- Relative formula mass or formula weight
- Avogadro constant, N_A and the mole
- Molar mass
- Empirical formula and molecular formula
- Empirical formula weight
- Per cent composition
- Quantitative interpretation of chemical equations; molecules to moles to mass
- Limiting reagent
- Gay Lussac's law of combining volumes and Avogadro's law (hypothesis)
- Molar volume of a gas
- Concentration of solutions, meaning of and various methods for expressing it
- Molarity, definition and use of
- Quantitative dilution of solutions

Some important equations

1. For the conversions

mass ⇌ number of moles ⇌ number of atoms or molecules:

$$\textit{number of moles} = \frac{\textit{mass}}{\textit{molar mass}} \qquad \text{.... (5.1)}$$

(where molar mass is atomic or molecular weight in grams)

$$\textit{number of atoms or molecules} = \left(\begin{matrix}\textit{number of}\\ \textit{moles}\end{matrix}\right) \times \left(\begin{matrix}\textit{the Avogadro}\\ \textit{constant}\end{matrix}\right) \qquad \text{.... (5.2)}$$

The Avogadro constant, $N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$.

2. The percentage of A in compound $A_xB_yC_z$ is

$$\%\ A = \frac{x \times (\textit{atomic weight of } A) \times 100}{\textit{molecular weight of } A_xB_yC_z} \qquad \text{.... (5.3)}$$

3. If the empirical formula of a compound is A_yB_z and the molecular formula $A_{ny}B_{nz}$ or $(A_yB_z)_n$ where n is an integer, then

$$\textit{molecular weight} = n \times \textit{empirical formula weight} \qquad \text{.... (5.4)}$$

4. The molarity of a solution is calculated from

$$\textit{molarity} = \frac{\textit{number of moles of solute}}{\textit{volume in litres}} \qquad \text{.... (5.5)}$$

or rearranging this,

$$\textit{number of moles of solute} = \textit{volume in litres} \times \textit{molarity} \qquad \text{.... (5.6)}$$

$$= \frac{\textit{volume in millilitres}}{1000} \times \textit{molarity}$$

$$\textit{volume required (in litres)} = \frac{\textit{number of moles}}{\textit{molarity}} \qquad \text{.... (5.7)}$$

Atomic and molecular weights

1. *(a) An atom of krypton, a noble gas, is seven times as heavy as an atom of carbon. What is the relative atomic mass (atomic weight) of krypton?

(b) An atom of helium, another noble gas, is one-third the mass of a carbon atom. What is the relative atomic mass of helium?

2. *(a) The atomic weight of titanium is 48. How many times heavier than a carbon atom is a titanium atom?

(b) Silver has an atomic weight of 108. How many times heavier than a carbon atom is a silver atom?

3. (a) Silicon has an atomic weight of 28 and nitrogen an atomic weight of 14. What does this tell you about the relative masses of silicon and nitrogen atoms?

(b) Bromine has an atomic weight of 80 and sulfur an atomic weight of 32. What does this tell you about the relative masses of bromine and sulfur atoms?

4. (a) Molybdenum, used in certain lubricants, has atoms that are eight times the mass of carbon atoms. What is the atomic weight of molybdenum?

(b) A calcium atom is 3.33 times the mass of a carbon atom. What is the atomic weight of calcium?

5. (a) A sulfur atom is twice the mass of an oxygen atom. Given that the atomic weight of oxygen is 16, what is the atomic weight of sulfur?

(b) An argon atom is twice the mass of a neon atom. Neon has an atomic weight of 20. What is the atomic weight of argon?

