The Periodic Table

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How Are Elements Arranged in the Periodic Table?

- The **periodic table** is a list of elements arranged in order of *increasing proton (atomic) numbers.*
- A **group** is a vertical column of elements. The groups run from top to bottom. The periodic table consists of 18 groups of elements, numbered 1 to 18.
- A **period** is a horizontal row of elements. The periods run from left to right. The periodic table consists of seven periods of elements, numbered 1 to 7.

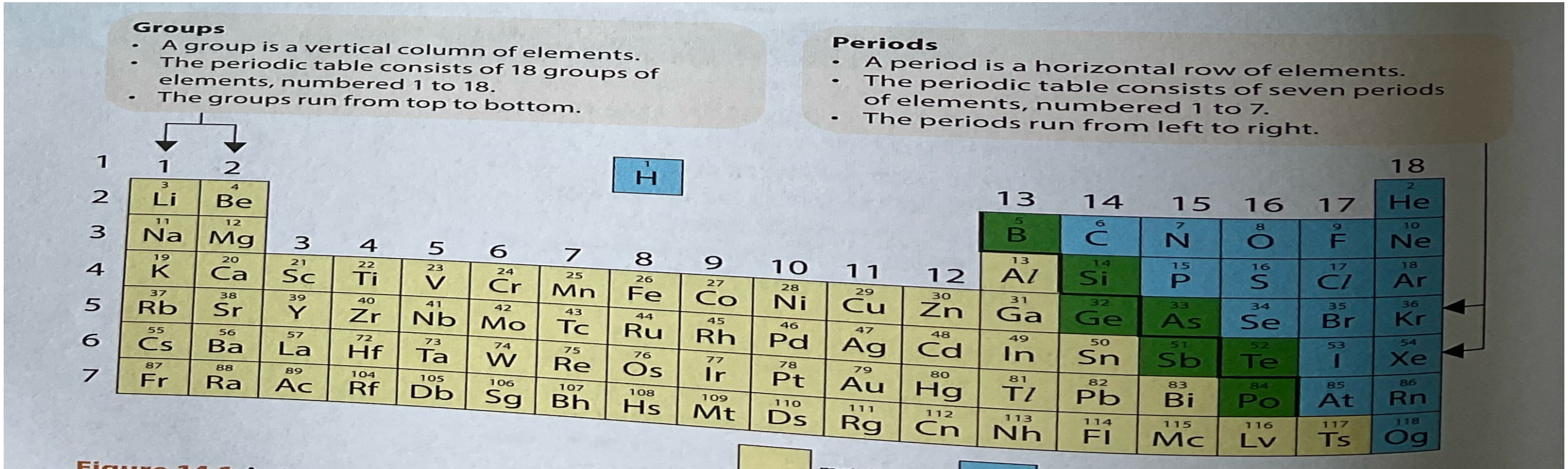

Figure 14.1 A simplified periodic table showing groups and periods

Proton Number and Electronic Configuration

- An element had a proton number of 7 is in period 2 and group 15 (i.e. nitrogen).
- Element X is located in Period 3, Group 2 of the periodic table. The electronic configuration of element X is therefore

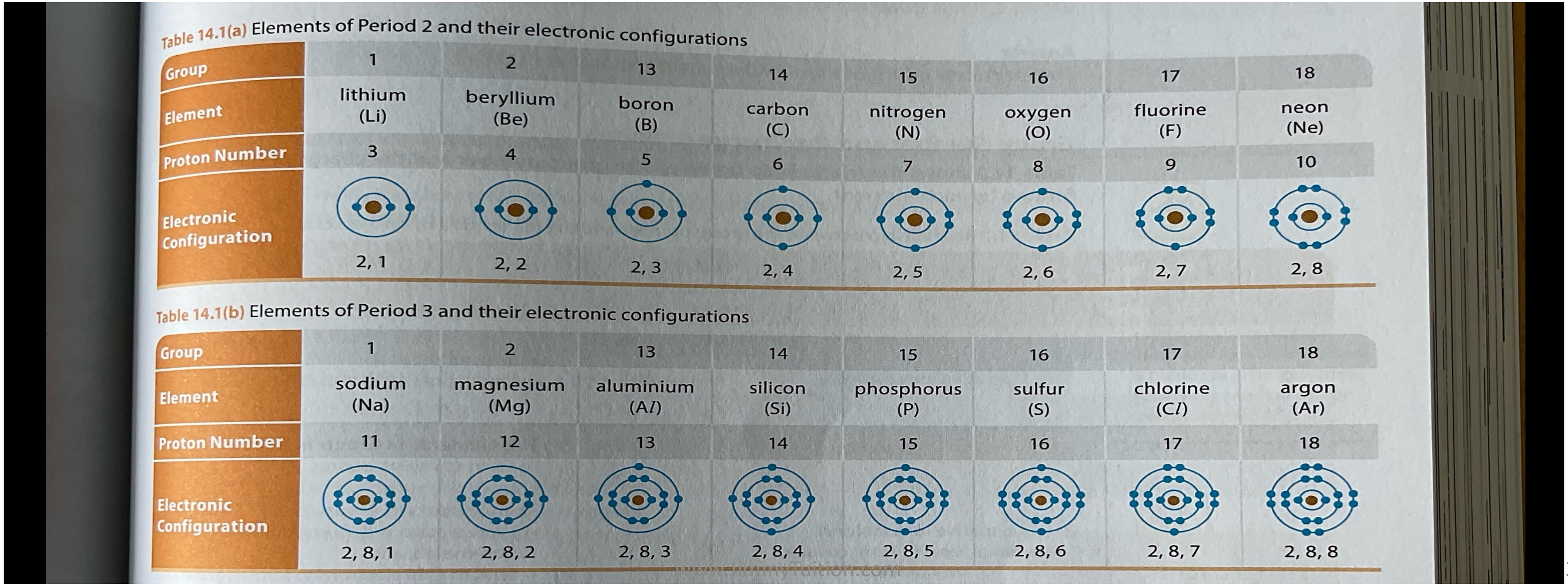

Table 14.1(a) Elements of Period 2 and their electronic configurations

Group	1	2	13	14	15	16	17	18
Element	lithium (Li)	beryllium (Be)	boron (B)	carbon (C)	nitrogen (N)	oxygen (O)	fluorine (F)	neon (Ne)
Proton Number	3	4	5	6	7	8	9	10
Electronic Configuration	2, 1	2, 2	2, 3	2, 4	2, 5	2, 6	2, 7	2, 8

