CHAPTER 5

The Periodic Table

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CONTENTS

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March 5, 2021

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1 INTRODUCTION

The **periodic table of the elements** is a method of showing the chemical elements in a table with the elements arranged in order of increasing atomic number. Most of the work that was done to arrive at the periodic table that we know can be attributed to a Russian chemist named **Dmitri Mendeleev**. Mendeleev designed the table in 1869 in such a way that recurring ("periodic") trends or patterns in the properties of the elements could be shown. Using the trends he observed, he left gaps for those elements that he thought were "missing". He also predicted the properties that he thought the missing elements would have when they were discovered. Many of these elements were indeed discovered and Mendeleev's predictions were proved to be correct.

2 THE ARRANGEMENT OF THE ELEMENTS

To show the recurring properties that he had observed, Mendeleev began new rows in his table so that elements with similar properties were in the same vertical columns, called **groups**. Each row was referred to as a **period**. Figure 1 shows a simplified version of the periodic table. You can view an online periodic table at *periodic table*.

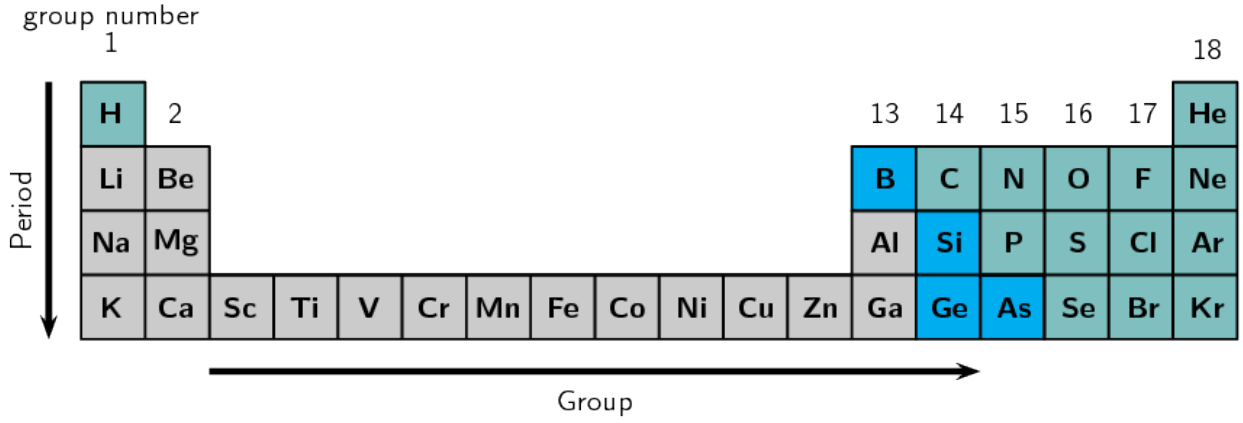

Figure 1: A simplified diagram showing part of the periodic table. Metals are given in gray, metalloids in light blue and non-metals in turquoise.

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2.1 Definitions and important concepts

Before we can talk about the trends in the periodic table, we first need to define some terms that are used:

- **Atomic radius**
  The atomic radius is a measure of the size of an atom.
- **Ionisation energy**
  The first ionisation energy is the energy needed to remove one electron from an atom in the gas phase. The ionisation energy is different for each element. We can also define second, third, fourth, etc. ionisation energies. These are the energies needed to remove the second, third, or fourth electron respectively.
- **Electron affinity**
  Electron affinity can be thought of as how much an element wants electrons.
- **Electronegativity**
  Electronegativity is the tendency of atoms to attract electrons. The electronegativity of the elements starts from about 0.7 (Francium (Fr)) and goes up to 4 (Fluorine (F))
- **Group**
  A group is a vertical column in the periodic table and is considered to be the most important way of classifying the elements. If you look at a periodic table, you will see the groups numbered at the top of each column. The groups are numbered from left to right starting with 1 and ending with 18. This is the convention that we will use in this book. On some periodic tables you may see that the groups are numbered from left to right as follows: 1, 2, then an open space which contains the **transition elements**, followed by groups 3 to 8. Another way to label the groups is using Roman numerals.
- **Period**
  A period is a horizontal row in the periodic table of the elements. The periods are labelled from top to bottom, starting with 1 and ending with 7.