6. Calculate the relative molecular mass (molecular weight) or the relative formula mass of the following:

(a) calcium oxide, CaO
*(b) barium bromide, $BaBr_2$
(c) sodium sulfide, Na_2S
*(d) aluminium oxide Al_2O_3
(e) dinitrogen pentoxide, N_2O_5
(f) lead sulfate, $PbSO_4$
(g) potassium carbonate, K_2CO_3
(h) ammonium sulfate, $(NH_4)_2SO_4$
(i) aluminium nitrate, $Al(NO_3)_3$

*(j) iron(III) sulfate, $Fe_2(SO_4)_3$
*(k) sodium carbonate decahydrate, $Na_2CO_3.10H_2O$

Mass, moles, atoms, molecules

7. What is the molar mass of the compounds in *(a), (e) and (k) of Exercise 6?

8. How many moles are there in
*(a) 13 g iron
(b) 0.55 g copper
(c) 1.8 kg aluminium
(d) 230 mg sulfur?

9. What is the mass of
*(a) 3.0 mol zinc
(b) 0.024 mol lead
(c) 0.5 mol helium
(d) 3.2×10^{-3} mol calcium?

10. The one cent coin that was in use until recently had a mass of 2.56 g. Assume that it was pure copper. How many atoms were present in it?

11. Use your results from Exercise 6 to calculate the number of moles in
*(a) 20 g sodium sulfide
(b) 36 g aluminium oxide
(c) 0.515 g potassium carbonate
(d) 0.0419 g ammonium sulfate

12. Use your results of Exercise 6 to calculate the mass of
(a) 7.14 mol barium bromide
(b) 2.28 mol aluminium nitrate
(c) 0.0434 mol calcium oxide
(d) 2.11×10^{-4} iron(III) sulfate

13. What is the mass of
(a) 2.82 mol oxygen gas
(b) 1.44 mol chlorine gas
(c) 0.37 mol helium gas
(d) 0.078 mol nitrogen gas?

14. How many moles (of molecules) are there in
(a) 3.62 g fluorine
(b) 0.415 g hydrogen?

***15.** How many atoms are there in each of (a) to (d) of Exercise 8?

16. Calculate the mass of one atom of
*(a) aluminium (b) lead (c) helium (d) sulfur

17. How many molecules are there in
*(a) 3.87 g sulfur dioxide (an air pollutant), SO_2
(b) 4.17 g ethanol (common alcohol), C_2H_6O
(c) 0.317 g freon-12 (which until recently was used in refrigerators and air conditioners), CCl_2F_2
(d) 300 mg aspirin (common pain reliever), $C_9H_8O_4$?

18. Calculate the mass of one molecule of
(a) ammonia, NH_3 (b) carbon dioxide, CO_2 (c) vitamin C, $C_6H_8O_6$

***19.** How many molecules are there in 3.8 g fluorine gas, F_2? How many fluorine atoms are there in this sample?

20. How many atoms in total are there in
(a) 13 g hydrogen sulfide (evil-smelling gas), H_2S
(b) 28.2 g potassium bromide, KBr
(c) 0.0177 g sulfuric acid, H_2SO_4?

21. *(a) How many moles of (i) calcium chloride (ii) calcium (iii) chlorine are there in 0.149 g calcium chloride, $CaCl_2$?
(b) How many moles of (i) phosphorus (ii) oxygen are there in 2.4×10^{-4} g diphosphorus pentoxide, P_2O_5?

22. A crystal of table sugar (pure sucrose, $C_{12}H_{22}O_{11}$) weighs 1.4 mg. How many molecules are in it? How many atoms in total are present?

Per cent composition

23. Calculate the percentage of
*(a) iron in iron(III) oxide, Fe_2O_3
(b) silver in silver sulfide, Ag_2S
(c) uranium in yellowcake, U_3O_8

24. Calculate the percentage of each element in
(a) potassium nitrate, KNO_3
(b) naphthalene (mothballs), $C_{10}H_8$
(c) aspirin (common pain-killer), $C_9H_8O_4$
(d) calcium phosphate (rock phosphate), $Ca_3(PO_4)_2$

25. How much iron can be extracted from 1 t (tonne) of iron ore, taken to be pure iron oxide, Fe_2O_3?

***26.** Calculate the percentage water in Epsom salts, $MgSO_4.7H_2O$.

Empirical and molecular formulae

27. Calculate the empirical formula for each of the following compounds; the molecular formula is given in brackets:
(a) butane (C_4H_{10})
(b) hydrogen peroxide (H_2O_2)
(c) glycerol ($C_3H_8O_3$)
(d) 1,1,1,2-tetrafluoroethane ($C_2H_2F_4$)

28. (a) Calculate the percentage of hydrogen and of carbon in each of the following compounds:
(i) ethene, C_2H_4
(ii) propene, C_3H_6
(iii) *cyclo*pentane, C_5H_{10}
(iv) heptene, C_7H_{14}
(b) What is the empirical formula for each compound in (a)?