Table 14.1(b) Elements of Period 3 and their electronic configurations

Group	1	2	13	14	15	16	17	18
Element	sodium (Na)	magnesium (Mg)	aluminium (Al)	silicon (Si)	phosphorus (P)	sulfur (S)	chlorine (Cl)	argon (Ar)
Proton Number	11	12	13	14	15	16	17	18
Electronic Configuration	2, 8, 1	2, 8, 2	2, 8, 3	2, 8, 4	2, 8, 5	2, 8, 6	2, 8, 7	2, 8, 8

How is the Electronic Configuration Across a period and Down a group?

- The number of electrons shells an element has is the same as its period number.
- Elements in the same group have the same number of valence electrons.
- Elements in Group 1 and 2 have the same number of valence electrons as the group number.
- For elements in group 13 to 18 (except helium), the number of valence electrons is the group number minus 10 (e.g. chlorine has 17-10 = 7 valence electrons).
- The elements in the same group have similar chemical properties as elements with the same number of valence electrons have similar chemical properties.

Group Number and the Charge of an Ion

- The elements in Group1, 2 and 13 are metals and tend to lose electrons to form positive ions. The charge on ion are +1, +2 and +3 respectively (Na^+, K^+, Mg^{2+}, Ca^{2+}, Al^{3+})
- The elements in Group 15, 16 and 17 share electrons to form covalent bonds with non-metals and tend to gain electrons to form negative ions when boned to a metal. The charge on ion are -3, -2 and -1 respectively (N^{3-}, O^{2-}, S^{2-}, F^-, Cl^-)
- The elements in Group 18 have full valence shells of electrons and do not form compounds. And the elements in Group 18 do not form ions.
- The elements in Group 14 share electrons to form covalent bonds.

Metallic and Non-metallic Properties

- The elements in the periodic table can be classified based on their metallic and non-metallic properties.

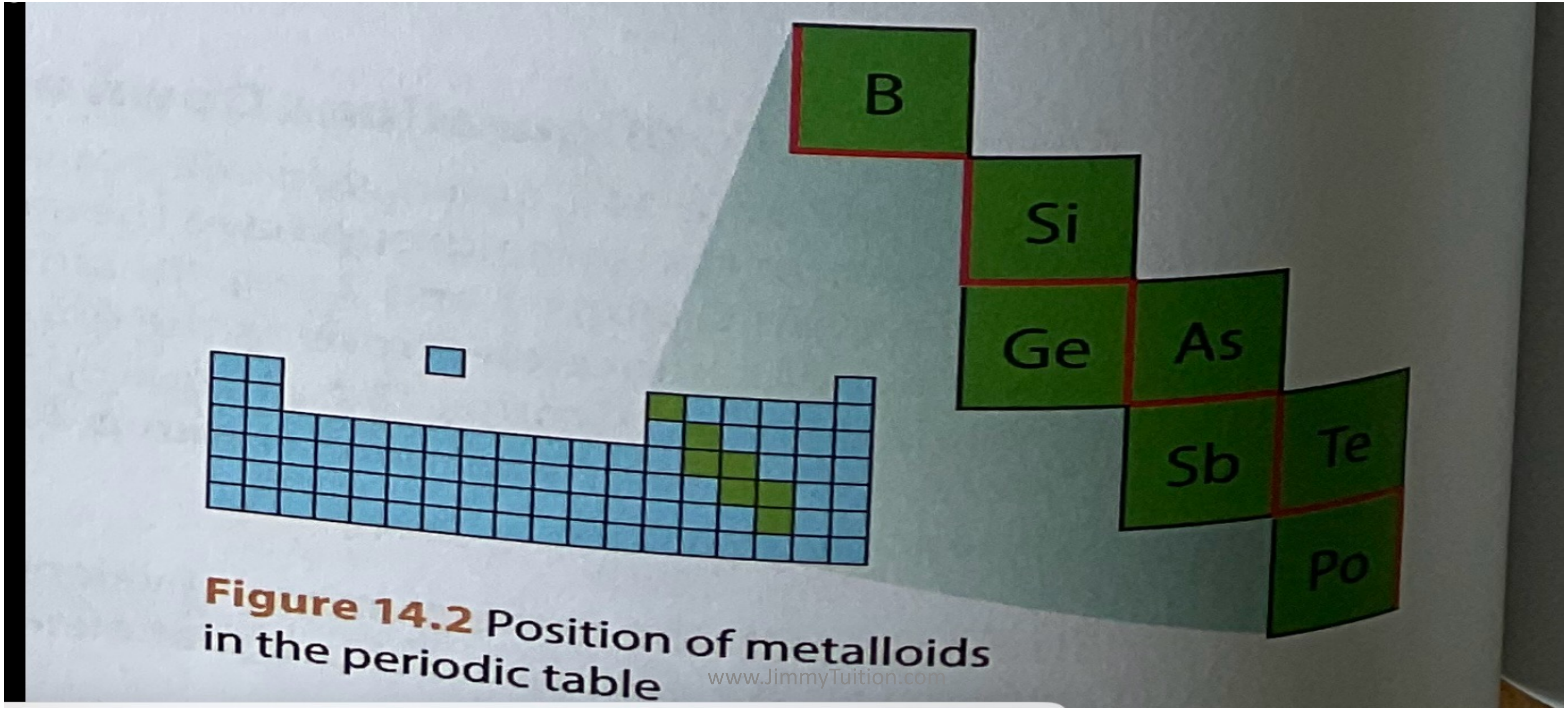

Figure 14.2 Position of metalloids in the periodic table

Metallic Properties of Elements Across a Period

- There is a decrease in metallic properties and an increase in non-metallic properties across a period.
- An atom displays more metallic properties then it is more likely to lose electrons than to gain electrons. As we move across a period, the atom becomes less likely to lose electrons. This is because it requires more energy to lose electrons (there are more protons in the nucleus)

