosive. You have a 5000 L truck cylinder that will withstand a pressure of 100 atm. The cylinder will be kept at 2°C throughout the trip. How many moles of chlorine gas can you safely ship?

91. Answers - Ideal Gas Law

1. Using kPa @STP
T = 0°C = 273.15 K
V = 22.4 L
n = 1 mol
P = 101.325 kPa

$$R = \frac{PV}{nT} = \frac{101.325 \text{ kPa} \bullet 22.4 \text{ L}}{1 \text{ mole} \bullet 273.15 \text{ K}}$$

$$= 8.314 \frac{\text{kPa} \bullet \text{L}}{\text{mole} \bullet \text{K}}$$

Using atm @STP
T = 0°C = 273.15 K
V = 22.4 L
n = 1 mol
P = 1 atm

$$R = \frac{PV}{nT} = \frac{1 \text{ atm} \bullet 22.4 \text{ L}}{1 \text{ mole} \bullet 273.15 \text{ K}}$$

$$= 0.082 \frac{\text{atm} \bullet \text{L}}{\text{mole} \bullet \text{K}}$$

Using kPa @SATP
T = 25°C = 298.15 K
V = 24.84 L
n = 1 mol
P = 101.325 kPa

$$R = \frac{PV}{nT} = \frac{101.325 \text{ kPa} \bullet 24.8 \text{ L}}{1 \text{ mole} \bullet 298.15 \text{ K}}$$

$$= 8.314 \frac{\text{kPa} \bullet \text{L}}{\text{mole} \bullet \text{K}}$$

Using atm @SATP
T = 25°C = 298.15 K
V = 24.8 L
n = 1 mol
P = 1 atm

$$R = \frac{PV}{nT} = \frac{1 \text{ atm} \bullet 24.8 \text{ L}}{1 \text{ mole} \bullet 298.15 \text{ K}}$$

$$= 0.082 \frac{\text{atm} \bullet \text{L}}{\text{mole} \bullet \text{K}}$$

2. T = 50°C = 323.15 K
V = ?
n = 1 mol
P = 98.6 kPa

$$V = \frac{nRT}{P} = \frac{1 \text{ mol} \bullet 8.314 \text{ kPa}\bullet\text{L/mol}\bullet\text{K} \bullet 323.15 \text{ K}}{98.6 \text{ kPa}} = 27.25 \text{ L}$$

The oxygen gas will occupy a volume of 27.25 L

3. T = 20°C = 293.15 K
V = 25.0 L
n = 4.25 mol

P = ?

$$P = \frac{nRT}{V} = \frac{4.25 \text{ mol} \bullet 8.314 \text{ kPa}\bullet\text{L/mol}\bullet\text{K} \bullet 293.15 \text{ K}}{25.0 \text{ L}} = 414.33 \text{ kPa}$$

Hydrogen gas under these conditions will have a pressure of 414.33 kPa or 4.09 atm

4. T = 27^{o}C = 300.15 K
V = 1.5 L
n = 10.0 mol
P = ?

$$P = \frac{nRT}{V} = \frac{10.0 \text{ mol} \bullet 8.314 \text{ kPa}\bullet\text{L/mol}\bullet\text{K} \bullet 300.15 \text{ K}}{1.5 \text{ L}} = 16\,636.314 \text{ kPa}$$

The pressure of the oxygen gas in the steel cylinder under these conditions will be 16636.314 kPa or 16.64 MPa or 164.19 atm

5. T = 25^{o}C = 298.15 K
V = 4.5 L
n = 40.0 mol
P = ?

$$P = \frac{nRT}{V} = \frac{40.0 \text{ mol} \bullet 0.082 \text{ atm}\bullet\text{L/mol}\bullet\text{K} \bullet 298.15 \text{ K}}{4.5 \text{ L}} = 217.32 \text{ atm}$$

The cylinder is not on the verge of exploding. It is at 217.32 atm of pressure and the cylinder is built to withstand 500 atm.

6. D = 1.14 g/L Therefore the m = 1.14 g and the volume = 1 L

T = 22^{o}C = 295.15 K
P = 100.6 kPa

$$n = \frac{P \bullet V}{R \bullet T} = \frac{100.6 \text{ kPa} \bullet 1 \text{ L}}{8.314 \text{ kPa}\bullet\text{L/mol}\bullet\text{K} \bullet 295.15 \text{ K}} = 0.04 \text{ moles}$$

$$M = \frac{m}{n} = \frac{1.14 \text{ g}}{0.04 \text{ mol}} = 27.81 \text{ g/mole}$$

The molecular mass of the gas is 27.81 g/mole.

7. $D = \frac{1.76 \text{ mg}}{\text{mL}} = \frac{1.76 \text{ g}}{\text{L}}$

m = 1.76 g
V = 1 L
T = 24^{o}C = 297.15 K
P = 98.8 kPa

$$n = \frac{P \bullet V}{R \bullet T} = \frac{98.8 \text{ kPa} \bullet 1 \text{ L}}{8.314 \text{ kPa}\bullet\text{L/mol}\bullet\text{K} \bullet 297.15 \text{ K}} = 0.03998 \text{ moles}$$

$$M = \frac{m}{n} = \frac{1.76 \text{ g}}{0.03998 \text{ mol}} = 44.01 \text{ g/mole}$$

The molecular mass of the gas is 44.01 g/mole.

