Module 2: Metals

Further exercises

For page107

A1. Give three major uses for each of the metals, iron, zinc, lead, and for each metal list the properties that make it particularly suitable for those uses.

A2. Name four common alloys. Give their approximate composition. Prepare a table that contrasts the properties of each alloy with those of the constituent metals.
(Answers are not given for questions A1 and A2.)

A3. Why is a copper–nickel alloy used for 'silver' coins instead of real silver?

A4. Mercury is generally considered a poison (because its vapour gets converted into organo-mercury compounds that can be absorbed into the bloodstream and affect the central nervous system). However mercury is widely used in amalgams (alloys) used for filling cavities in teeth. Why is this practice generally considered safe?
Actually it is generally thought that dentists are more at risk from mercury poisoning than their patients. Suggest a reason for this.

A5. Use the data in Table 4.4 on page 104 to test whether melting point of metals depends upon density. Do this by plotting melting point against density and seeing if there is any correlation between the two properties.

For page 114

B1. Tin and lead occur mainly as tin(IV) oxide and lead sulfide. The metals were extracted from these ores long before the science of chemistry had developed. Explain how early civilisations extracted the metals. Give chemical equations for the reactions that we now know to be occurring during these processes.
What were the major uses of these metals in the early centuries AD (or to be politically correct in the early centuries of the common era, CE)?

B2. Nickel occurs as sulfide ores such as NiS. The metal is obtained by roasting the ore in air (to form nickel oxide and sulfur dioxide) and then by heating the oxide with carbon. Write equations for these reactions.

For pages 118–9

C1. Write balanced equations for the following reactions:
- **(a)** potassium burning in oxygen
- **(b)** magnesium reacting with nitrogen (occurs when Mg is burnt in air)
- **(c)** barium reacting with water
- **(d)** magnesium dissolving in hydrochloric acid solution

C2. Write half reactions (equations) showing electron loss and gain for the reactions in (c) and (d) of Exercise C1.

For pages 121 and 126–7

D1. Four metals, P, Q, R and S, undergo the following reactions:

- S reacts rapidly with water, P reacts slowly with steam while R and Q do not react at all.
- P reacts with dilute acid whereas R and Q do not; S could not be tested with dilute acid, because it reacts rapidly with water.
- Q does not react with oxygen even when heated whereas all the others do.

Arrange these metals in order of decreasing activity (most active first, least active last).
Name metals that P, Q, R and S could be.

D2. Name two metals for which formation of a surface coating of oxide is an advantage and two where it is a disadvantage. State why it is an advantage or disadvantage.

For page 133–4

E1. **(a)** Bromine atoms are 6.67 times as heavy as carbon atoms. What is the atomic weight (relative atomic mass) of bromine?

(b) Aluminium atoms are 2.25 times as heavy as carbon atoms. What is the atomic weight of aluminium?

E2. **(a)** Iron has an atomic weight of 56 and silicon 28. What does this tell you about the relative masses of atoms of iron and silicon?

(b) Krypton atoms are six times as heavy as nitrogen atoms. Nitrogen has a relative atomic mass of 14. What is the relative atomic mass of krypton?

E3. Calculate the molecular weight (relative molecular mass) of:

(a) ethanol, C_2H_6O

(b) aluminium nitrate

(c) citric acid, $C_3H_5O(COOH)_3$

(d) calcium dihydrogen phosphate, $Ca(H_2PO_4)_2$

For page 138

F1. **(a)** How many moles of **(i)** iron(III) sulfide **(ii)** iron **(iii)** sulfur are there in 2.00 g iron(III) sulfide, Fe_2S_3?

(b) How many atoms are there in this sample?

F2. In 3.60 g glucose, $C_6H_{12}O_6$, there are

(a) how many moles of glucose

(b) how many moles of oxygen atoms

(c) how many molecules of glucose

(d) how many atoms of hydrogen

(e) how many atoms in total?

For pages 139–40 and 142

G1. Calculate the percentage nitrogen in ammonium nitrate, NH_4NO_3. How does this compound compare with those in Exercise 20 on page 139 as a nitrogenous fertiliser?

G2. Calculate the percentage composition of the common painkiller aspirin, $C_9H_8O_4$

G3. The average person needs 600 mg calcium per day. For people who are unable to eat food rich in calcium, such as milk and cheese, what mass of calcium carbonate do they need to take daily to provide this calcium?

G4. How much iron can be extracted per tonne of iron ore taken as being pure iron(III) oxide?

G5. The formulae of vitamin C and potassium oxide are given as $C_6H_8O_6$ and K_2O respectively. Why is it unnecessary to state whether these are molecular or empirical formulae?

G6. Methanal (formaldehyde), methanoic acid (acetic acid) and glucose all have the same empirical formula, CH_2O. However they are very different compounds with very different properties. Why is this so?

G7. Chloromycetin, a broad-spectrum antibiotic, contains 40.9% carbon, 3.7% hydrogen, 24.8% oxygen, 22.0% chlorine and 8.7% nitrogen. Calculate the empirical formula. If this is also its molecular formula, what is its molecular weight?

