Student book answers

3.1 Scientists refine models and theories over time

Pages 66–69

Extend your understanding 3.1

1 Who proposed the modern idea of an element and when?

Robert Boyle in 1661

2 What was a triad? Why were triads important?

A triad is a group of three elements that have similar properties. This arrangement, by Johann Dobereiner, was the first time the elements were grouped in this way.

3 Who was the first chemist to lead a team that produced elements that did not occur naturally?

Glen Seaborg

4 When Mendeleev proposed the periodic table, he went one step further. What else did he do and why is this significant?

When Mendeleev proposed the structure of the periodic table, he left gaps in the table for elements that were yet to be discovered. When elements were later discovered that had the properties he predicted for these gaps, many scientists were convinced of the validity of his model.

5 Originally, geometric symbols were used to represent each element. What would be some of the problems associated with using geometric symbols for the elements today?

There are currently 118 known elements. It would be difficult to develop geometric symbols for all of these.

6 Why were the gases that Ramsay discovered not able to be discovered any earlier?

Gases are hard to locate and separate because they will always fill the space available to them. Gases could not be separated until new technology became available that could cool gases to a liquid, and then allow them to heat up again slowly so that one gas could be evaporated at a time.

7 Moseley changed the periodic law proposed by Mendeleev by changing one word. What word was changed, and how did this improve the periodic table?

Moseley changed the word ‘weight’ in Mendeleev’s periodic law to ‘number’. This meant the periodic table can be arranged into periods according to the number of electrons in the outer shells rather than the relative mass of the atomic nucleus. This allows scientists to relate the structure of the atom to its properties.

Student book answers

3.2 The structure of an atom determines its properties

Pages 70–73

Check your learning 3.2

Remember and understand

1 What is the valence shell of an atom?

The valence shell is the outermost electron shell. It determines an atom’s reactivity.

2 What determines the atomic number of an atom?

The number of protons

3 For the Bohr model of the atom, what is the maximum number of electrons that the fourth electron shell can contain?

32

Apply and analyse

4 A potassium atom contains 19 protons.

a How many electrons will be present in a potassium atom? Justify your answer.

Nineteen electrons, as the atomic number is 19. This is also the number of protons, thus an atom has an equal number of positive protons and negative electrons so that they are neutral in charge

b What is the electronic configuration of a potassium atom according to the Bohr model?

2,8,8,1

c From the electronic configuration of potassium, it is clear that electrons do not normally occupy the fifth shell. What could be done to potassium atoms for electrons to jump into this shell?

It may be heated in a flame to allow the 1 outer shell electron (in the 4th shell) to gain enough energy to jump into the 5th shell. This level of energy cannot be sustained, however, and energy is emitted in the form of light when the electron returns to the 4th shell.

5 Copy and complete the following table.

|  |  |  |
| --- | --- | --- |
| ELEMENT | ATOMIC NUMBER | ELECTRON CONFIGURATION |
| Beryllium | 4 | 2,2 |
| Fluorine | 9 | 2,7 |
| Magnesium | 12 | 2,8,2 |
| Neon | 10 | 2,8 |
| Aluminium | 13 | 2,8,3 |
| Sodium | 11 | 2,8,1 |
| Chlorine | 17 | 2,8,7 |
| Sulfur | 16 | 2,8,6 |

Student book answers

3.3 Groups in the periodic table have properties in common

Pages 74–75

Check your learning 3.3

Remember and understand

1 What is the difference between a period and a group in the periodic table?

A period moves across the table. A group is the column that moves down the table.

2 Examine the periodic table in Figure 3.9.

a Identify the period and group for each of the following elements: fluorine, bromine, tin, radium, potassium, platinum, arsenic.

Fluorine: period 2, group 17

Bromine: period 4, group 17

Tin: period 5, group 14

Radium: period 7, group 2

Potassium: period 4, group 1

Platinum: period 6, group 10

Arsenic: period 4, group 15

b Are any of the elements in part a in the same group? What would this tell you about them?