8. T = 28^{o}C = 301.15 K
V = ?
n = 0.015 mol
P = 99.19 kPa

$$V = \frac{nRT}{P} = \frac{0.015 \text{ mol} \bullet 8.314 \text{ kPa}\bullet\text{L/mol}\bullet\text{K} \bullet 301.15 \text{ K}}{99.19 \text{ kPa}} = 0.38 \text{ L} = 380 \text{ mL}$$

The nitrogen gas will occupy a volume of 380 mL

9. $D = \frac{2.53 \text{ g}}{\text{L}}$

m = 2.53 g
V = 1 L
T = 27^oC = 300.15 K
P = 98.66 kPa

$$n = \frac{P \bullet V}{R \bullet T} = \frac{98.66\ kPa \bullet 1\ L}{8.314\ kPa\bullet L/mol\bullet K \bullet\ 300.15\ K} = 0.04\ moles$$

$$M = \frac{m}{n} = \frac{2.53\ g}{0.04\ mol} = 63.25\ g/mole$$

The molecular mass of the gas is 63.25 g/mole.

10. 0.25 g of O_2 T = 25^oC = 298.15 K P = 100.66 kPa

$$n = \frac{m}{M} = \frac{0.25\ g}{32.00\ g/mol} = 0.0078\ mol$$

$$V = \frac{n\bullet R\bullet T}{P} = \frac{0.078\ mol \bullet 8.314\ kPa\bullet L/mol\bullet K \bullet\ 298.15\ K}{100.66\ kPa} = 0.192\ L = 192\ mL$$

The volume of the oxygen gas will be 192 mL

11. m = 2.82 g
V = 3.16 L
T = 0^oC
P = 101.325

$$n = \frac{P \bullet V}{R \bullet T} = \frac{101.325\ kPa \bullet 3.16\ L}{8.314\ kPa\bullet L/mol\bullet K \bullet\ 273.15\ K} = 0.14\ moles$$

$$M = \frac{m}{n} = \frac{2.82\ g}{0.14\ mol} = 20.14\ g/mol$$

The molecules mass of the gas is 20.14 g/mol

12. m = 30 kg = 30 000 g P = 1.15 atm T = 20^oC = 293.15 K

$$n = \frac{m}{M} = \frac{30\ 000\ g}{4\ g/mol} = 7500\ mol$$

$$V = \frac{n\bullet R\bullet T}{P} = \frac{7500\ mol \bullet 0.082\ atm\bullet L/mol\bullet K \bullet\ 293.15\ K}{100.66\ kPa} = 156\ 771.52\ L$$

The volume of the balloon will be 156 771.52 L

13. m = 0.20 g of He V = 0.5 L P = 113.30 kPa T = ?

$$n = \frac{0.20\ g}{4\ g/mol} = 0.05\ mol\ of\ He$$

$$T = \frac{P \bullet V}{n \bullet R} = \frac{113.30\ kPa \bullet 0.5\ L}{0.05\ mol \bullet\ 8.314\ kPa\bullet L/mol\bullet K} = 136.28\ K = -136.87^oC$$

The temperature at which the He gas is fixed is -136.87^oC

14. empirical formula = CHCl empirical mass = 48.47 g/mol
T = 100^oC = 373.15 K P = 99.97 kPa

D = 3.12 X 10^{-3} g/cm^3 = 0.00312 g/mL = 3.12 g/L

$$n = \frac{P \bullet V}{R \bullet T} = \frac{99.97\ kPa \bullet 1\ L}{8.314\ kPa\bullet L/mol\bullet K \bullet\ 373.15\ K} = 0.032\ moles$$

$$M = \frac{3.12\ g}{0.032\ mol} = 97.5\ g/mol$$

The actual formula is 97.5/48.47 or 2 times larger than the empirical formula. Therefore the actual formula is $C_2H_2Cl_2$

15. a) Calculate moles of gas in the tank under the conditions it was filled at
b) Calculate the volume of gas released at depth
c) Calculate the time available at the volume.

a) Moles of gas in the tank at the filling station

$$n = \frac{P \bullet V}{R \bullet T} = \frac{21\ 00\ kPa \bullet 10\ L}{8.314\ kPa \bullet L/mol \bullet K \bullet 305.15\ K} = 82.2 \text{ mol of gas in the tank}$$

b) Volume of gas released at depth

$$V = \frac{n \bullet R \bullet T}{P} = \frac{82.2\ mol \bullet 8.314\ kPa \bullet L/mol \bullet K \bullet 281.15\ K}{200\ kPa} = 967.25\ L$$

c) @ a rate of 8 L /min the swimmer has $\frac{967.25\ L}{8\ L/min}$ = 120.9 min or aproximately 2 hr.

The time is actually 118 minutes because the person cannot suck the last 20 L out of the tank. (see below)

Alternate method using the combined gas law:
P_1 = 21 000 kPa P_2 = 200 kPa
V_1 = 10 L V_2 = ?
T_1 = 32°C = 305.15 K T_2 = 8°C = 281.15 K

$$V_2 = \frac{P_1 \bullet V_1 \bullet T_2}{P_2 \bullet T_1} = \frac{21\ 000\ kPa \bullet 10\ L \bullet 281.15\ K}{200\ kPa \bullet 305.15\ K} = 967.41\ L$$

$$\text{Time Available} = \frac{967.41\ L}{8\ L/min} = 120.9\ min$$

The diver can't suck out the last 20 L of gas (10 L at 2 X pressure = 20 L) therefore the actual bottom time is 118 min.

