Module 1: The Chemical Earth

Answers to Exercises

A1. If the air is clean (just a mixture of gases) then it is homogeneous: if it contains dust particles or water droplets (fog), it is heterogeneous.

A2. **(a)** Yes; solution of sugar in water, honey, whiskey

(b) No; by definition (Table 1.1 page 6) a pure substance must be homogeneous. It is tempting to think of a glass of water with ice in it as a pure substance, but by our definition it is not because there are two phases present, liquid and solid.

A3. Compound; because its properties are different from those of the starting substances (elements), it does not easily revert to the starting elements and it has constant composition.

B1. Distillate, because the distillate is richer in the more volatile component (the one with the lower boiling point) which is ethanol (alcohol). Higher, same reason.

B2. Allow the two liquids to settle and separate (they are immiscible, then use a separating funnel (pages 15–6).

B3. A mixture; richer in nitrogen (the one with the lower boiling point); fractionally distil it (page 14), nitrogen

B4. Use a magnet: iron attaches to it, lead does not.

B5. **(a)** By sublimation; put the mixture in a flask fitted with a cooled test tube as in the photo on page 68; the iodine sublimes on to the cold surface and the sand remains on the bottom of the flask.

(b) Again by sublimation; this time the ammonium chloride vaporises and condenses on the cooled surface.

B6. The milky mixture resulting from adding sodium hydroxide solution to copper sulfate solution is heterogeneous, because it can be separated into a solid and a liquid (solution) by centrifuging; the two solutions reacted to form copper hydroxide, a pale blue solid. The mixture of copper sulfate and ammonia solutions is a true solution: it cannot be separated by centrifuging; the change in colour results from a chemical reaction between the two solutions to form the deep blue solution of a new compound called tetraamminecopper(II) sulfate (or copper tetrammine sulfate).

B7. Add hexane to dissolve the iodine, filter to separate the solids from the iodine in hexane solution. Evaporate off the hexane to recover solid iodine. Then sublime the carbon, ammonium chloride mixture as in answer B5.
Alternatively you could add water to the original mixture to dissolve the ammonium chloride then after filtration separate the carbon and iodine by sublimation.
Still another method would be to separate the iodine by dissolving it in hexane and filtering it off, then adding water to the carbon, ammonium chloride mixture to dissolve the latter and so separate that pair.

C1. **(a)** Oxygen, nitrogen and hydrogen are gases, water, ethanol, ethyl acetate, ethylene glycol, acetic acid, chloroform and hexane are liquids and the rest are solids.

(b) **(i)** Water and acetic acid would change to solids
(ii) Sodium and phosphorus would change from solid to liquid; water, ethanol, ethyl acetate, chloroform and hexane would change from liquid to gas (vapour).

D1. 11.4 g/mL

D2. Determine its mass then measure its volume by dropping it into a burette partly filled with water and observing the change in volume (as in exercise D4). If it was gold plated copper its density would be about 9 g/mL. If it was pure gold (24 carat) its density would be 19.3 g/mL. If it was 18 or 9 carat gold its density would be about 17 or 13 g/mL respectively. Density would clearly distinguish between gold plated copper and any of the common gold alloys.

E1. 10% aspirin, 58% sodium bicarbonate, 32% citric acid

E2. 57% aggregate, 28% sand, 13% cement. There has been a 1.5% loss of material during the analysis so it is not as accurate as the measured masses suggest: hence the rounding off in the percentages.

E3. There was some loss of material as dust into the air or stuck to the seives, or even perhaps some spillage. Some cement would have stayed with the aggregate and sand (stuck on the surface of those coarse particles. This would have meant that the percentage of cement was low. After separating the aggregate and sand wash each with water to remove the cement, remove the solution/suspension of cement in water by sedimentation and decantation (page 13), dry the aggregate and sand then re-weigh each. This would give more accurate measures of the amounts of aggregate and sand; take the true mass of cement as the difference between starting mass and mass of aggregate plus sand.

E4. 80.1%

E5. 53.5% copper

E6. The percentage copper in the three samples is 58.7%, 49.0% and 56.1% (left to right). Combined with the answer in exercise E5, we have clear evidence that the composition of brass is variable. Therefore brass is a mixture (solid solution) and not a compound.

F1. Because they do not agree with the law of conservation of mass (matter) (page 69); mass of products is 1.25 g compared with 1.36 g of starting material.

F2. 1.43 g; law of conservation of mass says that the mass of products must equal the mass of reactant.