*(c) Use your answers in (a) and (b) to explain why a chemical analysis which yields results in the form of per cent composition of each element present can only produce an empirical formula for the compound and not a molecular formula.

***29.** A compound of carbon and hydrogen contained 83.8% carbon. Calculate its empirical formula.

30. Three compounds containing carbon, hydrogen and oxygen gave the following analyses. Calculate the empirical formula of each compound.
(a) 37.5% C, 12.6% H **(b)** 40.0% C, 53.3% O **(c)** 26.1% C, 4.4% H

***31.** A compound of sulfur and chlorine contained 52.6% chlorine. Calculate its empirical formula. It had an approximate molecular weight of 130. Calculate its molecular formula and its *accurate* molecular weight.

32. A compound of chromium and oxygen contains 68.4% chromium. Calculate its empirical formula.

Moles–moles calculations

***33.** Butane is the fuel in disposable cigarette lighters and in 'Handigas' cans for camping stoves and hobbyists' blowtorches. It burns in air to form carbon dioxide and water. Write a balanced equation for the reaction of butane, C_4H_{10}, with oxygen. How many moles of oxygen are needed to react with **(a)** 1 mol **(b)** 0.25 mol, of butane? How many moles of carbon dioxide are formed?

34. Common alcohol (ethanol, C_2H_5OH) is often used by bushwalkers in spirit burners to heat food and drink. Write an equation for the reaction of ethanol with oxygen to form carbon dioxide and water. How many moles of oxygen are needed to react with **(a)** 7 mol **(b)** 0.055 mol, of ethanol, and how many moles of carbon dioxide are formed?

***35.** Aluminium reacts with chlorine to form aluminium chloride.
(a) How many moles of chlorine are needed to form 16 moles of aluminium chloride?
(b) How many moles of chlorine are needed to react with 0.18 mol aluminium?

Moles–mass calculations

36. *(a) What mass of lead bromide is formed when 0.050 mol potassium bromide dissolved in water is added to excess lead nitrate solution?
(b) What mass of sodium sulfide is needed to precipitate all of the silver (as silver sulfide) from a solution containing 0.033 mol silver nitrate?

37. (a) What mass of hydrochloric acid (taken as pure HCl) is needed to neutralise 0.25 mol barium hydroxide?
(b) What mass of aluminium sulfate is formed when 0.040 mol aluminium hydroxide is reacted with just sufficient sulfuric acid to use it all up?
(c) What mass of sulfuric acid (taken as pure H_2SO_4) is just sufficient to use up all the aluminium hydroxide in (b)?

Mass–mass calculations

***38.** What mass of hydrogen gas is produced when 2.4 g magnesium reacts with excess hydrochloric acid? How much magnesium chloride is produced?

39. Black powdered copper oxide reacts with dilute sulfuric acid to form a clear blue solution of copper sulfate and water. How much sulfuric acid is needed to react completely with 2.64 g copper oxide? How much copper sulfate is formed?

40. How much hydrochloric acid is needed to dissolve 0.84 g zinc? What mass of zinc chloride is formed?

41. A student spilt 18.6 g hydrochloric acid on the bench. How much bicarbonate of soda (sodium hydrogen carbonate) needs to be sprinkled on this to neutralise it?

Limiting reagent

***42.** Copper reacts with nitric acid according to the following equation:

$$3Cu(s) + 8HNO_3(aq) \longrightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

How many moles of which reactant will be left over after mixing
(a) 6 mol Cu with 15 mol HNO_3
(b) 0.25 mol Cu with 0.7 mol HNO_3
(c) 0.5 mol Cu with 0.5 mol HNO_3?