Table 14.3 Properties of elements across Period 3

Group	1	2	13	14	15	16	17	18
Symbol	Na	Mg	Al	Si	P	S	Cl	Ar
Name	sodium	magnesium	aluminium	silicon	phosphorus	sulfur	chlorine	argon
Properties	← metallic →			metalloid	← non-metallic →			
Nature of Oxides	basic		amphoteric	acidic				

There is a *decrease in metallic properties* and an *increase in non-metallic properties* across a period.

Metallic Properties of Elements Down a Group

- Going down a group, there is an ***increase in metallic properties*** and a ***decrease in non-metallic properties.***
- This is because the size of the atom increases going down a group. Hence the outmost electrons of the element will be further away from the attractive force of nucleus. An element further down a group will thus lose its outmost electrons more easily.

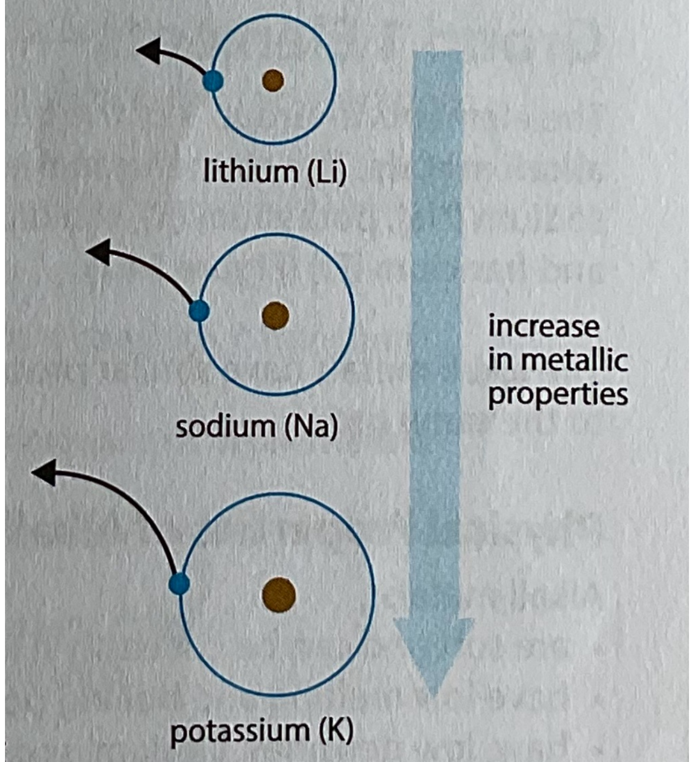

Figure 14.4 Metallic properties increase down Group 1 elements.

Practice #1

Let's Practise 14.1

1 Using only the elements shown in the simplified periodic table in Figure 14.5, answer the following questions.

(a) Deduce the electronic configuration of chlorine. Explain your answer.

(b) Give the symbol(s) of:

(i) **two** elements in the same group;

(ii) **two** elements in the same period;

(iii) **two** elements that combine together to form an acid;

(iv) the element whose atoms contain the greatest number of electrons; and

(v) the element that forms an ion with a charge of +1.