Fluorine and bromine are in group 17 of the periodic table. This means they are non-metals and have 7 electrons in their outer shell. Because they prefer to have 8 electrons in their outer shell, they react with any element that may be able to provide the extra electron. This makes them the most reactive of the non-metals.

c Are any of the elements listed in part a in the same period?

Bromine, potassium and arsenic are in period 4. This means they have electrons filling the fourth shell of their atom.

3 What proportion of the periodic table is composed of metals?

Between 75% and 80% of elements in the periodic table are metals.

4 What properties are shared by all metallic elements?

All metals are lustrous (shiny), conductors of heat and electricity, malleable and ductile.

5 Which metal will react most strongly with cold water: copper, iron, magnesium, sodium or zinc? Explain your answer.

Magnesium

6 Why is copper found as a native element on Earth, but calcium metal is never found as a native element?

Calcium metal reacts very easily with the oxygen and water in the air, whereas copper metal is less reactive. Therefore copper can be found as a native element whereas calcium is never found as a native element.

Apply and analyse

7 Name two properties shown by some transition metals that are not shown by group 1 or group 2 metals.

Some are magnetic, some are colourful and one (Mercury) is a liquid.

Evaluate and create

8 Design a way to represent the different groups of metals clearly and informatively, identifying the distinguishing properties of each group.

Students’ answers will vary. They may present this as, for example, a poster, a Venn diagram or an illustration.

Student book answers

3.4 Non-metals have properties in common

Pages 76–77

Check your learning 3.4

Remember and understand

1 Why are non-metals named according to what they are ‘not’ rather than what they have in common?

Non-metals have a wide variety of properties, meaning that they do not have many properties in common. As a result, it is easier to list the common properties they do not have (malleable, lustrous, ductile and so on).

2 The two main groupings of non-metals are in groups 17 and 18.

a What does the group number tell you about the elements it contains?

The group number suggests the number of electrons present in the outer shell of the element, which, in turn, suggests the properties of the element.

b What properties do members of each of these groups share?

Group 17 elements (the halogens) have 7 electrons in their outer shell and react with metals to produce ‘salts’. They are very effective at cleaning and sterilising because of their lethal effects on bacteria and fungi.

Group 18 elements (the noble gases) have very low melting and boiling points and, as a result, are gases at room temperature. They are largely inert.

3 What is a semiconductor?

Semiconductors only conduct electricity in a certain way under certain conditions.

4 What is the dominant state of matter within the groups of non-metals?

Most non-metals are gases at room temperature.

Evaluate and create

5 Why could the term ‘metal-like’ be used to describe metalloid elements? Suggest a better name for this group of elements. Explain your answer.

They are ‘metal-like’ as they exhibit some properties of metals but not all of them. They should be called non-metalloids as most of their properties are not metallic.

Student book answers

3.5 Metal cations and non-metal anions combine to form ionic compounds

Pages 78–79

Check your learning 3.5

Remember and understand

1 Carefully examine the periodic table.

a Which elements are likely to form positively charged ions?

Metals

b Which elements are likely to form negatively charged ions?

Non-metals

c What does this tell you about which elements will combine to form ionic compounds?

A metal and a non-metal will form an ionic bond.

2 What kinds of particles are present in ionic compounds?

Charged particles, which are called ions

Apply and analyse

3 How does the group in which an element is found in the periodic table quickly identify one or more of its properties?

The group number is the number of valence or outer shell electrons. This is an indication of the type of ion that the element forms and therefore some of its properties.

4 What is the maximum number of electrons that can be gained or lost by an atom? Why?

The maximum number of electrons gained or lost by an element is three. If an element has four electrons in its outer shell, it may equally gain or lose electrons to complete its shell to make it stable.

5 Use your knowledge of atomic structure and valence electrons to explain why many ionic compounds are made up of a metal and a non-metal.