43. How many moles of nitric oxide, NO, are formed in each case in Exercise 42?

44. An important reaction in the synthesis of nitric acid which is used industrially to make explosives, fertilisers, dyes, plastics and synthetic fibres is

$$4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$$

How many moles of nitric oxide, NO, are formed, and how many moles of which reactant are left over, after mixing
(a) 12 mol ammonia with 14 mol oxygen
(b) 15 mol ammonia with 20 mol oxygen?

***45.** 2.5 g limestone chips (calcium carbonate, $CaCO_3$) were added to a solution containing 1.0 g hydrochloric acid, HCl. How much calcium chloride is formed? How much of which reactant is left over?

46. What mass of hydrogen is formed when 1.7 g zinc is reacted with 2.2 g hydrochloric acid?

47. How much copper nitrate, $Cu(NO_3)_2$, is formed when 0.18 g copper carbonate, $CuCO_3$, reacts with 0.18 g nitric acid, HNO_3?

Mass–volume calculations

***48.** When 2.5 g zinc is dissolved in excess sulfuric acid, what volume of hydrogen (measured at 273 K and 101.3 kPa pressure) is formed?

49. What volume of carbon dioxide, measured at 25°C and 101.3 kPa, is formed when 2.33 g copper carbonate, $CuCO_3$, is reacted with excess sulfuric acid, H_2SO_4?

50. Iron(II) sulfide, FeS, reacts with hydrochloric acid, HCl, to form hydrogen sulfide, H_2S (rotten egg gas). The other product is iron(II) chloride, $FeCl_2$. What volume of hydrogen sulfide, measured at 0°C and 101.3 kPa, can be formed from 0.38 g iron(II) sulfide?

Volume–volume calculations

***51.** The volumes of oxygen that reacted with three different volumes of nitric oxide, NO, and the volumes of gaseous product that formed are tabulated below. All volumes were measured at the same temperature and pressure.

Volume of NO used (mL)	84	56	38
Volume of O_2 that reacted with this (mL)	42	28	19
Volume of product formed (mL)	84	56	38

(a) State Gay Lussac's law and explain how these results agree with it.
(b) Use these results to deduce the formula for the product of the reaction.

***52.** Nitric oxide, NO, an air pollutant produced by motor cars, reacts with oxygen to form nitrogen dioxide, NO_2, another air pollutant. What volume of oxygen is needed to react with 250 mL nitric oxide and what volume of nitrogen dioxide is formed? All volumes are measured at the same temperature and pressure.

53. What volume of oxygen is needed to react with 3 L methane (major constituent of natural gas)? The products are carbon dioxide and water. What volume of carbon dioxide is formed? All volumes are measured at the same temperature and pressure.

***54.** A mixture of 100 mL carbon monoxide (CO) and 100 mL oxygen is sparked to cause reaction (to form carbon dioxide). Calculate the change in volume resulting from the reaction. All volumes are measured at constant temperature and pressure.

Molarity calculations

The symbol M *is often used as an abbreviation for molarity,* mol L^{-1} *or* mol/L.

55. How many moles of solute do you need to weigh out to make the following solutions?
*(a) 2.00 L of 1.50 M (1.50 mol/L) sodium chloride
(b) 3.5 L of 0.20 M potassium hydroxide
*(c) 250 mL of 0.115 M sulfuric acid

56. Calculate the molarity of the solutions made by dissolving the following amounts of solute in water and making the volume up to the stated value.
*(a) 5.0 mol nitric acid in 2.0 L
(b) 2.5 mol sodium hydroxide in 0.50 L
*(c) 0.020 mol sulfuric acid in 100 mL

57. How many moles of solute are there in
*(a) 2.5 L of 1.27 M hydrochloric acid
(b) 1.7 L of 0.047 M sulfuric acid
*(c) 50 mL of 0.116 M sodium hydroxide?