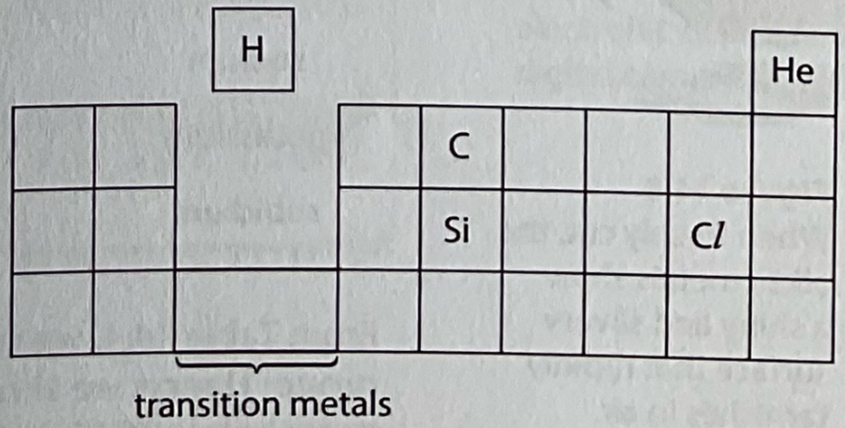

Figure 14.5

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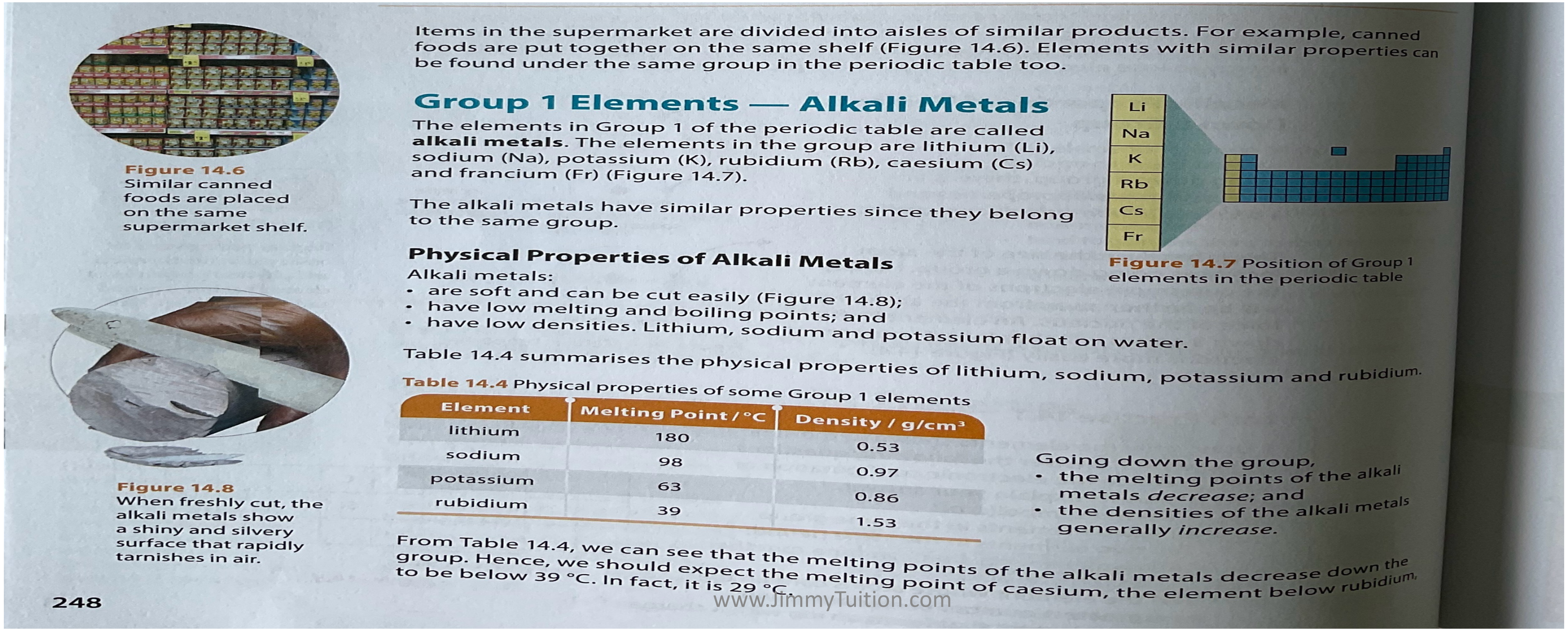
Group 1 Elements – Alkali Metals

- The elements in Group 1 are called **alkali metals.**
- The alkali metals have similar properties since they belong to the same group.
- **Physical properties of Alkali metals:**

1. Are soft and can be cut easily.
2. Have low melting and boiling points.
3. Have low density. Lithium, sodium and potassium float on water.

What Group Trend Are There for Group 1?

- Going down the group, the melting points of the alkali metals decreases,
- The density of the alkali metals generally increase.



Items in the supermarket are divided into aisles of similar products. For example, canned foods are put together on the same shelf (Figure 14.6). Elements with similar properties can be found under the same group in the periodic table too.

Figure 14.6 Similar canned foods are placed on the same supermarket shelf.

Group 1 Elements — Alkali Metals

The elements in Group 1 of the periodic table are called **alkali metals**. The elements in the group are lithium (Li), sodium (Na), potassium (K), rubidium (Rb), caesium (Cs) and francium (Fr) (Figure 14.7).

The alkali metals have similar properties since they belong to the same group.

Figure 14.7 Position of Group 1 elements in the periodic table

Physical Properties of Alkali Metals

Alkali metals:

- are soft and can be cut easily (Figure 14.8);
- have low melting and boiling points; and
- have low densities. Lithium, sodium and potassium float on water.

Table 14.4 summarises the physical properties of lithium, sodium, potassium and rubidium.

Table 14.4 Physical properties of some Group 1 elements

Element	Melting Point / °C	Density / g/cm^3
lithium	180	0.53
sodium	98	0.97
potassium	63	0.86
rubidium	39	1.53

Going down the group,

- the melting points of the alkali metals *decrease*; and
- the densities of the alkali metals generally *increase*.

Figure 14.8 When freshly cut, the alkali metals show a shiny and silvery surface that rapidly tarnishes in air.

From Table 14.4, we can see that the melting points of the alkali metals decrease down the group. Hence, we should expect the melting point of caesium, the element below rubidium, to be below 39 °C. In fact, it is 29 °C.

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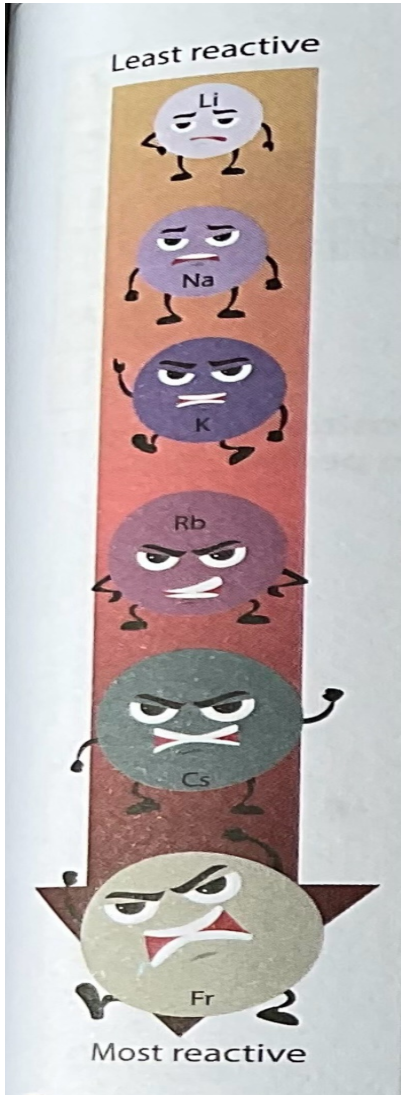
Chemical Properties of Alkali Metals

- Alkali metals are highly reactive. They are stored in oil to prevent them from reacting with air and water.
- Each alkali metal has 1 valence electron. By losing this valence electron, it achieves the electronic configuration of a noble gas.
- As we go down Group 1, the size of the atom increases. It is easier to lose the valence electron from bigger atoms. Hence, the reactivity ***increases*** down the group.



