ANSWERS TO UNIT VI : CHEMICAL REACTIONS

1. (a) A system that is enclosed by an opaque box. (Light can't get in.)
   (b) A system that is enclosed by a transparent box. (Material can't get in or out, but light can.)
   (c) A system that is enclosed by a sound–absorbing box (transparent or opaque).
   (d) A system that, for example, is surrounded by two boxes, one that is open at the top and one that is open at the bottom, as shown below.

   (e) A system in a container with heat–insulation. (This is not truly "closed"; see exercise 2; below.)

2. The only system which might be closed is the universe itself (and astronomers are still arguing about this point). In general approximately closed systems can be made; but even the best heat insulation cannot keep a liquid hot forever. The problem is making a container through which energy cannot pass.

3. (a) What is CONSERVED: the composition (the material is still paper); total mass and properties such as colour, volume and density
   (b) What is NOT CONSERVED: the number of pieces present, shape
   (c) What is CONSERVED: composition and properties such as colour and density
   What is NOT CONSERVED: total mass; volume, surface area, shape and number of pieces

4. (a) Conservation of atoms (primarily) and conservation of mass will also be violated since Fe atoms have a different mass from Cu atoms.
   (b) Conservation of mass (15 g of reactants cannot make 16 g of products)
   (c) Conservation of charge: total charge on left = +1; total charge on right = 0.
   (d) No conservation laws violated.
   (e) Conservation of atoms (different numbers of Cr's and O's on either side). Conservation of mass will also be violated as a result.
   (f) No conservation laws violated

5. Only (b) is **always** conserved. The others occasionally may be conserved in particular reactions.

6. (a) Left hand side contains: 1 C + 4 H + 4 O ; molar mass of reactants = 1 x 16.0 + 2 x 32.0 = 80.0 g
   Right hand side contains: 1 C + 4 O + 4 H ; molar mass of products = 1 x 44.0 + 2 x 18.0 = 80.0 g
   Since left and right sides have the same number and types of atoms and the same mass, atoms and mass are conserved.

   (b) Left hand side contains: 1 Na + 1 O + 2 H + 1 Cl ; molar mass of reactants = 40.0 + 36.5 = 76.5 g
   Right hand side contains: 1 Na + 1 Cl + 2 H + 1 O ; molar mass of products = 58.5 + 18.0 = 76.5 g
   Since left and right sides have the same number and types of atoms and the same mass, atoms and mass are conserved.

7. $2\,Sn + O_2 \longrightarrow 2\,SnO$
8. $H_2 + Cl_2 \longrightarrow 2\,HCl$
9. $N_2 + 3\,H_2 \longrightarrow 2\,NH_3$
10. $2\,Na + 2\,H_2O \longrightarrow 2\,NaOH + H_2$
11. $4\,NH_3 + 3\,O_2 \longrightarrow 2\,N_2 + 6\,H_2O$
12. $2\,C_6H_{14} + 19\,O_2 \longrightarrow 12\,CO_2 + 14\,H_2O$
13. $2\,KNO_3 \longrightarrow 2\,KNO_2 + O_2$
14. $CaC_2 + 2\,O_2 \longrightarrow Ca + 2\,CO_2$
15. $C_5H_{12} + 8\,O_2 \longrightarrow 5\,CO_2 + 6\,H_2O$
16. $K_2SO_4 + BaCl_2 \longrightarrow 2\,KCl + BaSO_4$
17. $2\,KOH + H_2SO_4 \longrightarrow K_2SO_4 + 2\,H_2O$
18. $Ca(OH)_2 + 2\,NH_4Cl \longrightarrow 2\,NH_3 + CaCl_2 + 2\,H_2O$
19. $5\,C + 2\,SO_2 \longrightarrow CS_2 + 4\,CO$