***58.** What mass of solute do you need to weigh out to make the solutions in Exercise 55?

***59.** What mass of solute is present in each solution in Exercise 57?

60. *(a) How many moles of (i) magnesium chloride (ii) magnesium ions (iii) chloride ions are there in 16.4 mL 0.117 mol/L magnesium chloride solution?
(b) How many moles of (i) sulfuric acid (ii) sulfate ions (iii) hydrogen ions are there in 14.5 mL 0.056 mol L^{-1} sulfuric acid solution?

61. What mass of the indicated substance do you need to weigh out to make the following solutions?
*(a) barium hydroxide to make 0.5 L of 0.060 M hydroxide solution
(b) sulfuric acid to make 250 mL of 0.330 M hydrogen ion solution

Reactions and moles

62. In each of the following, how many moles of the first substance are needed to reach the equivalence point in a titration with the stated amount of the second substance?
*(a) hydrochloric acid with 0.150 mol sodium hydroxide
*(b) nitric acid with 0.065 mol barium hydroxide
(c) hydrochloric acid with 0.25 mol zinc oxide
(d) sulfuric acid with 0.15 mol ammonia

63. What volume of Solution A in the following table is needed to reach the equivalence point in a titration with the stated volume of Solution B?

Solution A	*Solution B*
*(a) 0.215 M nitric acid	25 mL 0.334 M sodium hydroxide
*(b) 0.215 M nitric acid	50 mL 0.103 M barium hydroxide
(c) 0.271 M hydrochloric acid	50 mL 0.155 M ammonia
(d) 0.450 M hydrochloric acid	50 mL 0.202 M sodium carbonate

64. What volume of Solution A in the following table is needed to react with the given amount of substance in Column B?

Solution A	*Column B*
(a) 0.104 M hydrochloric acid	0.150 g sodium hydroxide
(b) 0.125 M nitric acid	2.02 g calcium hydroxide
*(c) 0.186 M hydrochloric acid	0.672 g sodium carbonate
(d) 0.085 M sulfuric acid	0.383 g sodium hydrogen carbonate

65. What is the molarity of Solution A in the following table if the stated volume is needed to reach the equivalence point in a titration with the amount of substance in Column B?

Solution A	*Column B*
*(a) 25.8 mL hydrochloric acid	1.35 g potassium carbonate
(b) 19.7 mL sulfuric acid	0.106 g sodium hydrogen carbonate
(c) 41.8 mL acetic (ethanoic) acid	3.622 g barium hydroxide hydrate, $Ba(OH)_2.8H_2O$
(d) 21.5 mL ammonia	25 mL 0.262 M nitric acid

Simple analyses

***66.** 'Cloudy ammonia' is often used in the home for cleaning. In order to determine the concentration of such a solution, a chemist titrated 5.0 mL of the commercial product with 0.250 M hydrochloric acid; 32.8 mL of the acid was required to reach the equivalence point. Calculate the molarity of the ammonia solution. Also calculate the per cent composition (that is grams of ammonia per 100 g of solution, which is approximately grams per 100 millilitres of solution).

67. To determine the solubility of calcium hydroxide, $Ca(OH)_2$, a chemist prepared a saturated solution then titrated 25 mL of it with 0.102 M hydrochloric acid; 8.13 mL of this acid was needed to reach the equivalence point. Calculate the molarity of the calcium hydroxide solution. Calculate its solubility in grams per 100 millilitres.

68. The electrolyte in car batteries is sulfuric acid. A curious student decided to determine the concentration of this acid in a well-charged battery by taking exactly 2 mL by pipette (using a safety bulb-filler) and titrating it with 1.16 M sodium hydroxide solution; 17.1 mL was needed to reach the equivalence point. Calculate the molarity of the sulfuric acid in the battery. Also calculate the concentration in grams per litre.

Dilutions

69. The volume of solution in Column A was diluted to the volume in Column B. Calculate the molarity of the diluted solution.