G8. Known masses of copper wire were gently heated with excess sulfur until all the copper had been converted to a black solid. Then the leftover sulfur was burnt off as sulfur dioxide. The mass of black solid formed was then measured. The masses of copper used and the mass of black solid formed are given below.

Mass of copper (g)	1.21	1.84	2.52	3.13
Mass of black solid (g)	1.52	2.30	3.16	3.92

(a) Calculate the ratio of the mass of copper to the mass of sulfur in each experiment.
(b) What do you conclude from the values you obtained?
(c) Calculate the formula of any compound that was formed.
(d) What type of formula is this?

For Section 5 (above) Calculating formulae from experimental data
(Click here to go to Section 5)

H1. Ethylene glycol, the common automotive antifreeze, contains 36.7% carbon and 9.7% hydrogen with the balance being oxygen. Calculate the empirical formula. An estimate of the molecular weight can be obtained by determining the lowering of the freezing point of water caused by a measured quantity of the compound; the approximate molecular weight thus determined was 59. Determine the molecular formula and the exact molecular weight.

H2. 5.50 g of a compound of mercury and chlorine contained 4.67 g mercury. Calculate the empirical formula. The molecular weight was found to be 470. Calculate the molecular formula.

H3. A certain compound of carbon and hydrogen was shown by analysis to contain 7.8% hydrogen. By measuring the mass of vapour of the compound that filled a known volume to atmospheric pressure at 100°C the analyst determined that its molecular weight was approximately 80 (±5). Calculate the molecular formula of the compound and its accurate molecular weight.

For page 146

J1. Butane is the fuel in disposable cigarette lighters and in 'Handigas' cans for camping stoves and hobbyists blow torches. It burns in air to form carbon dioxide and water. Write a balanced equation for the reaction of butane, C_4H_8, with oxygen. How many moles of oxygen are needed to react with **(a)** 1 mol **(b)** 0.25 mol **(c)** 4.3 X 10^{-4} mol of butane? How many moles of carbon dioxide are formed in each case?

J2. Aluminium reacts with chlorine to form aluminium chloride.

(a) How many moles of chlorine are needed to react with 0.18 mol aluminium?

(b) How many moles of chlorine are needed to form 1.6 moles of aluminium chloride?

J3. The first step in extracting aluminium from its common ore, bauxite, is to dissolve the aluminium oxide in the bauxite in sodium hydroxide solution. The reaction is

$Al_2O_3(s) + 2NaOH(aq) \rightarrow 2NaAlO_2(aq) + H_2O(l)$

How many moles of sodium hydroxide are required per kilogram of aluminium oxide?

J4. If solutions of iron(III) nitrate and barium hydroxide are mixed, a precipitate of iron(III) hydroxide is produced; barium nitrate remains in solution. Write an equation for the reaction. What mass of barium hydroxide is required per mole of iron(III) nitrate used?

J5. What mass of sulfuric acid is needed to react with 0.544 g aluminium? What mass of hydrogen gas is produced?

J6. One method of extracting zinc from its common ore, zinc sulfide, is to roast the ore in air to form zinc oxide and sulfur dioxide, then to heat the zinc oxide with carbon to form zinc and carbon monoxide. What mass of carbon is needed per tonne of zinc produced? What mass of sulfur dioxide is formed per tonne of Zn produced?

For page 148

K1. The extraction of copper from malachite can be represented by the equation

$Cu(OH)_2.CuCO_3(s) + 2C(s) \rightarrow 2Cu(s) + H_2O(g) + CO_2(g) + 2CO(g)$

When 53.4 g malachite was so treated, 23.9 g copper was obtained. What percentage yield does this represent?

K2. When the common ore of silver, silver sulfide is roasted in air, metallic silver and sulfur dioxide are formed. If the process has a yield of 92%, how much silver is obtained per tonne of silver sulfide?

For page 152

L1. Volumes are measured at the same temperature and pressure in each of the following:

(a) What volume of oxygen is needed to react with 150 mL nitric oxide, NO, to form nitrogen dioxide, NO_2? What volume of NO_2 is formed?

(b) Rotten egg gas, H_2S, can be destroyed by reacting it with oxygen according to the equation:

$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$

Using this equation, what volume of O_2 is needed to react with 200 mL H_2S and what volume of SO_2 is formed?

(c) What volume of oxygen is needed to react with 3.0 L ethane, C_2H_6, to form CO_2 and H_2O? What volume of CO_2 is formed?

L2. One method for making hydrogen gas for industrial use is to react steam (H_2O) with methane (CH_4) to form carbon monoxide (CO) and H_2. What volume of hydrogen can be obtained from 50 L methane? (Both volumes measured at the same temperature and pressure.)

L3. 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.

