REVIEW QUESTIONS

Chapter 2: Materials

1. Classify each of the following as either element, compound or mixture.
   (a) air (b) water (c) salty water
   (d) oxygen gas (e) brass (f) table salt

2. Mixtures can be homogeneous or heterogeneous. Give an example of each.

3. Mixtures can be separated by physical techniques such as decantation, filtration, crystallisation and distillation.

   Name the most suitable method to carry out the following separations.
   (a) sand and rock from a muddy slurry
   (b) alcohol from an alcohol/water solution
   (c) calcium carbonate (insoluble) from sodium chloride (soluble)
   (d) salt from sea water
   (e) water from sea water

4. Select from the following the most correct term for the descriptions that follow.

   evaporation, filtrate, element, solution, filtration, distillation, crystallisation, dissolution, mixture, decantation, solvent, residue

   (a) undissolved solid trapped by filter paper
   (b) the pouring off of a liquid, gently, from sediment
   (c) its constituents can be separated by simple physical techniques
   (d) a substance which cannot be split into simpler substances
   (e) clear solution remaining after filtration
   (f) the formation of crystals by cooling a saturated solution
   (g) technique for separating solids with very different solubilities
   (h) process by which a heated liquid changes to vapour
   (i) means by which alcohol is separated from wine
   (j) a homogeneous mixture

5. Using the values given in Figure 2.1 determine how many times larger the first mentioned particle is in each of the following pairs.
   (a) A buckyball compared to a hydrogen atom
   (b) A typical bacteria compared to the Adeno virus
   (c) A bee compared to a buckyball.

6. Nanoparticles are generally more reactive than the bulk materials of the same substance. Briefly explain the most likely reason for this.

7. The wavelength of visible light ranges from approximately 0.4 μm (violet light) to 0.7 μm (red light).
   (a) Convert these units to nanometres (nm).
   (b) Nanoparticles used in sunscreen lotions are typically, on average, 40 nm in size. Compare this size to that of the average wavelength of visible light, say 0.55 μm.
   (c) Explain why sunscreen lotions using nanoparticles are transparent.

8. The approximate diameters for three different particles are given below.

Sand grain particle	1 mm
Dust particle	1 μm
Carbon-60 buckyball	1 nm

(a) Assuming each of these particles to be spherical, calculate their surface area and volume and complete the table below.

For a sphere: Surface Area = $4\pi r^2$ Volume = $4/3\ \pi r^3$

PARTICLE	SURFACE AREA (m^2)	VOLUME (m^3)	SURFACE AREA / VOLUME RATIO
Sand grain			
Dust particle			
Carbon-60 buckyball			

(b) How does the surface area to volume ratio change as we consider smaller particles?

(c) Briefly explain why this is significant in terms of chemical properties.

9. Traditional sunscreens using bulk particles of zinc oxide appear white when applied to our skin. By comparison, sunscreen lotions using nanoparticles of zinc oxide are transparent when applied.

(a) What is the essential purpose of the sunscreens?
(b) Explain clearly why the sunscreens appear different
(c) The sunscreen containing nanoparticles is still effective even though transparent in appearance. Why is this?

10. Fabrics which are coated with a very thin polymer layer containing carbon nanotubes become stain resistant. Briefly answer the following.
(a) Describe the nature of the surface created by the polymer coating
(b) How does this help to make the fabric stain resistant?
(c) The look and feel of the fabric is not affected by the polymer coating. Why not?

11. There are a great variety of nanoparticles used in nanotechnology. Name the nanoparticle most associated with the following uses.
(a) Antibacterial bandages
(b) Carbon fibre tennis racquets
(c) Self-cleaning window spray
(d) Computer processor chip
(e) Auto sealants.

FOR THE EXPERTS

Some important substances used in the kitchen are as follows:

- **Table salt:** sodium chloride (NaCl). Used with food for seasoning and taste.
- **Sugar:** sucrose ($C_{12}H_{22}O_{11}$). Used as a sweetener in drinks and in the preparation of many foods particularly biscuits and cakes.
- **Baking soda:** sodium hydrogencarbonate powder ($NaHCO_3$). Also called carb-soda or sodium bicarbonate. An important ingredient of baking powder.
- **Baking powder:** a powder consisting of sodium hydrogencarbonate (baking soda), powdered acids such as tartaric acid and starch powder. Baking powder is a leavening agent. During baking it releases large amounts of carbon dioxide which are trapped in the flour and cause the mixture to rise.
- **Vinegar:** approximately 4% ethanoic (acetic) acid – (CH_3COOH), 96% water and very small amounts of natural colouring/flavours. Used mostly for seasoning foods.
- **Aluminium foil:** aluminium (Al). Used in cooking preparation and storage.