Column A	*Column B*
*(a) 50 mL 0.242 M hydrochloric acid	500 mL
(b) 25 mL 0.152 M sulfuric acid	2.0 L
(c) 10 mL 0.114 M sodium hydroxide	250 mL
(d) 37.5 mL 0.024 M ammonia	100 mL

70. What volume of Solution A in the following table is needed to prepare the solution in Column B?

Solution A	*Column B*
(a) 0.282 M hydrochloric acid	500 mL 0.0282 M
(b) 0.282 M hydrochloric acid	250 mL 0.0113 M
(c) 2.42 M sulfuric acid	2.0 L 0.121 M
(d) 0.318 M sodium hydroxide	1.0 L 0.300 M

(b) iron(II) carbonate and iron(II) hydroxide, $Fe(OH)_2$
(c) K^+
(d) Ag^+, Fe^{3+}, K^+

57. (a) hydrogen: $Fe(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$
(c) Iron and sulfur react to form iron(II) sulfide.
$Fe(s) + S(s) \longrightarrow FeS(s)$
(d) hydrogen sulfide: $FeS(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2S(g)$
(e) It would have gone black, because lead sulfide would have formed.
$Pb^{2+}(aq) + H_2S(g) \longrightarrow PbS(s) + 2H^+(aq)$

CHAPTER 5: FORMULAE AND EQUATIONS—QUANTITATIVE ASPECTS

1. (a) *see Complete Working* (b) 4
2. (a) *see Complete Working* (b) 9
3. (a) Silicon atoms are twice as heavy as nitrogen atoms.
(b) Bromine atoms are 2½ times heavier than sulfur atoms.
4. (a) 96 (b) 40
5. (a) 32 (b) 40
6. (b), (d), (j) and (k) *see Complete Working*
(a) 56.1 (c) 78.1 (e) 108.0 (f) 303.3 (g) 138.2 (h) 74.1 (i) 213.0
7. (a) *see Complete Working* (e) 108.0 g/mol (k) 342.3 g/mol
8. (a) *see Complete Working* (b) 8.6×10^{-3} (c) 67 (d) 7.17×10^{-3}
9. (a) *see Complete Working* (b) 5.0 g (c) 2 g (d) 1.3×10^{-3} g
10. 2.42×10^{22}
11. (a) *see Complete Working* (b) 0.35 (c) 3.73×10^{-3} (d) 3.17×10^{-4}
12. (a) 2.12×10^{-5} g (b) 486 g (c) 2.43 g (d) 0.0844 g
13. (a) 90.2 g (b) 102 g (c) 1.5 g (d) 2.2 g
14. (a) 0.0953 (b) 0.205
15. (a), (c) *see Complete Working* (b) 5.2×10^{21} (d) 4.32×10^{21}
16. (a) *see Complete Working*
(b) 3.44×10^{-22} g (c) 6.64×10^{-24} g (d) 5.33×10^{-23} g
17. (a) *see Complete Working*
(b) 5.45×10^{22} (c) 1.58×10^{21} (d) 1.00×10^{21}
18. (a) 2.82×10^{-23} g (b) 7.3×10^{-23} g (c) 2.92×10^{-22} g
19. *see Complete Working*
20. (a) 6.89×10^{23} (b) 2.85×10^{23} (c) 7.61×10^{20}
21. (a) *see Complete Working* (b) (i) 3.38×10^{-6} (ii) 8.45×10^{-6}
22. 2.46×10^{18}, 1.11×10^{20}
23. (a) *see Complete Working* (b) 87.1% (c) 84.8%
24. (a) 38.7% K, 13.8% N, 47.5% O (b) 94.1% C, 5.9% H
(c) 60.0% C, 4.5% H, 35.5% O (d) 38.8% Ca, 20.0% P, 41.3% O
25. 0.70 t (700 kg)
26. *see Complete Working*
27. (a) C_2H_5 (b) HO (c) $C_3H_8O_3$ (d) CHF_2