Reactions of some alkali metals with water

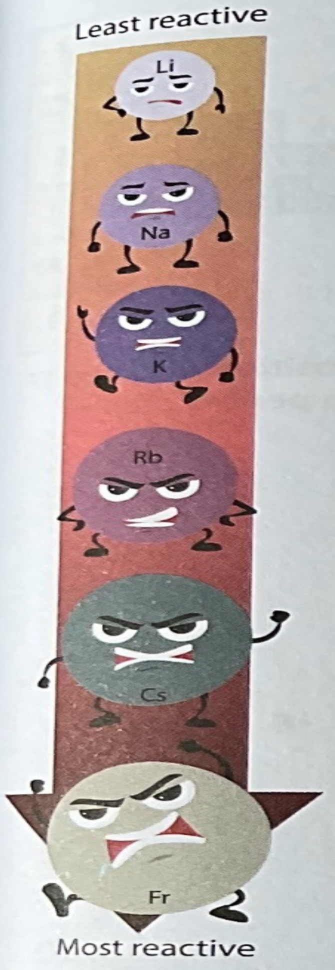


Figure 14.9 Going down Group 1, the alkali metals become more reactive.

Chemical Properties of Alkali Metals

Alkali metals are *highly reactive*. They are stored in oil to prevent them from reacting with air and water. Each alkali metal has 1 valence electron. By losing this valence electron, it achieves the electronic configuration of a noble gas.

As we go down Group 1, the size of the atom increases, as seen in Figure 14.9. It is easier to lose the valence electron from bigger atoms. Hence, the reactivity *increases* down the group. Table 14.5 illustrates the reactivity of alkali metals with water to form soluble bases (alkalis).

Table 14.5 Reactions of some alkali metals with water

Alkali Metal	Observations and Equations for Reaction With Water
lithium	Reacts quickly. Lithium floats on the water. lithium + water ⟶ lithium hydroxide + hydrogen $2Li(s) + 2H_2O(l) \longrightarrow 2LiOH(aq) + H_2(g)$
sodium	Reacts violently. Sodium darts around the water surface. Reaction may be explosive. sodium + water ⟶ sodium hydroxide + hydrogen $2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$
potassium	Reacts very violently. Reaction is explosive. potassium + water ⟶ potassium hydroxide + hydrogen $2K(s) + 2H_2O(l) \longrightarrow 2KOH(aq) + H_2(g)$

Order of reactivity:
lithium < sodium < potassium < rubidium < caesium < francium

Group 17 Elements – Halogens

- Group 17 elements are called halogens. They exist as diatomic molecules and are non-metals.
- The halogens have low melting and boiling points
- Chlorine is yellow-green gas
- Bromine is red-brown liquid
- Iodine is purple-black solid
- Going down the group,

1. the melting and boiling points of the halogens increases
2. The colours become darker (colour intensities increase)

Chemical Properties of the Halogens

- The size of the atom increases down the group, this makes it more difficult for the nucleus to attract one more electron. Hence the reactivity of halogens decreases down the group.
- Order of reactivity:

fluorine > chlorine > bromine > iodine > astatine > tennessine

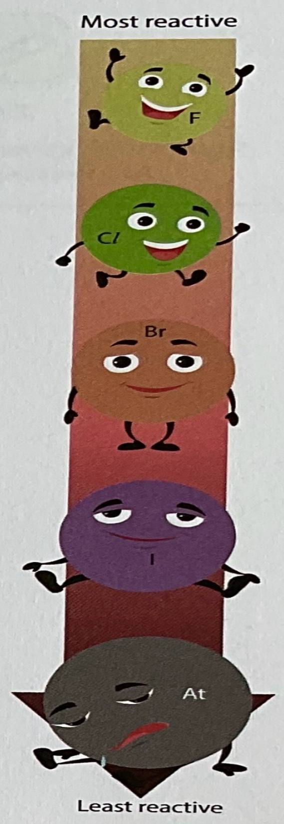
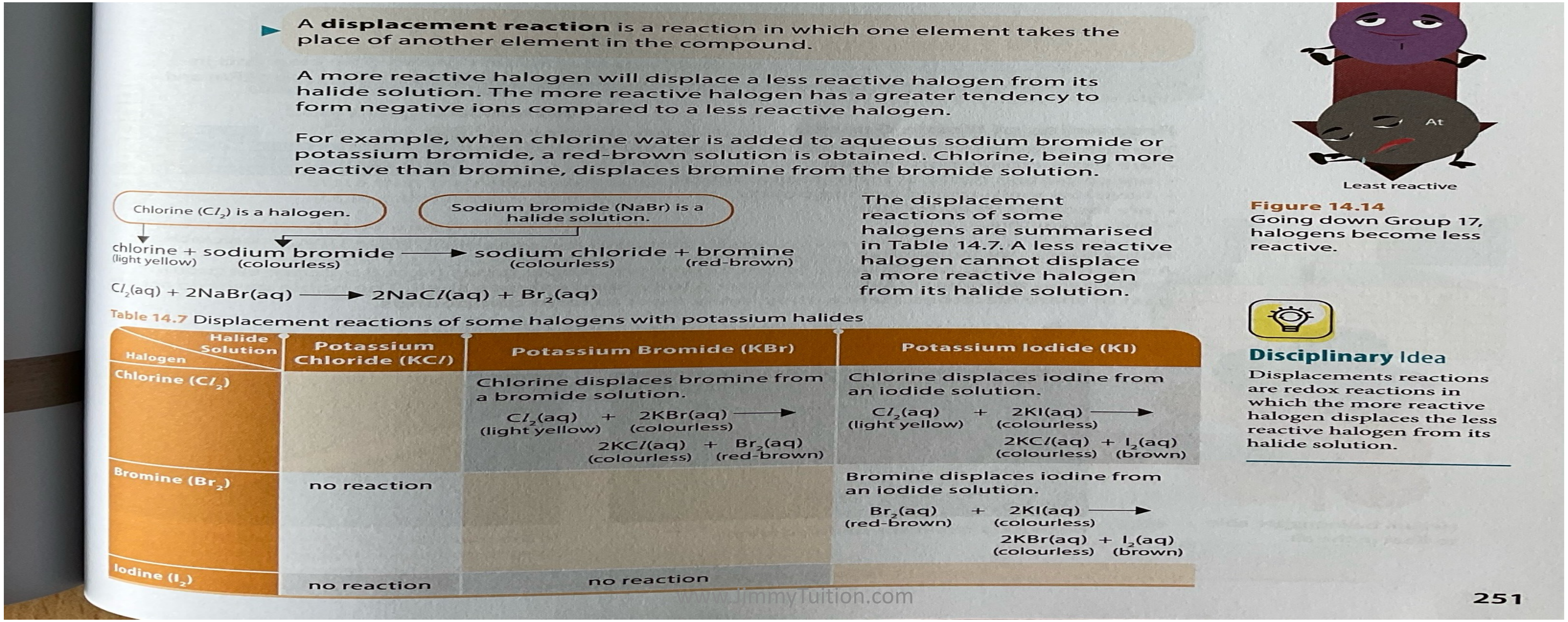


Figure 14.14
Going down Group 17, halogens become less reactive.

Displacement Reaction

- Displacement reaction: a more reactive halogen will displace a less reactive halogen from its halide solution. The more reactive halogen has a greater tendency to form negative ions compared to a less reactive halogen.



A **displacement reaction** is a reaction in which one element takes the place of another element in the compound.

A more reactive halogen will displace a less reactive halogen from its halide solution. The more reactive halogen has a greater tendency to form negative ions compared to a less reactive halogen.

For example, when chlorine water is added to aqueous sodium bromide or potassium bromide, a red-brown solution is obtained. Chlorine, being more reactive than bromine, displaces bromine from the bromide solution.

Chlorine (Cl_2) is a halogen.

Sodium bromide (NaBr) is a halide solution.

chlorine (light yellow) + sodium bromide (colourless) ⟶ sodium chloride (colourless) + bromine (red-brown)

$Cl_2(aq) + 2NaBr(aq) \longrightarrow 2NaCl(aq) + Br_2(aq)$

The displacement reactions of some halogens are summarised in Table 14.7. A less reactive halogen cannot displace a more reactive halogen from its halide solution.

Table 14.7 Displacement reactions of some halogens with potassium halides

Halogen / Halide Solution	Potassium Chloride (KCl)	Potassium Bromide (KBr)	Potassium Iodide (KI)
Chlorine (Cl_2)		Chlorine displaces bromine from a bromide solution. $Cl_2(aq)$ (light yellow) + $2KBr(aq)$ (colourless) ⟶ $2KCl(aq)$ (colourless) + $Br_2(aq)$ (red-brown)	Chlorine displaces iodine from an iodide solution. $Cl_2(aq)$ (light yellow) + $2KI(aq)$ (colourless) ⟶ $2KCl(aq)$ (colourless) + $I_2(aq)$ (brown)
Bromine (Br_2)	no reaction		Bromine displaces iodine from an iodide solution. $Br_2(aq)$ (red-brown) + $2KI(aq)$ (colourless) ⟶ $2KBr(aq)$ (colourless) + $I_2(aq)$ (brown)
Iodine (I_2)	no reaction	no reaction	

Figure 14.14 Going down Group 17, halogens become less reactive.

Disciplinary Idea

Displacements reactions are redox reactions in which the more reactive halogen displaces the less reactive halogen from its halide solution.

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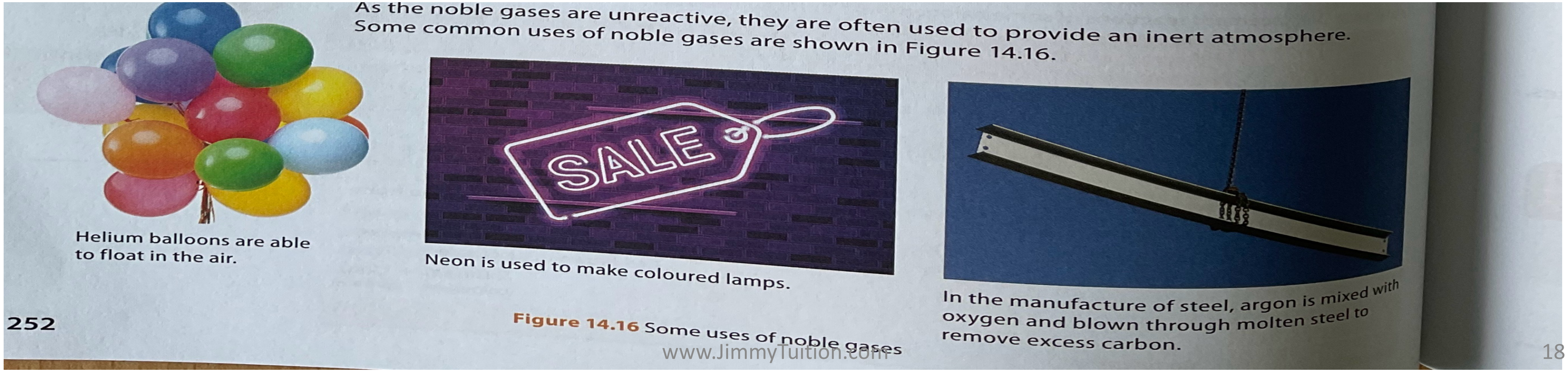
Group 18 Elements – Noble Gases