12. (a) Which substance/s listed above is/are:
    (i) pure substances
    (ii) mixtures
    (iii) elements
    (iv) compounds.

    (b) Some salt is accidentally dissolved in a bowl of water.
    (i) Is this a physical or chemical change?
    (ii) Suggest a method for recovering the salt.

    (c) If some baking soda is added to vinegar a fizzy reaction is observed. The word equation for the reaction is:

    sodium hydrogencarbonate + ethanoic acid → sodium ethanoate + carbon dioxide + water

    (i) Is this a physical or chemical change? Explain.
    (ii) Give a balanced equation for the reaction.

    (d) Baking powder can help to make cakes rise due to the reaction of two of its ingredients, baking soda and tartaric acid.
    (i) What is produced by the reaction of these two ingredients to make cakes rise?
    (ii) Is this a chemical or physical reaction?
    (iii) (Difficult) What prevents baking powder from reacting while stored for long periods in the pantry?

(Clue – the powdered starch helps to prevent this but is itself not the reason.)

be recovered by filtration and the sugar by recrystallisation of the filtrate.

2.8

(i) *salt from water: salt will crystallise from solution.*
(ii) *water from salt: water evaporates, salt does not.*
(iii) *sand from water: sand is insoluble.*
(iv) *charcoal from salt: salt is soluble, charcoal is not.*
(v) *KNO_3 from NaCl: Differences in solubility, NaCl crystallises first.*
(vi) *blue dye from ink: selective adsorption of different components of ink.*
(vii) *alcohol from wine: different boiling points allow fractional distillation.*
(viii) *salt from sugar: differences in solubility.*

2.9

(a) *(i) 10^9 (ii) 10^6 (ii) 1000*
(b) *(i) 0 .22 m / 1.1 × 10^{-9} m = 2.0 × 10^8 times larger*
(ii) Volume of a sphere is proportional to its radius cubed.
Hence volume ratio = $(0.11)^3$ / 0.55 × $10^{-9})^3$ = $(2.0 \times 10^8)^3$ = 8.0 × 10^{24}
Hence volume of the soccer ball is 8.0 × 10^{24} times larger than that of a buckyball.

2.10

(a) *2 cm = 20 mm hence*
N° of cubes with 1 mm sides = 20 × 20 × 20 = 8000

(b) *Total surface area = (8000) × (6) × (0.1 cm × 0.1 cm)*
= 480 cm^2

(c) *Change in surface area = 480/24 = 20*
The surface area is 20 times greater.

(d) *For nanocubes of 1.0 nm sides; 2 cm = 2.0 × 10^7 nm*
N° of cubes = (2 × 10^7) × (2 × 10^7) × (2 × 10^7)
= 8 × 10^{21}
S.A. = (8 × 10^{21}) × (6) × (1.0 × 10^{-7}cm × 1.0 × 10^{-7}cm)
= 48 × 10^7 cm^2
Change in S.A. = 48 × 10^7/24 = 2 × 10^7 times

2.11

ZnO nanoparticles are good absorbers of harmful UV rays present in sunlight. They are also smaller than the wavelength of visible light. Hence light is able to pass between the particles creating a transparent effect.

2.12

(a) *The carbon nanotubes create a surface with nano-size bumps and low surface energy.*
(b) *The higher surface energy of water prevents it from wetting the fabrics surface. Instead the water will bead into droplets, roll over the nano-sized bumps of the fabric, and carry any dirt along with it.*
(c) *Water and dirt also roll off the leaves of lotus plants. The nano-sized bumps on its surface prevent water from soaking it. This was the inspiration for the development of stain resistant and waterproof fabrics.*

2.13

If water droplets form and then dry on glass, they leave water marks due to small amounts of dirt or impurities in them. The effect of the TiO_2 layer is to prevent droplets forming and so water runs off carrying any dirt along with it. The photo-catalytic properties of the TiO_2 layer also help to break down any organic material on the glass.

2.14

Nanoparticles used in nanocomposite materials have very high surface area to volume ratios. This markedly increases the interaction and bonding which occurs between the atoms and particles in the material. The added nanoparticles may also have a high aspect ratio, that is, they are thin and long. This further helps to bond and tie a great number of particles together.

Review Questions

1. (a) *mixture* (d) *element*
(b) *compound* (e) *mixture*
(c) *mixture* (f) *compound.*

2. ***homogeneous mixture*** *e.g. salt solution, coffee drink, cordial.*
heterogeneous mixture *e.g. concrete mix, sand and salt mixture, fruit cake mix.*

3. (a) *decantation and filtration*
(b) *fractional distillation*
(c) *dissolution and filtration*
(d) *evaporation/crystallisation*
(e) *evaporation/distillation.*

4. (a) *residue* (f) *crystallisation*
(b) *decantation* (g) *filtration/crystallisation*
(c) *mixture* (h) *evaporation*
(d) *element* (i) *distillation*
(e) *filtrate* (j) *solution.*

5.