28. (a) 14.4% H and 85.6% C for all four compounds
(b) CH_2 for all four compounds
(c) An analysis gives the proportions (or ratios) of the elements in the compound by mass. By dividing by atomic weights, these ratios by mass can be converted to ratios by atoms, so analysis leads directly to the empirical formula. However an analysis in terms of per cent composition cannot tell us how many atoms of any one element are present in one molecule of the compound and so cannot give us the molecular formula. The results in (a) and (b) illustrate this: the four different compounds have the same empirical formula and so give the same analysis.
29. *see Complete Working*
30. (a) CH_4O (b) CH_2O (c) CH_2O_2
31. *see Complete Working*
32. Cr_2O_3
33. *see Complete Working*
34. $C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$
(a) 21 mol O_2, 14 mol CO_2 (b) 0.165 mol O_2, 0.110 mol CO_2
35. *see Complete Working*
36. (a) *See Complete Working* (b) 1.29 g
37. (a) 18 g (b) 6.8 g (c) 5.9 g
38. *see Complete Working*
39. 3.25 g H_2SO_4; 5.30 g $CuSO_4$
40. 0.47 g HCl; 1.75 g $ZnCl_2$
41. 42.8 g
42. *see Complete Working*
43. (a) 3.75 (b) 0.167 (c) 0.125
44. (a) 11.2 mol NO formed, 0.8 mol NH_3 left over
(b) 15 mol NO formed, 1.25 mol O_2 left over
45. *see Complete Working*
46. 0.053 g
47. 0.27 g
48. *see Complete Working*
49. 0.462 L (462 mL)
50. 0.097 L (97 mL)
51. *see Complete Working*
52. *see Complete Working*
53. 6 L O_2; 3 L CO_2
54. *see Complete Working*
55. (a) and (c) *see Complete Working* (b) 0.70
56. (a) and (c) *see Complete Working* (b) 5.0 mol/L
57. (a) and (c) *see Complete Working* (b) 0.080
58. (a) *see Complete Working* (b) 39 g (c) 2.82 g
59. (a) *see Complete Working* (b) 7.8 g (c) 0.232 g
60. (a) *see Complete Working*
(b) (i) 8.12×10^{-4} mol H_2SO_4 (ii) 8.12×10^{-4} mol SO_4^{2-}
(iii) 1.62×10^{-3} mol H^+
61. (a) *see Complete Working* (b) 4.05 g