20. $Mg_3N_2 + 6\,H_2O \longrightarrow 3\,Mg(OH)_2 + 2\,NH_3$
21. $V_2O_5 + 5\,Ca \longrightarrow 5\,CaO + 2\,V$
22. $2\,Na_2O_2 + 2\,H_2O \longrightarrow 4\,NaOH + O_2$
23. $Fe_3O_4 + 4\,H_2 \longrightarrow 3\,Fe + 4\,H_2O$
24. $Cu + 2\,H_2SO_4 \longrightarrow CuSO_4 + 2\,H_2O + SO_2$
25. $2\,Al + 3\,H_2SO_4 \longrightarrow 3\,H_2 + Al_2(SO_4)_3$
26. $2\,Si_4H_{10} + 13\,O_2 \longrightarrow 8\,SiO_2 + 10\,H_2O$
27. $4\,NH_3 + O_2 \longrightarrow 2\,N_2H_4 + 2\,H_2O$
28. $2\,C_{15}H_{30} + 45\,O_2 \longrightarrow 30\,CO_2 + 30\,H_2O$
29. $2\,BN + 3\,F_2 \longrightarrow 2\,BF_3 + N_2$
30. $CaSO_4{\cdot}2H_2O + 2\,SO_3 \longrightarrow CaSO_4 + 2\,H_2SO_4$
31. $4\,C_3H_7N_2O_7 + 5\,O_2 \longrightarrow 12\,CO_2 + 14\,H_2O + 4\,N_2$
32. $C_7H_{16}O_4S_2 + 11\,O_2 \longrightarrow 7\,CO_2 + 8\,H_2O + 2\,SO_2$
33. $9\,Na + 4\,ZnI_2 \longrightarrow 8\,NaI + NaZn_4$
34. $HBrO_3 + 5\,HBr \longrightarrow 3\,H_2O + 3\,Br_2$
35. $Al_4C_3 + 12\,H_2O \longrightarrow 4\,Al(OH)_3 + 3\,CH_4$
36. $2\,Ca(NO_3)_2{\cdot}3H_2O + 3\,LaC_2 \longrightarrow 2\,Ca(NO_3)_2 + 3\,La(OH)_2 + 3\,C_2H_2$
37. $CH_3NO_2 + 3\,Cl_2 \longrightarrow CCl_3NO_2 + 3\,HCl$
38. $Ca_3(PO_4)_2 + 3\,SiO_2 + 5\,C \longrightarrow 3\,CaSiO_3 + 5\,CO + 2\,P$
39. $Al_2C_6 + 6\,H_2O \longrightarrow 2\,Al(OH)_3 + 3\,C_2H_2$
40. $2\,NaF + CaO + H_2O \longrightarrow CaF_2 + 2\,NaOH$
41. $4\,LiH + AlCl_3 \longrightarrow LiAlH_4 + 3\,LiCl$
42. $2\,CaF_2 + 2\,H_2SO_4 + SiO_2 \longrightarrow 2\,CaSO_4 + SiF_4 + 2\,H_2O$
43. $3\,CaSi_2 + 2\,SbCl_3 \longrightarrow 6\,Si + 2\,Sb + 3\,CaCl_2$
44. $2\,TiO_2 + B_4C + 3\,C \longrightarrow 2\,TiB_2 + 4\,CO$
45. $4\,NH_3 + 5\,O_2 \longrightarrow 4\,NO + 6\,H_2O$
46. $SiF_4 + 8\,NaOH \longrightarrow Na_4SiO_4 + 4\,NaF + 4\,H_2O$
47. $2\,NH_4Cl + CaO \longrightarrow 2\,NH_3 + CaCl_2 + H_2O$
48. $4\,NaPb + 4\,C_2H_5Cl \longrightarrow Pb(C_2H_5)_4 + 3\,Pb + 4\,NaCl$
49. $Be_2C + 4\,H_2O \longrightarrow 2\,Be(OH)_2 + CH_4$
50. $4\,NpF_3 + O_2 + 4\,HF \longrightarrow 4\,NpF_4 + 2\,H_2O$
51. $3\,NO_2 + H_2O \longrightarrow 2\,HNO_3 + NO$
52. $3\,LiAlH_4 + 4\,BF_3 \longrightarrow 3\,LiF + 3\,AlF_3 + 2\,B_2H_6$
53. $3\,Cu + 8\,HNO_3 \longrightarrow 3\,Cu(NO_3)_2 + 2\,NO + 4\,H_2O$
54. $3\,FeCl_2 + KNO_3 + 4\,HCl \longrightarrow 3\,FeCl_3 + NO + 2\,H_2O + KCl$
55. $2\,KMnO_4 + 16\,HBr \longrightarrow 2\,MnBr_2 + 5\,Br_2 + 2\,KBr + 8\,H_2O$
56. $K_2Cr_2O_7 + 14\,HCl \longrightarrow 2\,KCl + 2\,CrCl_3 + 7\,H_2O + 3\,Cl_2$
57. (a) $2\,K + 2\,H_2O \longrightarrow 2\,KOH + H_2$
    (b) $Sr + 2\,H_2O \longrightarrow Sr(OH)_2 + H_2$
    (c) $2\,Al + 3\,Cl_2 \longrightarrow 2\,AlCl_3$
    (d) $2\,Cu_2O + C \longrightarrow 4\,Cu + CO_2$
    (e) $2\,NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$
58. $2\,H_3PO_4(l) + 3\,Ba(OH)_2(aq) \longrightarrow Ba_3(PO_4)_2(s) + 6\,H_2O(l)$
59. $Al_2O_3(s) + 3\,H_2SO_4(aq) \longrightarrow 3\,H_2O(l) + Al_2(SO_4)_3(aq)$
60. $2\,NF_3(g) + 3\,H_2(g) \longrightarrow N_2(g) + 6\,HF(g)$
61. $Na_2CO_3(s) + 2\,HBr(aq) \longrightarrow CO_2(g) + 2\,NaBr(aq) + H_2O(l)$