G1. **(a)** **(i)** 1 boron, 3 oxygen and 3 hydrogen atoms
(ii) 2 carbon, 4 hydrogen and 2 oxygen atoms
(iii) 1 carbon, 4 hydrogen, 1 oxygen and 2 nitrogen atoms
(iv) 6 carbon, 8 hydrogen, and 6 oxygen atoms

(b) **(i)** 7 **(ii)** 8 **(iii)** 8 **(iv)** 24

G2. **(a)** $C_2H_2F_4$
(b) $C_3H_7O_2SN$
(c) $C_2H_3O_5N$

H1. atomic numbers: **(a)** 14 **(b)** 33 **(c)** 18 **(d)** 12
mass numbers:**(a)** 29 **(b)** 75 **(c)** 40 **(d)** 24
Names and symbols: **(a)** phosphorus, P **(b)** arsenic, As **(c)** argon, Ar
(d) magnesium, Mg

H2. Both have 12 electrons; same element (It is the number of protons that determines which element an atom belongs to: as we shall see on page 141 these two atoms are *isotopes* of the one element.

H3. Sr (2, 8, 18, 8, 2) Tc (2, 8, 18, 13, 2) Xe (2, 8, 18, 18,8)
Zr (2, 8, 18, 10, 2) Sb (2, 8, 18, 18, 5)

H4. O (2, 6) S (2, 8, 6) Se (2, 8, 18, 6) Te (2, 8, 18, 18, 6);They all have six electrons in their outermost energy level (that is, six valence electrons).

J1. 9: (2, 7) Group 7
3: (2, 1) Group 1
12: (2, 8, 2) Group 2
18: (2, 8, 8) Group 0 (or 8)
15: (2, 8, 5) Group 5
4: (2, 2) Group 2
20: (2, 8, 8, 2) Group 2
30: (2, 8, 18, 2
13: (2, 8, 3) Group 3
36: (2, 8, 18, 8) Group 0 (or 8)
6: (2, 4) Group 4
16: (2, 8, 6) Group 6

J2. barium, 2
bromine, 7
gallium, 3
arsenic, 5
caesium, 1
selenium, 6

J3. **(a)** K (2, 8, 8, 1); K^+ (2, 8, 8)
(b) F (2, 7); $F^–$ (2, 8)
(c) Al (2, 8, 3) ; Al^{3+} (2, 8)
(d) S (2, 8, 6); $S^{2–}$ (2, 8, 8)

J4. **(a)** **(i)** all are (2, 8)
(ii) all are (2, 8, 8)
(b) They all have a stable noble gas configuration; because atoms tend towards the configuration of the noble gas nearest to them.

K1. Your diagram should show:

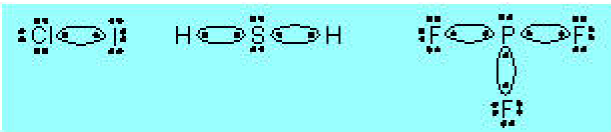
(a) a lithium atom with configuration (2, 1) donating an electron to a bromine atom (2, 8, 18, 7) to form Li^{+} (2) and Br^{-} (2, 8, 18, 8)

(b) a magnesium atom (2, 8, 2) donating 2 electrons to a sulfur atom (2, 8, 6) to form Mg^{2+} (2, 8) and S^{2-} (2, 8, 8)

(c) each of *two* sodium atoms (2, 8, 1) donating one electron to the same oxygen atom (2, 6) to form two Na^{+} (2, 8) ions and one O^{2-} (2, 8) ions

K2. **(a)** Sr^{2+} (2, 8, 18, 8) **(b)** I^{-} (2, 8, 18, 18, 8) **(c)** Rb^{+} (2, 8, 18, 8)
(d) Se^{2-} (2, 8, 18, 8)

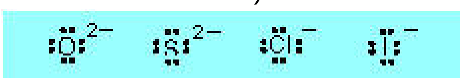
K3.



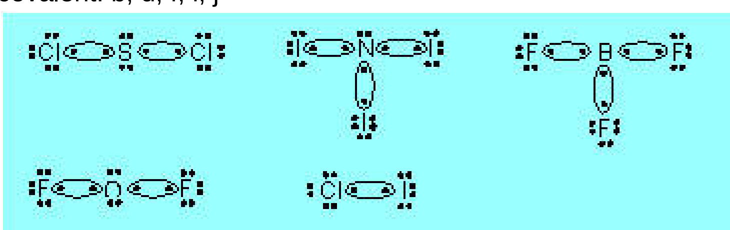
K4.

NaH, Na_3N

K5. Ionic: a, c, e, g, h
Mg^{2+}, Ba^{2+}, Na^{+}, Ca^{2+}, K^{+} (electron-dot diagrams show only valence electrons (outer shell electrons): positive ions are formed by the atoms giving away all the valence electrons, so their diagrams have no electrons on them.)