For pages 161–3

M1. Use the data below to draw graphs (on separate pieces of paper) of **(a)** melting point and **(b)** atomic radius against group number (in the Periodic Table). Use your graphs to summarise (if possible) the ways in which melting point and atomic radius vary as we go across a period of the Periodic Table. For each graph, should you draw a smooth curve through the points or a series of straight lines? Justify your choice.

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Group number	1	2	3	4	5	6	7	8
Melting point (ºC)	98	650	660	1410	44	113	–101	–189
Atomic radius (pm)	186	160	143	118	110	102	99	94

M2. **(a)** Explain what is meant by first ionisation energy.

(b) In the Periodic Table how does the first ionisation energy vary **(i)** from left to right across a period, **(ii)** from top to bottom down a group?

(c) Place the elements in each of the following sets in order of *increasing* first ionisation energy:

(i) magnesium, sodium, potassium

(ii) silicon, sulfur, tin

(iii) potassium, caesium, calcium

M3. The table below gives ionisation energies (in MJ/mol) for six consecutive elements in the Periodic Table labelled L, M, N, P, Q and R; these labels do *not* correspond to the chemical symbol of the elements.

L	M	N	P	Q	R
0.98	1.01	1.26	1.53	0.43	0.60

Which of these elements would be:
(a) a noble gas
(b) a member of Group 1
(c) in the same group as oxygen?
Explain how you made your decisions.

M4. **(a)** In the Periodic Table how does atomic radius vary **(i)** across a period from left to right, and **(ii)** down a group from top to bottom?

(b) In each of the following sets place the elements in order of *increasing* atomic radius:

(i) potassium, calcium, magnesium

(ii) chlorine, fluorine, silicon

(iii) gallium, phosphorus, aluminium

(iv) chlorine, argon, arsenic, bromine

For page 1764

N1. **(a)** Element W forms the chloride WCl_2 and the oxide WO. Element Y is in the same group of the Periodic Table as W. What would you expect for the formulae of the hydroxide and bromide of element Y? Which, if any, of these compounds of W and Y would you expect to be ionic? Explain.

(b) Element X forms the oxide XO_2 and the chloride XCl_4. Element Z is in the same group of the periodic Table as X. What would you expect for the formulae of the sulfide and iodide of Z?

Which, if any, of these compounds of X and Z would you expect to be ionic? Explain.

N2. **(a)** Give the electron configurations of **(i)** sodium **(ii)** the sodium ion **(iii)** chlorine **(iv)** the chloride ion.

(b) The radii of the ions formed from Group 1 elements (Li, Na, K etc) are smaller than the radii of the respective atoms. When Group 7 elements (F, Cl, Br etc) form ions, the ions have larger radii than the respective atoms. Explain these observations in terms of electron configurations.

N3. The table below gives the electron configuration of six species which are labelled with letters which do *not* correspond to normal symbols of the elements.

Species	*Electron configuration*
U	2, 8, 7
V^+	2, 8, 8
W	2, 8, 14, 2
X^-	2, 8, 8
Y	2, 8, 18, 8, 1
Z^{2-}	2, 8, 18, 8

(a) Which element or elements belong(s) to Group 1 of the Periodic Table?

(b) Which element or elements is (are) transition elements?

(c) Which element has atomic number 34?

(d) Which element, if any, belongs to the same group as oxygen?

(e) Which element or elements is(are) halogens?

(f) Write the formula you would expect for the compound formed between elements Y and Z. State whether the compound would be ionic or covalent.

N4. For each of the elements, carbon, calcium, phosphorus and sodium:

(a) Give the formula of the hydride and indicate whether it is ionic or covalent.

(b) Write the formula of the chloride, again stating whether you expect it to be ionic or covalent.

(c) Give the formula of the oxide; if more than one is possible, give the one in which the element has the highest valence.

For page 167

P1. **(a)** An element X conducts electricity and has a melting point of about 300°C. It forms a chloride, XCl_4 and a sulfide, XS_2. To what group of the Periodic Table does it belong? What elements could X be? Explain why. How would you determine experimentally which of these it was?

(b) Element Y is a non-conducting solid at room temperature. With sodium and calcium it forms ionic compounds of formulae, NaY and CaY_2. Identify Y, giving your reasoning.

(c) Element Z is a solid at room temperature. It does not conduct electricity. It forms two chlorides, ZCl_3 and ZCl_5. To which group of the Periodic Table does it belong? What are the possibilities for Z? Explain why. What measurements would you make to decide between these?

P2. Electronegativity was defined on page 166. As stated there it can be used to determine whether the compound formed between two elements will be ionic or covalent. As we shall see in Module 3 (pages 188–9), it can also be used to determine whether a particular covalent bond will be polar (unequal charge distribution) or non-polar.
Values for electronegativity are given in Table 6.7 on page 166.

(a) For the elements of Groups 1 and 2 plot electronegativity against period number, using circles for Group 1 and squares for Group 2. On the basis of your graphs, summarise the way that

electronegativity change as we go down a group.

(b) Would you expect the compound formed between (i) potassium and sulfur (ii) silicon and bromine (iii) calcium and nitrogen to be ionic or covalent? Why?