(a) *1.1 nm / 0.1 nm = 11*
A buckyball is 11 times larger than a hydrogen atom.
(b) *5 μm / 80 nm = 62.5 ≈ 60*
A typical bacteria is about 60 times larger than the Adeno virus.

(c) *1 cm / 1.1 nm = $0.9 \times 10^7 \approx 10^7$*
A bee is about 10,000,000 times larger than a buckyball.

6. *When the particles of a substance become smaller their surface area to volume ratio increases. Hence, for nanoparticles this means that a significant percentage of their atoms are at or near the surface where they can more readily interact.*

7.
(a) *0.4 μm = 400 nm, 0.7 μm = 700 nm*
(b) *0.55 μm / 40 nm = 550 nm / 40 nm = 13.8*
Hence visible light waves are about 14 times larger than the 40 nm nanoparticles.
(c) *The 40 nm particles are too small to reflect visible light and are not visible. The light is either scattered, absorbed, or passes between the particles.*

8.
(a) *For the sand grain particle*
$SA = 4\pi r^2 = 4\pi(0.5 \times 10^{-3})^2 = 3.14 \times 10^{-6}\ m^2$
Volume $= 4/3\ \pi r^3 = 4/3\ \pi(0.5 \times 10^{-3})^3$
$= 0.52 \times 10^{-9}\ m^3$
Similarly for the others as given below:

PARTICLE	SURFACE AREA (m^2)	VOLUME (m^3)	SURFACE AREA / VOLUME RATIO
Sand grain	$3.14 \times 10^{-6}\ m^2$	$0.52 \times 10^{-9}\ m^3$	6.0×10^3
Dust particle	$3.14 \times 10^{-12}\ m^2$	$0.52 \times 10^{-18}\ m^3$	6.0×10^6
Carbon-60 buckyball	$3.14 \times 10^{-18}\ m^2$	$0.52 \times 10^{-27} m^3$	6.0×10^9

(b) *The surface area to volume ratio is much greater for smaller particles?*
(c) *The greater surface area allows more contact and interaction between the atoms of adjoining surfaces.*
This leads to unique chemical properties and often greater reactivity.

9.
(a) *Sunscreens absorb harmful ultraviolet radiation present in sunlight.*
(b) *Bulk particles of zinc oxide are good reflectors of visible light and so appear white. Nanoparticles are much smaller than the wavelength of light and do not readily reflect it. Hence they are not visible.*
(c) *The nanoparticles of zinc oxide are still effective as they retain their excellent UV-light absorbing capacity. They also scatter or absorb visible light and so create a transparent appearance.*

10.
(a) *The carbon nanotubes attach themselves to the fabric fibres and create a surface with nano-sized bumps and low surface energy.*
(b) *This surface prevents water from penetrating or adhering to it.*
(c) *The water forms droplets and rolls off carrying any dirt away with it.*

11.
(a) *Silver* (b) *Carbon nanotubes*
(c) *Titanium dioxide* (d) *Silicon*
(e) *Silicon dioxide*

For the Experts

12.
(a) (i) *pure substance – table salt, sugar, baking soda*
(ii) *mixture – baking powder, vinegar*
(iii) *elements – aluminium foil*
(iv) *compounds – table salt, sugar, baking soda*
(b) (i) *physical change*
(ii) *allow water to evaporate, salt will crystallise.*
(c) (i) *chemical change because new substances are formed*
(ii) $NaHCO_{3(aq)} + CH_3COOH_{(aq)} \rightarrow NaCH_3COO_{(aq)} + CO_{2(g)} + H_2O_{(l)}$
(d) (i) *Carbon dioxide gas.*
(ii) *Chemical reaction.*
(iii) *The baking soda and tartaric acid are both in powder form and cannot react unless moisture is present. The starch helps to keep the baking powder dry by absorbing any moisture absorbed from the air.*

CHP 3: BONDING

Chapter Questions

3.1

ELEMENT	ELECTRON DOT DIAGRAM	TO FORM IONS THIS ATOM TENDS TO	ION FORMED	ION HAS SAME ELECTRON CONFIGURATION AS
sodium	Na •	lose 1 e–	Na^+	Ne
magnesium	• Mg •	lose 2 e–	Mg^{2+}	Ne
nitrogen	•• • N • •	gain 3 e–	N^{3-}	Ne
sulfur	•• •• S • •	gain 2 e–	S^{2-}	Ar
bromine	•• •• Br • ••	gain 1 e–	Br^-	Kr
calcium	• Ca •	lose 2 e–	Ca^{2+}	Ar
potassium	K •	lose 1 e–	K^+	Ar
lithium	Li •	lose 1 e–	Li^+	He