62. $2\,NaNO_3(s) + 10\,Na(s) \longrightarrow 6\,Na_2O(s) + N_2(g)$
63. $BCl_3(g) + 3\,H_2O(g) \longrightarrow B(OH)_3(s) + 3\,HCl(g)$
64. $XeF_6(g) + 3\,H_2O(l) \longrightarrow XeO_3(s) + 6\,HF(g)$
65. (a) $H_2SO_4 + 2\,NaOH \longrightarrow Na_2SO_4 + 2\,H_2O$
    (b) $H_3PO_4 + 3\,KOH \longrightarrow K_3PO_4 + 3\,H_2O$
    (c) $3\,H_2SO_4 + 2\,Fe(OH)_3 \longrightarrow Fe_2(SO_4)_3 + 6\,H_2O$
    (d) $H_4P_2O_7 + 2\,Ca(OH)_2 \longrightarrow Ca_2P_2O_7 + 4\,H_2O$
    (e) $H_2SO_4 + Ba(OH)_2 \longrightarrow BaSO_4 + 2\,H_2O$
66. (a) $2\,C_2H_2 + 5\,O_2 \longrightarrow 4\,CO_2 + 2\,H_2O$ (combustion)
    (b) $Mg + CuSO_4 \longrightarrow MgSO_4 + Cu$ (single replacement)
    (c) $4\,Na + O_2 \longrightarrow 2\,Na_2O$ (synthesis)
    (d) $2\,Fe(NO_3)_3 + 3\,MgS \longrightarrow Fe_2S_3 + 3\,Mg(NO_3)_2$ (double replacement)
    (e) $2\,N_2O \longrightarrow 2\,N_2 + O_2$ (decomposition)
    (f) $Sn(OH)_4 + 4\,HBr \longrightarrow 4\,H_2O + SnBr_4$ (neutralization)
    (g) $Cl_2 + 2\,KI \longrightarrow 2\,KCl + I_2$ (single replacement)
    (h) $2\,Al + 3\,S \longrightarrow Al_2S_3$ (synthesis)
    (i) $C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O$ (combustion)
    (j) $3\,HF + Fe(OH)_3 \longrightarrow FeF_3 + 3\,H_2O$ (neutralization)
    (k) $2\,H_2O_2 \longrightarrow 2\,H_2O + O_2$ (decomposition)
    (l) $FeCl_2 + K_2S \longrightarrow FeS + 2\,KCl$ (double replacement)
    (m) $2\,Ca + O_2 \longrightarrow 2\,CaO$ (synthesis)
    (n) $H_2SO_4 + 2\,NaOH \longrightarrow Na_2SO_4 + 2\,H_2O$ (neutralization)
    (o) $C_2H_5OH + 3\,O_2 \longrightarrow 2\,CO_2 + 3\,H_2O$ (combustion)
    (p) $4\,Cr + 3\,SnCl_4 \longrightarrow 4\,CrCl_3 + 3\,Sn$ (single replacement)
    (q) $Pb(NO_3)_2 + K_2CrO_4 \longrightarrow PbCrO_4 + 2\,KNO_3$ (double replacement)
    (r) $Fe + I_2 \longrightarrow FeI_2$ (synthesis)
    (s) $C_3H_6OS_2 + 6\,O_2 \longrightarrow 3\,CO_2 + 3\,H_2O + 2\,SO_2$ (combustion)
    (t) $MgCl_2 \longrightarrow Mg + Cl_2$ (decomposition)
    (u) $Co(NO_3)_2 + H_2S \longrightarrow CoS + 2\,HNO_3$ (double replacement)
    (v) $H_4P_2O_7 + 4\,KOH \longrightarrow K_4P_2O_7 + 4\,H_2O$ (neutralization)
    (w) $Mg + 2\,HCl \longrightarrow H_2 + MgCl_2$ (single replacement)
    (x) $2\,HI \longrightarrow H_2 + I_2$ (decomposition)
67. (a) $2\,HNO_3 + Sr(OH)_2 \longrightarrow Sr(NO_3)_2 + 2\,H_2O$ (neutralization)
    (b) $2\,C_6H_4(OH)_2 + 13\,O_2 \longrightarrow 12\,CO_2 + 6\,H_2O$ (combustion)
    (c) $Zn + Ni(NO_3)_2 \longrightarrow Ni + Zn(NO_3)_2$ (single replacement)
    (d) $2\,AlCl_3 + 3\,Na_2CO_3 \longrightarrow Al_2(CO_3)_3 + 6\,NaCl$ (double replacement)
    (e) $4\,Al + 3\,O_2 \longrightarrow 2\,Al_2O_3$ (synthesis)
    (f) $Ba(OH)_2 + H_2SO_4 \longrightarrow BaSO_4 + 2\,H_2O$ (neutralization)
    (g) $2\,NO_2 \longrightarrow N_2 + 2\,O_2$ (decomposition)
    (h) $Cl_2 + CaBr_2 \longrightarrow Br_2 + CaCl_2$ (single replacement)
    (i) $C_9H_{20}O_4S_2 + 14\,O_2 \longrightarrow 9\,CO_2 + 10\,H_2O + 2\,SO_2$ (combustion)
    (j) $ZnSO_4 + SrCl_2 \longrightarrow SrSO_4 + ZnCl_2$ (double replacement)
    (k) $8\,Zn + S_8 \longrightarrow 8\,ZnS$ (synthesis)
    (l) $2\,NH_3 \longrightarrow N_2 + 3\,H_2$ (decomposition)
    (m) $HCl + KOH \longrightarrow KCl + H_2O$ (neutralization)
    (n) $2\,ICl \longrightarrow I_2 + Cl_2$ (decomposition)