Metals have few electrons in their outer valence shell. They are more likely to lose this electron and form a positive ion. Non-metals have electron shells that are almost full. They are more likely to gain an extra electron and therefore form a negative ion. Positive ions and negative ions attract each other to form ionic compounds.

Student book answers

3.6 Non-metals combine to form covalent compounds

Pages 80–81

Check your learning 3.6

Remember and understand

1 What is a diatomic molecule?

A molecule that consists of two atoms

2 What types of atoms form covalent bonds?

Non-metallic atoms

Apply and analyse

3 Explain why molecular substances cannot conduct electricity.

Molecular substances are uncharged and do not have delocalised electrons. This makes it difficult for them to conduct electricity.

4 In terms of the structure of the substance, why is it easier to turn liquid water into a gas than to break the bonds between the hydrogen and oxygen atoms?

The force between the atoms that hold the atoms in the molecule together (within the molecule) are stronger that the attraction of one molecule to another (between molecules).

5 a When chlorine atoms combine to form molecules, how many electrons need to be shared between the two chlorine atoms?

Chlorine has seven electrons in its outer shell. This means that it needs a share of another electron to make it stable. If there are two chlorine atoms present, they will share a single electron with each other, providing each atom with a share of eight electrons.

b Would this be the same for two oxygen atoms combining to form a molecule? Explain your reasoning.

Oxygen has six electrons in its outer shell. This means it needs a share of two electrons to be stable. Because other oxygen atoms are identical, two oxygen atoms can share two electrons between them, providing each with a share of eight electrons.

Student book answers

3.7 Metals form unique bonds

Pages 82–83

Check your learning 3.7

Remember and understand

1 Describe the structure of a metal.

Metals are cations, arranged into structured layers, in a sea of delocalised (outer-shell) electrons.

2 Identify the arrangement of atoms in a metal that enables each of the following properties.

a Malleability

Metal atoms arrange themselves into layers. When the metal is bent or hammered into shape, the atoms slide over one another.

b Conductivity

The outer-shell electrons are free to move from nucleus to nucleus along the metal.

c Shiny appearance

The delocalised electrons on the surface of the metal reflect light.

Apply and analyse

4 Compare the properties of an alloy with those of pure metal.

Alloys are stronger as the metal atoms are different sizes and can therefore fit more tightly together. This also means that they are not arranged in layers and so are not as malleable – they are harder.

5 Memory alloys have been used to repair broken bones. Suggest why a memory alloy would be beneficial in this situation.

The atoms in the memory alloy would arrange themselves into a pattern that would mould to the shape of the bone. If it is every bent, it will return to its bone shape. This could act as a cast.

Student book answers

3.8 Nanotechnology involves the specific arrangement of atoms

Pages 84–85

Extend your understanding 3.8

1 How many nanometres in a millimetre?

1 000 000 = 1 million nanometres in 1 millimetre

2 How many average-sized atoms would fit in a single nanometre?

1 000 000 ÷ 0.3 = 3 333 333.33 atoms in 1 mm **OR** 1 ÷ 0.0000003 = 3 333 333.33 atoms in 1 mm

3 What is a nanobot?

A nanobot is a very small structure that can be used to boost the immune system, repair parts of the body or clean up the environment.

4 What is a carbon nanotube? Describe its structure.

A carbon nanotube is an arrangement of carbon atoms into a hollow, long tube.

5 What two main manufacturing processes are used to make nanomaterials?

1 The top-down method involves using mass materials and breaking them down by physical or other means into nanoscale components.

2 The bottom-up method relies on the construction of templates on which nanomolecules will form under the appropriate chemical and physical conditions.

6 All powders are made up of small particles. How is a nanopowder different from a normal powder?

Nanopowders are ground down from powders to make the particles smaller. Powders appear as a white, opaque mass (as the particles are larger) as opposed to invisible, nano-sized particles.