K6. covalent: b, d, f, i, j

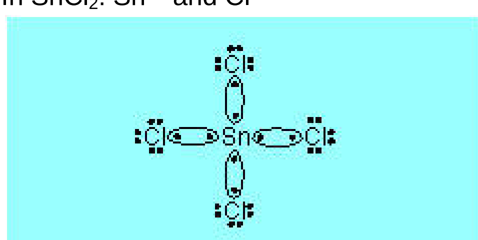


L1. Arsenic tribromide is a covalent molecular compound while magnesium bromide is ionic; ionic compounds consist of an infinite lattice of positive and negative ions: this is hard to break up so ionic compounds have high melting points. However once molten there are mobile ions present that are able to move under the influence of an electric voltage and so ionic compounds conduct electricity. Covalent molecular compounds consist of discrete small molecules with only weak intermolecular forces between them; hence they melt at low temperatures. These molecules are neutral so such substances do not conduct electricity.

L2. It is a covalent lattice

L3. **(a)** Ionic in $SnCl_2$ and covalent in $SnCl_4$; similar reasoning to that given in the answer to exercise L1.

(b) In $SnCl_2$: Sn^{2+} and Cl^{-}



L4. **(a)** **(i)** RbCl, Rb_2O
(ii) CsF, Cs_2S

(b) Lithium, potassium, rubidium and caesium

(c) MgF_2, $MgBr_2$, MgI_2, CaF_2, $CaBr_2$, CaI_2

(d) CCl_4 and CBr_4

(e) H_2S, PH_3

L5. **(a** L and Q; both are conductors as solids and both are malleable

(b) P and R; conduct electricity as liquids but not as solids, relatively high melting points, hard and/or brittle

(c) M; low melting point, does not conduct electricity either as a solid or as a liquid, soft

(d) N; very high melting point, does not conduct electricity, extremely hard

M1. A gas has been formed; chemical, because two new substances have been formed (the black solid and the invisible gas), and the change does not easily reverse. The original solid was a compound, because it decomposed into two other substances.

M2. **(a)** Mixtures: bauxite, sodium hydroxide solution, solution of sodium aluminate, red mud, dishwashing powder

Elements: aluminium, graphite (carbon)

Compounds: aluminium oxide, iron oxide, aluminium hydroxide, cryolite, carbon dioxide, sodium hydroxide (as a solid)

(b) Chemical: (i) reaction of hot concentrated sodium hydroxide with aluminium oxide, (ii) conversion of sodium aluminate to aluminium hydroxide, (iii) heating the aluminium hydroxide to form aluminium oxide, (iv) electrolysis of alumina to form aluminium, (v) reaction of oxygen with graphite to form carbon dioxide, (vi) attack of sodium hydroxide on aluminium (in dishwashers)

Physical: (i) grinding up the bauxite, (ii) filtering off the red mud, (iii) filtering off the aluminium hydroxide (iv) mixing alumina and cryolite to form a solution (homogeneous molten mixture)

M3. **(a)** $P_2O_5(s) + 3H_2O(l) \rightarrow 2H_3PO_4(l)$

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

M4. **(a)** Two atoms of solid arsenic react with five diatomic molecules of liquid bromine to form two molecules of solid arsenic pentabromide.

(b) One molecule of gaseous dichlorine heptoxide reacts with one molecule of liquid water to form two molecules of liquid perchloric acid, each molecule of which contains one hydrogen, one chlorine and four oxygen atoms.

N1. **(a)**sulfur trioxide
(b) magnesium hydride
(c) lithium sulfide
(d) diarsenic trioxide (arsenic trioxide is acceptable)
(e) carbon tetrafluoride
(f) aluminium oxide
(g) copper sulfide (copper(II) sulfide is also acceptable)
(h) nitrogen dioxide
(i) disulfur dichloride
(j) iron(III) chloride
(k) dichlorine heptoxide
(l) zinc hydroxide

N2. **(a)**
(i) K_2O
(ii) Cl_2O_3
(iii) SbF_5
(iv) $Al(OH)_3$
(v) Ag_2O
(vi) ICl_3
(vii) P_2S_3
(viii) Fe_2S_3
(ix) $SiBr_4$
(x) $FeCl_2$
(xi) MgH_2
(xii) SF_6

(b)
(i) $Mg(NO_3)_2$
(ii) Ag_2CO_3
(iii) $(NH_4)_2SO_4$
(iv) $Fe_2(SO_4)_3$
(v) $AlPO_4$
(vi) $PbCl_4$