16. V = 5000 L
P = 100 atm
T = 2°C = 275.15 K

$$n = \frac{P \bullet V}{R \bullet T} = \frac{100\ atm \bullet 5000\ L}{0.082\ atm \bullet L/mol \bullet K \bullet 275.15\ K} = 22\ 160.86 \text{ moles of gas in the tank}$$

m = n • M = 22 160.86 mol • 70.90 g/mol = 1 571 205 g = 15 712 kg
There are 22 160.86 moles of chlorine gas in the truck.

92. Gas Laws

1. A sample of krypton gas with a volume of 6.25 L, a pressure of 102 kPa and a temperature of 20.0°C expanded to a new volume of 9.55 L and a pressure of 50 kPa. What is its final temperature in °C?
2. A sample of Freon, a refrigerant gas, that has been banned, occupies a volume of 445 mL, at a pressure of 1.50 atm and a temperature of 25.0°C. It is compressed into a volume of 225 mL with a pressure of 2.00 atm. To what temperature did it have to change?
3. A steel cylinder containing nitrogen has a volume of 25.0 L at 24°C and a pressure of 150 atm. How many grams of nitrogen does this cylinder hold?
4. What is the density, in g/L, of each of the following gases at STP?
   a) CH_4 b) O_2 c) H_2
5. At 100.2 kPa and 20.0°C, what is the density of argon in grams/litre?
6. Working on a vacuum line, a chemist isolated a gas in a weighing bulb with a volume of 255 mL, at a temperature of 25.0°C, and under a pressure of 1.3 kPa. The gas weighed 12.1 mg. What is the molecular mass of this gas?
7. In the Haber process of synthesizing ammonia: $N_{2(g)}$ + 3 $H_{2(g)}$ ----> 2 $NH_{3(g)}$
   How many litres of N_2 are needed to react completely with 45.0 L of H_2 if both gases are at STP?
8. In the first step of the Ostwald process for making nitric acid, ammonia reacts with oxygen at 650°C and 1 atm. the following reaction occurs:

   4 $NH_{3(g)}$ + 5 $O_{2(g)}$ -----> 4 $NO_{(g)}$ + 6 $H_2O_{(g)}$

   How many litres of oxygen at 650°C and 1 atm are needed to react with 48 L of NH_3 also at 650°C and 1 atm?
9. A common laboratory preparation of hydrogen on a small scale uses the reaction of zinc with hydrochloric acid that produces zinc chloride and hydrogen
   a) Write a balanced chemical equation
   b) If 10.0 L of hydrogen at 101.3 kPa and 25.0 is wanted, how much zinc is needed in theory?
   c) How many moles of HCl are needed if we use the condition from part b)?
10. One industrial synthesis of acetylene, a gas used as a raw material for making countless synthetic drugs, dyes, and plastics, is the addition of water to calcium carbide.

    $CaC_{2(s)}$ + 2 $H_2O_{(l)}$ --------> $Ca(OH)_{2(aq)}$ + $C_2H_{2(g)}$

    a) In a small scale test to improve efficiency, 100 grams of CaC2 is converted into acetylene. What is the theoretical yield of acetylene in moles and litres at SATP?
    b) To make 1.0 X 10^6 L of acetylene at SATP by this method requires how much calcium carbide in kilograms?
11. A steel cylinder contains neon at a pressure of 101.325 kPa and a temperature of 25°C. The cylinder survives a fire in which the temperature reaches 800°C. What would be the internal pressure of the cylinder. (Expansion of the metal cylinder will increase the volume slightly but will be considered negligible.) Express the result in atmospheres and MPa.
12. A sample of 248 mL of wet nitrogen gas was collected over water at a pressure of 98.13 kPa and a temperature of 21.0°C. (The vapour pressure of water at 21°C is 2.49 kPa.) The nitrogen was produced by the reaction of sulfamic acid, HNH_2SO_3, with 425 mL of a solution of sodium nitrite according to the following reaction.

    $NaNO_2(aq)$ + $HNH_2SO_{3(aq)}$ ----> $N_{2(g)}$ + $NaHSO_{4(aq)}$ + $H_2O_{(l)}$

    Calculate the molar concentration of the sodium nitrite solution.
13. Hydrogen peroxide, H_2O_2, is decomposed by potassium permanganate according to the following reaction:

    5 H_2O_2 + 2 $KMnO_4$ + 3 H_2SO_4 ---> 5 O_2 + 2 $MnSO_4$ + K_2SO_4 + 8 H_2O

    What is the minimum number of millilitres of 0.125 M $KMnO_4$ solution required to prepare 375 mL of dry O_2 when the gas column is measured at 22°C and 98.39 kPa. The gas is collected over water. $P_{H2O@22^{o}C}$ = 2.67 kPa
14. The density of a certain gas at 27°C and 98.66 kPa is 2.53 g/L. Assuming that the gas behaves in an ideal manner, calculate its molecular mass.
15. A certain gas is found to have a density of 0.16 g/L at 25°C and 99.34 kPa. What is the molecular mass of the gas?
16. An explosion occurs as a result of a rapid chemical reaction attended by the formation of a large volume of gas. The equation for the detonation of nitroglycerine is:

    4 $C_3H_5(NO_3)_{3(l)}$ ------> 12 $CO_{2(g)}$ + 10 $H_2O_{(l)}$ + 6 $N_{2(g)}$ + $O_{2(g)}$

    52 grams of nitroglycerine is packed into the inside of a hand grenade. At the moment of explosion, the nitroglycerine reaches a temperature of 700°C. If the volume of the inside of the hand grenade is 200 mL, what is the pressure in atmospheres just before the metal grenade case fractures into shrapnel?