Student book answers

Review 3

Pages 86–87

Remember and understand

1 What is the atomic number of the element known as ununpentium?

115

2 What is the overall order of elements in the periodic table based on?

The order of the elements is based on the atomic number of the atom. The atomic number is based on the number of protons in the atom

3 What is the difference between an atom and an element?

An atom is the basic building block of all matter. An element is only one type of atom.

4 What is the name given to the following features of the periodic table?

a Horizontal row

Period

b Vertical column

Group

c The set of 10 groups from group 3 to group 12

Transition metals

5State the group number of the:

a alkaline earth elements

Group 2

b halogens

Group 17

c noble gases

Group 18

d alkali metals.

Group 1

6 What is a valence shell?

The outermost electron shell

7 State the features that elements in the same group have in common.

They have the same number of outer-shell or valence electrons, the types of compounds formed, similar trends for melting points and boiling points, similar properties and so on.

8 Suggest why transition metals are much more widely used than the alkali metals.

Transition metals react less violently than the alkali metals. This means they are easier to use and less explosive.

9An inert substance is one that will not react with any other substance. Originally, group 18 elements were known as the ‘inert gases’. Suggest why the name was changed to ‘noble gases’.

An inert gas is any gas that is unreactive. This can be a compound (like carbon dioxide) or an element (like neon). Thus, the name ‘inert gas’ was changed to ‘noble gas’ to reflect the elemental nature of the group.

10 What special feature of metals allows them to conduct electricity in the solid state?

Their structure contains free moving delocalised (outer-shell) electrons.

11 What number of electrons in the valence shell makes an atom particularly stable?

8

12 When naming an ionic compound, which ion is written first?

The metal cation (positive ion)

13 Give explanations for the following.

a Argon will not react with any other element.

It has a full valence shell of 8 electrons and so is stable.

b The reaction between sodium and chlorine gives out a lot of heat and light.

Both sodium and chlorine are very reactive; therefore, it is expected that this reaction will be an exothermic reaction, producing heat and light. (There are several YouTube clips of this reaction.)

c When you accidentally spill sodium chloride onto a stove while cooking, it does not melt.

The melting point of sodium chloride is around 800°C due to the strength of the electrostatic interaction between the sodium ion and the chloride ion.

Apply and analyse

14 Only two elements are liquids at room temperature – bromine and mercury. Bromine is a non-metal and mercury is a metal. Describe how these two liquids are likely to appear and behave differently from each other.

Bromine is a reddish liquid, whereas mercury is a lustrous, silvery liquid. Mercury is very dense (almost anything will float on it) and, when cooled, it becomes a tough malleable metal. Bromine has a much lower boiling point (59°C) and is usually found as part of a compound because it is one of the halogens.

15 Consider the following pairs of elements:

i chlorine and oxygen

ii nitrogen and lithium

iii fluorine and argon

iv aluminium and potassium.

aWhich pair(s) will react to form an ionic compound?

Nitrogen and lithium will form an ionic compound. Lithium is a metal and will form a positive cation, while lithium is a non-metal and will form a negative anion. The positive and negative ions interact, forming an ionic bond.

bWhich pair(s) will react to form a molecular compound?

Chlorine and oxygen will form a molecular compound. Both are non-metals and will fill their valence shell by sharing electrons with each other.

c Which pair(s) will not react to form a compound?

Fluorine and argon will form a compound. Argon is a noble gas and, despite the high reactivity of fluorine, will not react with another element.

In each case, justify your answer.

Evaluate and create

16 Scientists such as Berzelius and Mendeleev worked on their own to produce new ideas. Others, like Seaborg, worked in a team. Now most scientists work in teams. What are the advantages of working in a team?

Working in teams allows scientists to develop their ideas through discussion. Different scientists have strengths in different areas. The development of the periodic table was a result of chemists purifying the elements and testing their properties and physicists developing the structure of the atom.

17 Scientists have had to deduce what it is like inside an atom from indirect evidence, similar to how astronomers determine the temperature and composition of stars. List three advantages and three disadvantages of using indirect evidence to develop scientific theories.