- The elements in Group 18 are called the noble gases or inert gases.
- The noble gases:

1. Are monoatomic non-metals;
2. Are colourless gases at room temperature;
3. Have low melting and boiling points;
4. Are insoluble in water;
5. Are Unreactive.

Noble Gases Are Unreactive

- Apart from helium, which has 2 valence electrons, noble gases have 8 valence electrons.
- **Noble gases are Unreactive** as they have a fully filled valence shell. The noble gases do not lose, gain or share electrons. Hence, they rarely react to form compounds.
- Helium balloons are able to float in the air.
- Neon used to make coloured lamps.
- In the manufacture of steel, argon is mixed with oxygen and blown through molten steel to remove excess carbon.


As the noble gases are unreactive, they are often used to provide an inert atmosphere. Some common uses of noble gases are shown in Figure 14.16.

Helium balloons are able to float in the air.

Neon is used to make coloured lamps.

In the manufacture of steel, argon is mixed with oxygen and blown through molten steel to remove excess carbon.

Figure 14.16 Some uses of noble gases

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Transition Elements

- Transition elements are the block of metals found in Group 3 to 11 of the periodic table.
- Properties of Transition Metals:

1. High meting points and high density
2. Variable Oxidation States
3. Form Coloured Compounds
4. Transition metals and their compounds are good catalysts.

High melting points and high density

points, high densities, variable oxidation states and forming coloured compounds.

- State that transition elements and/or their compounds are often able to act as catalysts.

Transition elements are the block of metals found in Groups 3 to 11 of the periodic table (Figure 14.17). They are also called the **transition metals**. Examples of some common transition metals include chromium (Cr), manganese (Mn), iron (Fe) and copper (Cu).

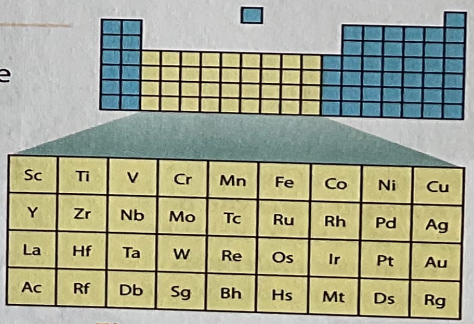

Figure 14.17 Position of the transition metals in the periodic table

Properties of Transition Metals

High Melting Points And High Densities

Table 14.8 shows the melting points and densities of some transition metals. Potassium and calcium have been included for comparison.

Table 14.8 Melting points and densities of metals in Period 4

	Group 1 Metal	Group 2 Metal	Transition Metals			
Element	potassium (K)	calcium (Ca)	chromium (Cr)	manganese (Mn)	iron (Fe)	copper (Cu)
Melting Point / °C	63	839	1857	1244	1538	1084
Density / g/cm³	0.86	1.55	7.19	7.21	7.86	9.92

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Variable Oxidation States

Variable Oxidation States

Haemoglobin, a component of blood, is responsible for the distribution of oxygen around the body. Oxygen is able to bind to the haemoglobin molecules in the lungs and is released as blood passes through the body (Figure 14.19). This is possible due to the iron in the haemoglobin having different oxidation states of +2 and +3.

Figure 14.19 Blood flowing through a blood vessel

Link

Recall from Chapter 12: Oxidation states can be used to identify whether a substance undergoes oxidation or reduction in a reaction.

We learnt in Chapter 12 that the metals in Groups 1 and 2 form one type of positive ion only. For example, Group 1 metals form ions with an oxidation state of +1.

Unlike the metals in Groups 1 and 2, transition metals form ions with different oxidation states. Table 14.9 shows the variable oxidation states of some transition metals in their compounds.

Table 14.9 Oxidation states of some transition metals

Compounds of							
Chromium (Cr)		Manganese (Mn)		Iron (Fe)		Copper (Cu)	
Common Oxidation State	Example	Common Oxidation State	Example	Common Oxidation State	Example	Common Oxidation State	Example
+3 +6	$CrCl_3$ $K_2Cr_2O_7$	+2 +4 +7	$MnCl_2$ MnO_2 $KMnO_4$	+2 +3	$FeCl_2$ $FeCl_3$	+1 +2	Cu_2O $CuSO_4$