93. Answers - Gas Laws

1. V_1 = 6.25 L V_2 = 9.55 L
   P_1 = 102 kPa P_2 = 50 kPa
   T_1 = 20°C = 293.15 K T_2 = ?

   $T_2 = \frac{V_2 \bullet P_2 \bullet T_1}{V_1 \bullet P_1} = \frac{9.55\ L \bullet 50 kPa \bullet 293.15\ K}{6.25\ L \bullet 102\ kPa}$ = 219.58 K = -53.6°C

   The krypton gas will reach the above conditions at -53.6°C

2. V_1 = 445 mL V_2 = 225 mL
   P_1 = 1.5 atm P_2 = 2.0 atm
   T_1 = 25.0°C = 298.15 K T_2 = ?

   $T_2 = \frac{V_2 \bullet P_2 \bullet T_1}{V_1 \bullet P_1} = \frac{225\ mL \bullet 2.00\ atm \bullet 298.15\ K}{445\ mL \bullet 1.5\ atm}$ = 201.0 K = -72.15°C

   The sample of Freon must change to -72.15°C to meet the above conditions.

3. V = 25.0 L
   T = 24.0°C
   P = 150 atm

   $n = \frac{PV}{RT} = \frac{150\ atm \bullet 25.0\ L}{0.082\ atm \bullet L/mole \bullet K \bullet 297.15\ K}$ = 153.90 mol

   g = n • M = 153.90 mol • 28.02 g/mol = 4 312.3 g

   The steel cylinder contains 4.32 kg of nitrogen gas.

4. Using the STP definition of 1 mole = 22.4 L we can use any gas.

   a) CH_4 = 16.05 g/mol $D = \frac{g}{L} = \frac{16.05\ g}{22.4\ L}$ = 0.717 g/L

   b) O_2 = 32.00 g/mol $D = \frac{g}{L} = \frac{32.00\ g}{22.4\ L}$ = 1.43 g/L

   c) H_2 = 2.02 g/mol $D = \frac{g}{L} = \frac{2.02\ g}{22.4\ L}$ = 0.09 g/L

5. 1 mole of any gas at STP = 22.4 L
   mass = 39.95 g

   V_1 = 22.4 L V_2 = ?
   P_1 = 101.325 kPa P_2 = 100.2 kPa
   T_1 = 0.0°C = 273.15 K T_2 = 20.0°C = 293.15 K

   $V_2 = \frac{V_1 \bullet P_1 \bullet T_2}{P_2 \bullet T_1} = \frac{22.4\ L \bullet 101.325\ kPa \bullet 293.15\ K}{100.2\ kPa \bullet 273.15\ K}$ = 24.31 L

   $D = \frac{g}{L} = \frac{39.95\ g}{24.31\ L}$ = 1.64 g/L

   The density of argon gas is under the above conditions

6. V = 255 mL = 0.255 L
   T = 25°C = 298.15 K
   P = 1.3 kPa

   $n = \frac{PV}{RT} = \frac{1.3\ kPa \bullet 0.255\ L}{8.314\ kPa \bullet L/mole \bullet K \bullet 298.15\ K}$ = 1.34×10^{-4} mol

   $M = \frac{m}{n} = \frac{12.1\ mg}{1.34 \times 10^{-4}\ mol} = \frac{0.0121\ g}{1.34 \times 10^{-4}\ mol}$ = 90.43 g/mol

   The molecular mass of the gas is 90.43 g/mol

7. N_2 + 3 H_2 ---> 2 NH_3
45 L

Step #1 Moles of H_2

@STP $\frac{1\ mol}{x} = \frac{22.4\ L}{45\ L}$ x = 2.01 mol of hydrogen gas

Step #2 Moles of N_2

$\frac{N_2}{x} = \frac{3\ H_2}{2.01\ mol}$ x = 0.67 mol

Step #3 Volume of N_2

@STP $\frac{1\ mol}{0.67\ mol} = \frac{22.4\ L}{x}$ x = 14.93 L of nitrogen gas

45.0 L of hydrogen gas requires 14.93 L of nitrogen to react under STP conditions

8. 4 $NH_{3(g)}$ + 5 $O_{2(g)}$ ----> 4 $NO_{(g)}$ + 6 $H_2O_{(g)}$

P = 1 atm
V = 48 L
T = 650^{o}C = 923.15 K

Step #1 Moles of ammonia

$n = \frac{PV}{RT} = \frac{1\ atm \bullet 48\ L}{0.082\ atm \bullet L/mole \bullet K \bullet 923.15\ K}$ = 0.63 mol of NH_3

Step #2 Moles of oxygen

$\frac{4\ NH_3}{0.63\ mol} = \frac{5\ O_2}{x}$ x = 0.79 mol of oxygen

Step #3 Volume of oxygen gas

$V = \frac{nRT}{P} = \frac{0.79\ mol \bullet 0.082\ atm \bullet L/mole \bullet K \bullet 923.15\ K}{1\ atm}$ = 60 L

The above solution was the long way to do it. As long as the conditions don't change then the units will cancel and a simple ratio of volumes will work.