Advantages:

• easier to test when the actual model is too large/small/far away

• gives results that can be used to support/disprove a theory

• can provide explanations for gaps in knowledge.

Disadvantages:

• can give misleading results if a theory has not been developed fully

• unable to directly see what has happened

• scientists have to imagine why the results were obtained.

18 What two elements would you expect to react together in the most violent way? Justify your answer.

The most reactive metal is francium and the most reactive non-metal is chlorine. These two elements should react violently when mixed together.

19Before the 1980s, the groups of the periodic table were numbered with Roman numerals. Some scientists prefer this version because the atoms of the elements in group III (now 13) have three electrons in their valence shell, those in group IV (now 14) have four electrons in their valence shell and so on. Examine how the groups of transition metals were numbered in the old way. Which numbering system do you think is the most helpful? How can you deduce the number of electrons in the valence shell from the new group number?

Prior to 1980, the transition metals were either not given a number or were given a Roman numeral that reflected their order across the table (III, IV, V, VI, VII, VIII and so on), with the letter B added to signify it was a transition metal. This was changed to prevent the duplication of numbers. The numbers of the groups can still be used to reflect the number of electrons in the outer shells of electrons. For example, group 13 elements have three electrons in their outer shell (13 − 10 = 3).

20 A certain particle was found to contain 16 protons and 18 electrons.

a What element must it be? State your reasoning.

The element is sulfur. The number of protons determines the identity of an element. The number of electrons can change to form ions of the same element.

b Is the particle neutral, positively charged or negatively charged?

It is negatively charged as it has 2 extra electrons and therefore 2 extra negatives.

c What is the formula of the particle? Justify your answer.

Its charge is 2-, S2-.

21 When the uncharged atoms of potassium lose an electron, they then have an electronic configuration of 2,8,8. This is the same as the electronic configuration of argon. Does this mean that the potassium atoms have become argon atoms? Discuss.

No, while they have the same number of electrons, they have a different number of protons and therefore a different atomic number.

Ethical understanding

22 Meyer and Mendeleev each published a periodic table within months of each other. However, Mendeleev is given sole credit for developing the periodic table.

a Is it fair that the person who first discovers, develops or publishes something receives the credit for this discovery?

Students’ opinions may vary.

b What did Mendeleev do to get sole credit for developing the periodic table?

Mendeleev left gaps in his version of the periodic table that predicted the properties of elements that were yet to be discovered. This meant his version of the periodic table was further developed than Meyer’s.

Critical and creative thinking

23A substance will conduct electricity if it contains charged particles that are free to move across the sample. The charged particles can be electrons or ions. Suggest why ionic compounds cannot conduct electricity when in the solid state, but can conduct electricity when melted.

In a solid state, the ions are in a set structure where they cannot move. When melted, the charged ions can move and are therefore able to conduct electricity.

24 A student claimed that sodium chloride is made of molecules. Is the student correct? Discuss.

No, the sodium chloride is a lattice of positive and negativeions attracted to one another.

Research

25 Choose one of the following topics fora research project. Some questions have been included to help you begin your research. Present your report in a format of your own choosing.

The noble gases

The story behind the discovery of the noble gases is a fascinating one. The challenge was this: how do you detect the existence of something that only exists as a gas that does not react with anything and, except for argon, is only present in the air in extremely small concentrations? How was the first noble gas found? What role did the periodic table of that time play in helping chemists hunt for other noble gases?

Hydrogen

Hydrogen is a most unusual non-metal because it can form H+ ions and H– ions depending on what it reacts with. Although alkali metals do not react with one another, hydrogen will react with alkali metals and form compounds, such as lithium hydride (LiH). Show why the hydride ion (H–) is stable. What are the properties of metal hydrides such as lithium hydride? What uses are made of these compounds?

Nanotechnology

Nanomaterials are now being used to assist in a range of chemical reactions, often to increase the rate of very specific reactions that produce valuable products. Research the products that are produced by using nanoparticles and how the use of these has improved the production method.

Students’ answers will vary.