(o) $2\,Na_3PO_4 + 3\,Ca(OH)_2 \longrightarrow Ca_3(PO_4)_2 + 6\,NaOH$ (double replacement)
(p) $C_4H_8S + 7\,O_2 \longrightarrow 4CO_2 + 4\,H_2O + SO_2$ (combustion)
(q) $Mg + ZnSO_4 \longrightarrow Zn + MgSO_4$ (single replacement)
(r) $4\,Li + O_2 \longrightarrow 2\,Li_2O$ (synthesis)

68. (a) Step 1 absorbs energy to break bonds.
(b) Step 2 gives off energy as bonds are made.
(c) Step 2 gives off more energy than step 1 absorbs.

69. $H + Cl \longrightarrow HCl + 432$ kJ. The two reactions are exact opposites of each other, including the heat term.

70. Exothermic; heat is produced

71. Endothermic; heat is absorbed by the sugar in order to melt

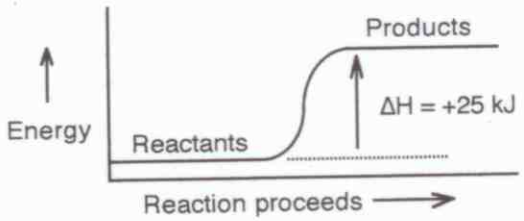
72. Chemicals are **losing** energy to the surrounding beaker. The reaction is exothermic.

73. Products. The reactants gain energy and become high energy products.

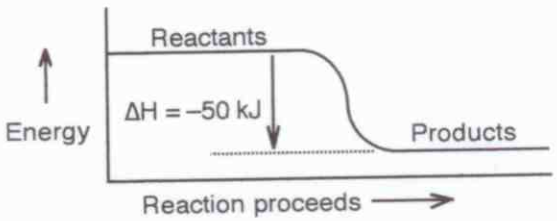
74. Energy is removed from reactants as lower energy products are formed.

75. Since $H_{REACTANTS} < H_{PRODUCTS}$; then $\Delta H = H_{PRODUCTS} - H_{REACTANTS} > 0$ for an endothermic reaction.
Since $H_{REACTANTS} > H_{PRODUCTS}$; then $\Delta H = H_{PRODUCTS} - H_{REACTANTS} < 0$ for an exothermic reaction.

76. The actual energies of the reactants and products are not important; only the energy difference matters.



77. Again; only the energy difference of the reactants and products matters.



78. $F \longrightarrow G + 50$ kJ

79. $\Delta H = +30$ kJ

80. $\Delta H = -25$ kJ; the reactants have more energy.