Simple version

$\frac{4\ NH_3}{45\ L} = \frac{5\ O_2}{x}$ x = 60 L of oxygen

9. a) Zn + 2 HCl ------> H_2 + $ZnCl_2$

b) Solution steps
Step #1 Find the moles of H_2 present
Step #2 Find the moles of Zn necessary
Step #3 Find the grams of Zn needed

Step #1 Moles of Hydrogen gas
V = 10.0 L
P = 101.325 kPa
T = 25^{o}C = 293.15 K

$n = \frac{PV}{RT} = \frac{101.325\ kPa \bullet 10\ L}{8.314\ kPa \bullet L/mole \bullet K \bullet 923.15\ K}$ = 0.41 mol of H_2

Step #2 Moles of Zn needed

$\frac{Zn}{x} = \frac{H_2}{0.41\ mol}$ x = 0.41 moles of Zn metal

Step #3 Grams of Zn needed

$m = n \bullet M = 0.41 \text{ mol} \bullet 65.38 \text{ g/mol} = 26.73$ grams of Zn

c) Moles of HCl needed

$$\frac{2\,HCl}{x} = \frac{H_2}{0.41 \text{ mol}} \qquad x = 0.82 \text{ mol of HCl}$$

To generate this particular volume of H_2 gas under these conditions 26.73 grams of Zn is needed.

10. $CaC_{2(s)} + 2\,H_2O_{(l)} \text{ ----> } Ca(OH)_{2(aq)} + C_2H_{2(g)}$

a) Step #1 Find the moles of CaC_2
Step #2 Find the moles of C_2H_2 that can be generated
Step #3 Under SATP conditions determine the volume of C_2H_2

Step #1 Moles of calcium carbide

$$n = \frac{m}{M} = \frac{100 \text{ g}}{64.10 \text{ g/mol}} = 1.56 \text{ mol of } CaC_2$$

Step #2 Moles of acetylene produced

$$\frac{CaC_2}{1.56 \text{ mol}} = \frac{C_2H_2}{x} \qquad x = 1.56 \text{ mol of acetylene gas}$$

Step #3 Volume of acetylene under SATP conditions

$$\frac{1 \text{ mol}}{1.56 \text{ mol}} = \frac{24.8 \text{ L}}{x} \qquad x = 38.69 \text{ L}$$

b) Kilograms of CaC_2 needed to generate 1 000 000 L of acetylene

$$\frac{1 \text{ mol}}{x} = \frac{24.8 \text{ L}}{1\,000\,000 \text{ L}} \qquad x = 40\,320.50 \text{ mol of } C_2H_2$$

$$\frac{CaC_2}{x} = \frac{C_2H_2}{40\,320.50 \text{ mol}} \qquad x = 40\,320.50 \text{ mol of } CaC_2$$

$m = n \bullet M$
$= 40320.5 \text{ mol} \bullet 64.60\text{g/mol}$
$= 2\,584\,543.8 \text{ g}$
$= 2\,584.54 \text{ kg}$

11. $P_1 = 101.325$ kPa $\quad P_2 = ?$
$T_1 = 25^oC = 298.15$ K $\quad T_2 = 800^oC = 1073.15$ K

$$P_2 = \frac{P_1 \bullet T_2}{T_1} = \frac{101.325 \text{ KPa} \bullet 1073.15 \text{ K}}{298.15 \text{ K}} = 364.71 \text{ kPa} = 0.36 \text{ MPa}$$

The steel cylinder contains neon gas at 0.36 MPa pressure.

12. $P_T = 98.13$ kPa
$P_{N2} = 98.13 \text{ kPa} - 2.49 \text{ kPa}$
$= 95.64$ kPa (corrected)

$NaNO_2 + HNH_2SO_3 \text{ ---> } N_2 + NaHSO_4 + H_2O$
425 mL — 248 mL
95.64 kPa
$21^oC = 294.15$ K

Step #1 Find the moles of nitrogen gas present
Step #2 Find the moles of sodium nitrite needed
Step #3 Find the molarity of the $NaNO_2$ solution

Step #1 Moles of nitrogen gas present

$$n = \frac{PV}{RT} = \frac{95.64 \text{ kPa} \bullet 0.248 \text{ L}}{8.314 \text{ kPa}\bullet\text{L/mole}\bullet\text{K} \bullet 294.15 \text{ K}} = 0.0097 \text{ mol of } N_2$$

Step #2 Moles of sodium nitrite needed

$$\frac{NaNO_2}{x} = \frac{N_2}{0.0097 \text{ mol}} \qquad x = 0.0097 \text{ mol of } NaNO_2$$

Step #3 Molarity of the $NaNO_2$ solution

$$M = \frac{mol}{L} = \frac{0.0097 \text{ mol}}{0.425 \text{ L}} = 0.023 \frac{mol}{L} = 0.023 \text{ M}$$

The concentration of the sodium nitrite solution is 0.023 M

13. $5\ H_2O_2 + 2\ KMnO_4 + 3\ H_2SO_4 \text{ ---> } 5\ O_2 + 2\ MnSO_4 + K_2SO_4 + 8\ H_2O$

$KMnO_4$: 0.125 M, ? mL

O_2: 375 mL, P_T = 98.39 kPa

Solution steps

Step #1 Find the moles of oxygen gas correcting for water vapour.