62. (a) and (b) *see Complete Working* (c) 0.50 (d) 0.075
63. (a) and (b) *see Complete Working* (c) 28.6 mL (d) 44.9 mL
64. (a) 36.1 mL (b) 43.6 mL
(c) *See Complete Working* (d) 26.8 mL
65. (a) *see Complete Working* (b) 0.0320 M (c) 0.550 M (d) 0.305 M
66. *see Complete Working*
67. 0.0166 M; 0.123 g/100 mL
68. 4.96 M; 486 g/L
69. (a) *see Complete Working* (b) 1.90×10^{-3} M (c) 4.56×10^{-3} M (d) 9.0×10^{-3} M
70. (a) 50 mL (b) 10 mL (c) 100 mL (d) 0.943 L
71. (a) *see Complete Working* (b) (i) 0.0707 M (ii) 0.0693 M (iii) 0.211 M
72. A 73. C 74. B 75. A 76. C 77. B
78. D 79. A 80. D 81. B 82. A
83. (a) N_2O_3, N_2O_5 (b) dinitrogen trioxide, dinitrogen pentoxide
(c) 1.26×10^{-22} g
84. (a) 118.6 (b) tin (c) 150.6
85. (a) $Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$
(b) 0.114 g
86. (a) The temperature passes through a maximum, because that combination of volumes contains stoichiometric proportions of the two reactants; that is the amounts of potassium iodide and lead nitrate in the solutions are such that they exactly react with each other with none of either of them left over. For all other combinations of volumes of reactants, one reactant will be in excess which means that less product will be formed than from the stoichiometric mixture; this means that the temperature rise will be less.
(b) The stoichiometric mixture (the mixture that produces the maximum temperature rise) is 100 mL lead nitrate and 200 mL potassium iodide; that is 0.10 mol lead nitrate and 0.2 mol potassium iodide. The formula is therefore PbI_2.
(c) $Pb(NO_3)_2(aq) + 2KI(aq) \longrightarrow PbI_2(s) + 2KNO_3(aq)$
87. (a) C_3H_7O (b) 111 g/mol (c) $C_6H_{14}O_2$
88. (a) 39 (b) 2.05×10^{20} (c) 1.02×10^{21}
89. (a) Cu_2S (b) CuS
90. (b) 0.150 M (c) 3.11 g/100 mL
91. (b) 0.052 M
92. (b) Allow the precipitate in (a) to settle then add a drop of fairly concentrated potassium bromide (1 or 2 M) to the clear solution and observe the development of some turbidity (formation of a precipitate of silver bromide).
(c) 1.6 g
93. (a) $Ca_3(PO_4)_2(s) + 2H_2SO_4(aq) \longrightarrow Ca(H_2PO_4)_2(aq) + 2CaSO_4(s)$
(b) 0.632 t
94. (a) CH_2 (b) C_4H_8
95. (a) $C_4H_5N_2O$ (b) 97 g/mol
96. (b) 0.0115 mol (c) 0.0115 mol (d) 55.6%
(e) Bubble it through limewater; the clear solution goes milky.
97. (a) Provided that sufficient calcium carbonate is used to react with all the hydrochloric acid in the 50 mL of solution, any extra calcium carbonate will not produce any additional carbon dioxide. Therefore starting with small amounts of solid, the volume of carbon dioxide increases as the mass of calcium carbonate increases until that sufficient amount of calcium carbonate is reached. After that the volume of carbon dioxide produced remains constant.
(b) 0.90 g (c) 0.0180 mol
98. (a) $KH(C_4H_4O_6)(aq) + NaHCO_3(aq) \longrightarrow KNa(C_4H_4O_6)(aq) + H_2O(l) + CO_2(g)$
(b) 0.71 L
99. (a) $CClF_2$ (b) $C_2Cl_2F_4$; 171
(c) The value of 171 is based upon an average atomic weight of chlorine of 35.5. In fact there are no chlorine atoms with this mass; rather there are two isotopes with masses of 35 and 37. This means that in the mass spectrum there will be peaks corresponding to masses 100 (for C_2F_4) + 35 + 35 = 170, 100 + 35 + 37 = 172 and 100 + 37 + 37 = 174.
100. (b) Sb_2O_3
(c) straight line through the origin, but with a larger slope; it passes through the point, mass of antimony = 15 g, mass of oxygen = 5.0 g.

CHAPTER 6: ENERGY AND CHEMICAL REACTIONS—BASIC IDEAS

1. (a), (d) and (e) *see Complete Working* (b) 2.9×10^2 J (c) 1.95×10^4 J
2. 3.0×10^7 J
3. 0.86 J K^{-1} g^{-1}
4. *see Complete Working*
5. (a) and (c) *see Complete Working* (b) 3.1×10^2 kJ (d) 84 kJ (e) 1.3 kJ
6. *see Complete Working*
7. 11.5 kJ
8. *see Complete Working*
9. 17
10. 41 kJ mol^{-1}
11. (b) 61.8 J s^{-1} (c) 42 kJ mol^{-1}
12. A → B gas cools from starting temperature to its boiling point
B → C gas changes to liquid (condenses) at its boiling point
C → D liquid cools to its melting point
D → E liquid changes to solid (freezes) at its melting point
E → F solid cools
There are two horizontal portions because these correspond to changes of state. Latent heat is removed to condense the vapour and to freeze the liquid, but the temperature does not fall until all the sample has liquefied or frozen.
15. (a) Exothermic: (i), (iv); endothermic: (ii), (iii)
(b) Temperature would increase for (i), (iv); temperature would decrease for (ii), (iii).
16. (a) and (b) *see Complete Working*
(c) $NH_4Cl(s) \longrightarrow NH_3(g) + HCl(g)$ $\Delta H = +176$ kJ/mol
(d) $NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$ $\Delta H = -55$ kJ/mol
17. (a) *see Complete Working*
(b) 8.1 kJ absorbed (c) 8.3 kJ absorbed (d) 3.7 kJ released
18. (a) +114 kJ/mol (b) −57 kJ/mol