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Form Coloured Compounds

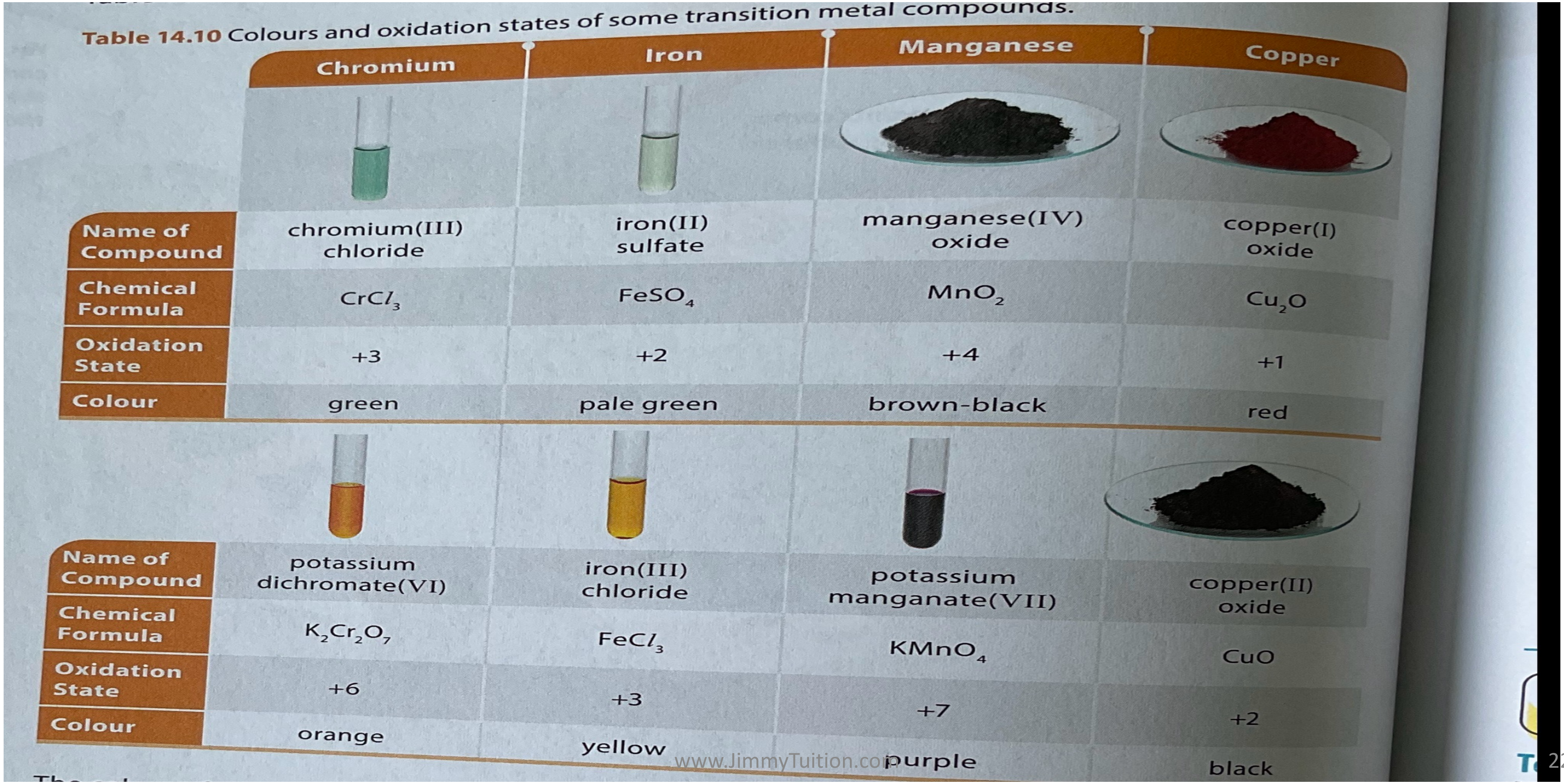
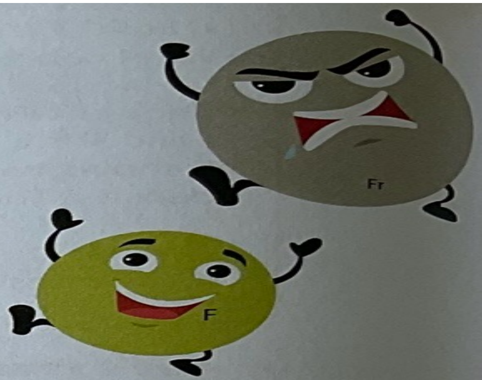


Table 14.10 Colours and oxidation states of some transition metal compounds.

	Chromium	Iron	Manganese	Copper
Name of Compound	chromium(III) chloride	iron(II) sulfate	manganese(IV) oxide	copper(I) oxide
Chemical Formula	$CrCl_3$	$FeSO_4$	MnO_2	Cu_2O
Oxidation State	+3	+2	+4	+1
Colour	green	pale green	brown-black	red
Name of Compound	potassium dichromate(VI)	iron(III) chloride	potassium manganate(VII)	copper(II) oxide
Chemical Formula	$K_2Cr_2O_7$	$FeCl_3$	$KMnO_4$	CuO
Oxidation State	+6	+3	+7	+2
Colour	orange	yellow	purple	black

Catalysts

Catalyst	Industrial Process
Iron	Huber process for manufacture of ammonia
Nickel	Manufacture of margarine from vegetable oil



The Periodic Table

arranges

Elements
in order of increasing proton number

into

- **Groups** (vertical columns)
- **Periods** (horizontal rows)
  - *which show* The number of electron shells as the period number

left-hand side

Metals

examples

Group 1 — Alkali metals

- Examples: Li, Na, K
- Soft and easily cut
- Low melting and boiling points
- Low densities

Transition Metals

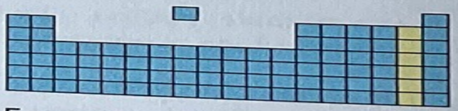
- Examples: Mn, Fe, Cu
- High melting and boiling points
- High densities
- Form coloured compounds
- Exhibit variable oxidation states in their compounds
- Act as catalysts in a number of industrial processes

right-hand side

Non-metals

examples

Group 17 — Halogens



- Examples: F, Cl, I
- Diatomic
- Low melting and boiling points
- Colour becomes darker down the group
- Reactivity decreases down the group
- A more reactive halogen displaces a less reactive halogen from its halide solution

Group 18 — Noble Gases

- Examples: He, Ne, Ar
- Monoatomic
- Do not form ions or molecules
- Are unreactive