Step #2 Find the moles of KMnO4 needed

Step #3 Using the molarity determine the volume of KMnO4 needed

Step #1 Moles of O_2

P_T = 98.39 kPa

P_{O2} = 98.39 kPa - 2.67 kPa = 95.72 kPa

$$n = \frac{PV}{RT} = \frac{95.72 \text{ kPa} \bullet 0.375 \text{ L}}{8.314 \text{ kPa}\bullet\text{L/mole}\bullet\text{K} \bullet 295.15 \text{ K}} = 0.015 \text{ mol of } O_2$$

Step #2

$$\frac{2\ KMnO_4}{x} = \frac{5\ O_2}{0.015 \text{ mol}} \qquad x = 0.006 \text{ mol of } KMnO_4$$

Step #3 Volume of KMnO4 solution needed

$$0.125 \text{ M} = \frac{0.125 \text{ mol}}{1000 \text{ mL}} = \frac{0.006 \text{ mol}}{x} \qquad x = 48.0 \text{ mL}$$

This reaction requires 48.0 mL of the 0.125 M $KMnO_4$ solution

14. D = 2.53 g/L Therefore m = 2.53 g and V = 1 L

T = 27°C = 300.15 K

P = 98.66 kPa

$$n = \frac{PV}{RT} = \frac{98.66 \text{ kPa} \bullet 1 \text{ L}}{8.314 \text{ kPa}\bullet\text{L/mole}\bullet\text{K} \bullet 300.15 \text{ K}} = 0.04 \text{ mol of gas}$$

$$M = \frac{m}{n} = \frac{2.53 \text{ g}}{0.04 \text{ mol}} = 63.25 \text{ g/mol}$$

The unknown gas has a molecular mass of 63.25 g/mol

15. D = 0.16 g/L Therefore m = 0.16 g and V = 1 L

T = 25°C = 298.15 K

P = 99.34 kPa

$$n = \frac{PV}{RT} = \frac{99.34 \text{ kPa} \bullet 1 \text{ L}}{8.314 \text{ kPa}\bullet\text{L/mole}\bullet\text{K} \bullet 298.15 \text{ K}} = 0.04 \text{ mol of gas}$$

$$M = \frac{m}{n} = \frac{0.16 \text{ g}}{0.04 \text{ mol}} = 4 \text{ g/mol}$$

The unknown gas has a molecular mass of 4 g/mol

16. $4\ C_3H_5(NO_3)_3 \text{ -----> } 12\ CO_2 + 10\ H_2O + 6\ N_2 + O_2$

Solution steps

Step #1 Find the moles of nitroglycerine

Step #2 Find the moles of gas created

Step #3 Find the pressure generated by the heated gases

Step #1 Moles of nitroglycerine

$C_3H_5(NO_3)_3$ = 3 C = 3 • 12.01 = 36.03 g/mol
5 H = 5 • 1.01 = 5.05 g/mol
3 N = 3 • 14.01 = 42.03 g/mol
9 0 = 9 • 16.00 = 144.00 g/mol
227.11 g/mol

$$n = \frac{m}{M} = \frac{52\ g}{227.11\ g/mol} = 0.23\ mol$$

Step #2 Moles of generated gas

$4\ C_3H_5(NO_3)_3$ -----> $12\ CO_2 + 10\ H_2O + 6\ N_2 + O_2$

$$\frac{4\ moles}{0.23\ moles} = \frac{29\ moles}{x} \qquad x = 1.66\ moles\ of\ gas$$

Step #3 Pressure of generated gas

$$P = \frac{n \bullet R \bullet T}{V} = \frac{1.66\ mol \bullet 0.082\ atm \bullet L/mole \bullet K \bullet 973.15\ K}{0.2\ L} = 662.33\ atm$$

The hand grenade's steel casing is being subjected to an internal pressure of 662.33 atm.

94. Thermo Specific Heat Questions

1. Which kind of substance needs more energy to undergo a rise of 5 degrees in temperature - something with a high specific heat or something with a low specific heat? Explain.
2. How much heat in kilojoules has to be removed from 225 g of water to lower its temperature from 25°C to 10.0°C? (This would be like cooling a glass of lemonade.)
3. To bring 1.0 kg of water from 25 °C to 99 °C takes how much heat input, in joules? In kilojoules? This would be like making four cups of coffee.
4. Fat tissue is 85% fat and 15% water. The complete breakdown of the fat itself converts it to CO_2 and H_2O, and releases about 37.665 kJ/g (of fat in the fat tissue).

   (a) How many kilojoules are released by a loss of 0.45 kg (1 lb.) of fat tissue in a weight-reduction program?

   (b) A person running at 13 km/hr expends about 2.0 X 10^3 kJ/hr of extra energy. How far does a person have to run to "burn off" 0.45 kg of fat tissue by this means alone.
5. If a gold ring with a mass of 5.5 grams changes temperature from 25.0°C to 28.0°C, how much energy (in joules) has it absorbed?
6. The specific heat of helium is 5.188 J/g°C and of nitrogen is 1.042 J/g°C. How many joules can one mole of each gas absorb when its temperature increases 1.00°C?
7. We wish to determine how much heat paraffin gives off on burning. We use a candle flame to heat some water in a calorimeter. These data were obtained:

   Mass of water in calorimeter 350 g
   Initial mass of candle 150 g
   Final mass of candle 112 g
   Initial temperature of water 15°C
   Final temperature of water 23°C

   Calculate:
   a) the temperature rise,
   b) the joules absorbed by the water in the calorimeter,
   c) the grams of paraffin burned,
   d) the approximate value of heat of combustion of paraffin in J/g.
   Neglect the energy absorbed by the calorimeter.
8. Ethanol has a heat capacity of 2.51 J/g°C. 25.00 grams of this at 40°C has been used to heat 500 mL of water. What would have been the temperature change of the water if the alcohol ends up at 10°C?
9. Ethyl alcohol in a container is lit. The heat produced during burning was used to heat a flask of water. The data collected are shown below:

   Mass of container plus ethanol, before burning 42.70 g
   Mass of container plus ethanol, after burning 40.70 g
   Mass of flask plus water 582.0 g
   Mass of the empty flask 182.0 g
   Initial temperature of the water 5.3°C
   Final temperature of the water 35.3°C
   Calculate the heat of combustion of ethyl alcohol.
10. 100 grams of ethanol at 25°C is heated until it reaches 50°C. How much heat does the ethanol gain?
11. A beaker contains 50 grams of liquid at room temperature. The beaker is heated until the liquid gains 10°C. A second beaker contains 100 grams of the same liquid at room temperature. This beaker is also heated until the liquid gains 10°C. In which beaker does the liquid gains the most thermal energy? Explain
12. You know that $\Delta T = T_f - T_i$. Combine this equation with the heat equation $Q = mc\,\Delta T$ to solve for the following quantities.
    a) T_i in terms of Q, m, c and T_f
    b) T_f in terms of Q, m, C and T_i
13. How much heat is required to raise the termperature of 789 grams of liquid ammonia from 25.0°C to 82.7°C?
14. A solid substance has a mass of 250.00 grams. It is cooled by 25.00°C and loses 4937.50 J of heat. What is it's specific heat capacity. Identify this substance.
15. A piece of metal with a mass of 14.9 grams is heated to 98.0°C. When the metal is placed in 75.0 grams of water at 20.0°C. The temperature of the water rises by 28.5°C. What is the specific heat capacity of the metal?
16. A piece of gold (c = 0.129 J/g°C) with a mass of 45.5 grams and a temperature of 80.5°C is dropped into 192 grams of water at 15.0°C. What is the final temperature of the system?
17. Whe iron nails are hammered into wood, friction causes the nails to heat up.
    a) Calculate the heat that is gained by a 5.2 gram nail as it changes from 22.0°C to 38.5°C?

    b) Calculate the heat that is gained by a 10.4 gram nail as it changes from 22.0°C to 38.5°C?

    c) Calculate the heat that is gained by a 5.2 gram nail as it changes from 22.0°C to 55.0°C?
18. A 23.9 grams silver spoon is put in a cup of hot chocolate. It takes 0.343 kJ of energy to change the temperature of the spoon from 24.5°C to 85.0°C. What is the specific heat capcacity of the silver?
19. The specific heat capacity of aluminum is 0.920 J/g°C. The specific heat capacity of copper is 0.389 J/g°C. The same amount od heat is applied to equal masses of these 2 metals. Which metal increases more in temperature? Explain.

    Explain why there is an energy difference between the following reactions.
20. $CH_4(g) + 2\,O_2(g)$ -----> $CO_2(g) + H_2O(g)$ + 802 kJ
    $CH_4(g) + 2\,O_2(g)$ -----> $CO_2(g) + H_2O(l)$ + 890 kJ

95. Answers – Thermo Specific Heat Questions

1. The substance with the higher specific heat content requires more energy.

2. $q = m \bullet c \bullet \Delta t$
   $= 225\text{ g} \bullet 4.184\text{ J/g}^oC \bullet (25^oC - 10^oC)$
   $= 14\,121.0\text{ J}$
   $= 14.12\text{ kJ}$

3. $q = m \bullet c \bullet \Delta t$
   $= 1000\text{ g} \bullet 4.184\text{ J/g}^oC \bullet (99^oC - 25^oC)$
   $= 309\,616\text{ J}$
   $= 309.6\text{ kJ}$

4. (a) 0.45 kg of fat X 0.85% = 0.3825 kg or 382.5 g of actual fat

   Heat released = 37.665 kJ/g X 382.5 g
   = 14 406.86 kJ

   Hours of energy available = $\frac{14\,406.86\text{ kJ}}{2.0 \times 10^3\text{ kJ/h}}$ = 7.20 h

   Distance travelled = 13 km/h X 7.20 h = 93.64 km

   The fat eaten would require 93.64 km of jogging to burn off

5. $q = m \bullet c \bullet \Delta t$
   $= 5.5\text{ g} \bullet 0.128\text{ J/g}^oC \bullet (28.0^oC - 25.0^oC)$
   $= 5.5\text{ g} \bullet 0.128\text{ J/g}^oC \bullet (3.0^oC)$
   $= 2.112\text{ kJ}$

6. N_2
   1 mole = 28.02 g/mol X 1.042 J/g^{o}C = 29.20 J/mol^{o}C

   He
   1 mole = 4.00 g/mol X 5.18 J/g^{o}C = = 20.72 J/mol^{o}C

7. a) $\Delta t = 23^oC - 15^oC = 8^oC$

   b) $q = m \bullet c \bullet \Delta t$
   $= 350\text{ g} \bullet 4.184\text{ J/g}^oC \bullet 8.0^oC$
   $= 11{,}715.2\text{ J}$

   c) mass of paraffin = 150 g - 112 g = 38 grams of paraffin

   d) Heat of combustion = Energy / mole = 11 715.2 J/38 g = 308.29J/g

8. $m_h \bullet c_h \bullet \Delta t_h = m_c \bullet c_c \bullet \Delta t_c$
   $m_h \bullet c_h \bullet (t_i - t_f) = m_c \bullet c_c \bullet (t_f - t_i)$
   $25.0\text{ g} \bullet 2.51\text{ J/g}^oC \bullet (40^oC - 10^oC) = 500\text{ g} \bullet 4.184\text{ J/g}^oC \bullet (10^oC - t_i)$
   $1882.5\text{ J} \bullet = 20920\text{ J} - 2092 \bullet t_i$
   $-19037.5\text{ J} = -2092 \bullet t_i$
   $t_i = \frac{19037.5}{2092} = 9.10^oC$
   Therefore $\Delta t_c = 10^oC - t_i = 10^oC - 9.10^oC = 0.9^oC$
   The temperature change was 0.9^{o}C

9. Mass of alcohol burned = 42.70 g - 40.70 g = 2.00 grams of alcohol
   Mass of water = 582.0 g - 182.0 g = 400 grams of water
   $\Delta t = 35.3^oC - 5.3^oC = 30.^oC$

   $q = m \bullet c \bullet \Delta t$
   $= 400\text{ g} \bullet 4.184\text{ J/g}^oC \bullet 30^oC$
   $= 50208\text{ J}$

CH_3CH_2OH = 46.08 g/mol

$n = \frac{g}{M} = \frac{2.0\ g}{46.08\ g/mol} = 0.043\ mol$

Heat of combustion = $\frac{50208\ J}{2.00\ g} = \frac{25104\ J}{g} = \frac{25104\ J}{0.043\ mol}$

= 1156792.3 J/mol

= 1156.79 kJ/mol

The heat of combustion for the alcohol is 1156.79 kJ/mol

10. $q = m \bullet c \bullet \Delta t$
 $= 100\ g \bullet 2.5\ J/g^oC \bullet 25.0^oC$
 = 6250 J
 = 6.25 kJ

11. The beaker with 100 mL @ 10oC holds more heat because it has more mass

12. Using $q = m \bullet c \bullet \Delta t$ & $\Delta t = t_f - t_i$

 $q = m \bullet c \bullet (t_f - t_i)$

 $q = m \bullet c \bullet t_f - m \bullet c \bullet t_i$

 $m \bullet c \bullet t_i + q = m \bullet c \bullet t_f$ ---------------------> $m \bullet c \bullet t_i + q = m \bullet c \bullet t_f$

 $\frac{m \bullet c \bullet t_i}{m \bullet c} + \frac{q}{m \bullet c} = \frac{m \bullet c \bullet t_f}{m \bullet c}$ $\frac{m \bullet c \bullet t_i}{m \bullet c} = \frac{m \bullet c \bullet t_f}{m \bullet c} - \frac{q}{m \bullet c}$

 $t_i + \frac{q}{m \bullet c} = t_f$ $t_i = t_f - \frac{q}{m \bullet c}$

13. $q = m \bullet c \bullet \Delta t$ M_{NH3} = 17.04 g/mol
 = 789 g • 35.1 J/mol K • 57.7 K
 = 46.30 mol • 35.1 J/mol K • 57.7 K
 = 93775.7 J
 = 93.78 kJ (using molar heat capacity)

Alternate Method
$\frac{35.1\ J/mol\ K}{17.04\ g/mol}$ = 2.06 J/g K (specific heat capacity)

$q = m \bullet c \bullet \Delta t$
 = 789 g • 2.06 J/g K • 57.7 K
 = 93775.7 J
 = 93.78 kJ (using specific heat capacity)

14. $q = m \bullet c \bullet \Delta t$

 $c = \frac{q}{m \bullet \Delta t} = \frac{4937.50\ J}{250\ g \bullet 25^oC} = 0.79\ J/g^oC$

 Based on the specific heat table this substance is probably sand!

15. $E_h = E_c$
 $m_h \bullet c_h \bullet \Delta t_h = m_c \bullet c_c \bullet \Delta t_c$
 $m_h \bullet c_h \bullet (t_i - t_f) = m_c \bullet c_c \bullet (t_f - t_i)$
 $14.9\ g \bullet c_h \bullet 49.5^oC = 75\ g \bullet 4.184\ J/g^oC \bullet 28.5\ ^oC$
 $c_h = \frac{75\ g \bullet 4.184\ J/g^oC \bullet 28.5\ ^oC}{14.9\ g \bullet 49.5^oC}$

 $= 12.12\ J/g^oC$

16. $m_h \bullet c_h \bullet (t_i - t_f) = m_c \bullet c_c \bullet (t_f - t_i)$
 $45.5\ g \bullet 0.129\ J/g^oC \bullet (80.5 - t_f) = 192\ g \bullet 4.184\ J/g^oC \bullet (t_f - 15^oC)$

$472.49 - 5.8695 \bullet t_f = 803.3 \bullet t_f - 12049.92$

$12522.41 = 809.17 \bullet t_f$

$t_f = \frac{12522.41}{809.17} = 15.48^{o}C$

17. a) $q = m \bullet c \bullet \Delta t$

    $= 5.2\ g \bullet 0.444\ J/g^{o}C \bullet 16.5^{o}C$

    $= 38.5\ J$

    b) Should be 2X a) = 77.05 J

    c) $q = m \bullet c \bullet \Delta t$

    $= 5.2\ g \bullet 0.444\ J/g^{o}C \bullet 33^{o}C$

    $= 77.05\ J$

18. $q = m \bullet c \bullet \Delta t$

    $c = \frac{q}{m \bullet \Delta t} = \frac{3430\ J}{23.9\ g \bullet 60.5^{o}C} = 0.246\ J/g^{o}C$

19. The copper will increase the most since it has the lower heat capacity. To put it into other terms the lower the heat capacity the less enrgy is required to raise the temperature when heat is added.