For each element on the periodic table we can give its period number and its group number. For example, B is in period 2 and group 13. We can also determine the electronic structure of an element from its position on the periodic table. In Chapter 4 you worked out the electronic configuration of various elements. Using the periodic table we can easily give the electronic configurations of any element. To see how this works look at the following:

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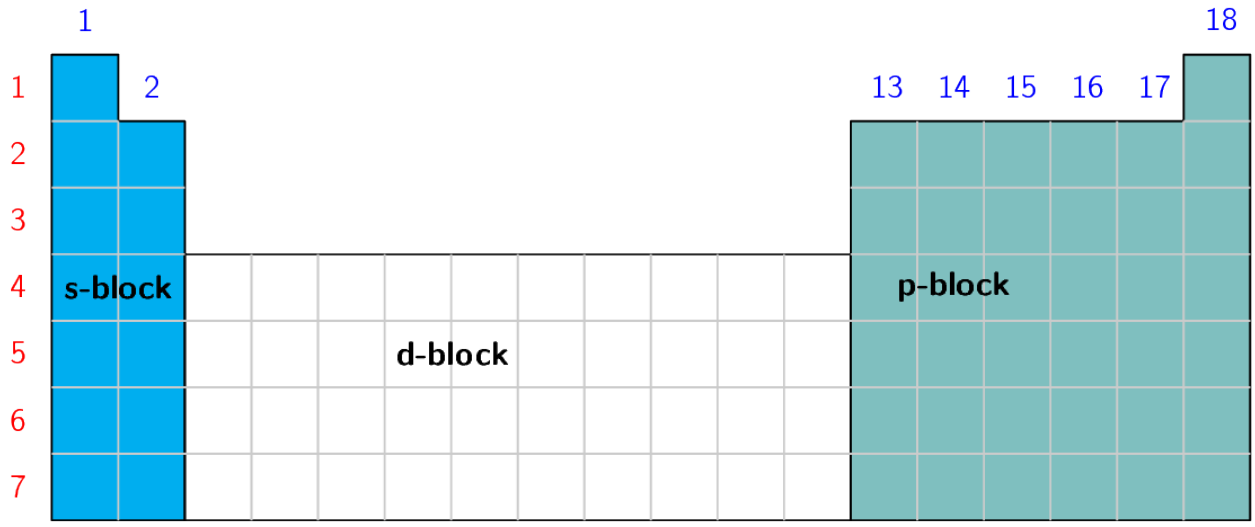

We also note that the period number gives the energy level that is being filled. For example, phosphorus (P) is in the third period and group 15. Looking at the figure above, we see that the p-orbital is being filled. Also the third energy level is being filled. So its electron configuration is: $[\text{Ne}]3s^2 3p^3$ (Phosphorus is in the third group in the p-block, so it must have 3 electrons in the p shell.)

2.2 Periods in the periodic table

The following diagram illustrates some of the key trends in the periods:

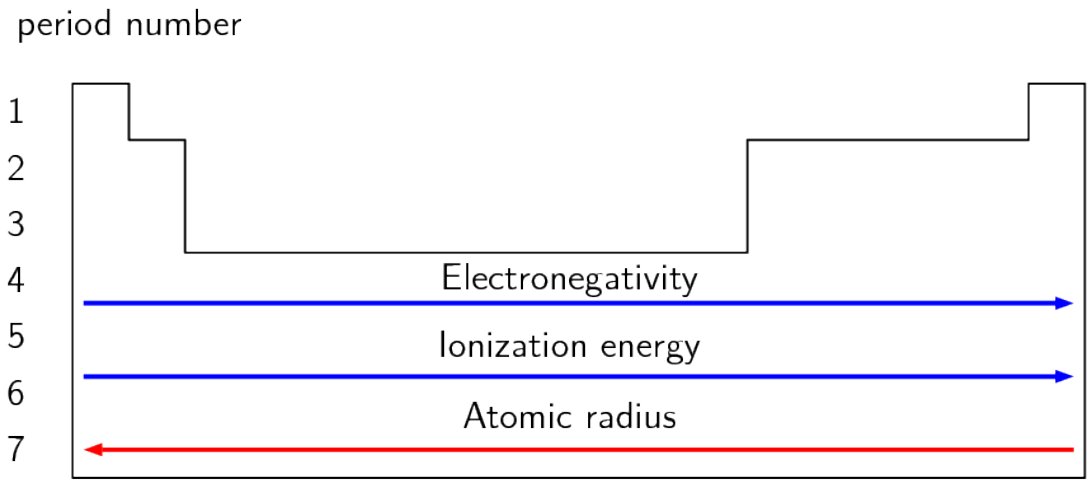

Figure 2: Trends on the periodic table.

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Table 1 summarises the patterns or trends in the properties of the elements in period 3. Similar trends are observed in the other periods of the periodic table. The chlorides are compounds with chlorine and the oxides are compounds with oxygen.

Table 1: Summary of trends in period 3

Element	$^{23}_{11}$Na	$^{24}_{12}$Mg	$^{27}_{13}$Al	$^{28}_{14}$Si	$^{31}_{15}$P	$^{32}_{16}$ S	$^{35}_{17}$Cl
Chlorides	NaCl	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_5 or PCl_3	S_2Cl_2	no chlorides
Oxides	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_6 or P_4O_{10}	SO_3 or SO_4	Cl_2O_7 or Cl_2O
Valence electrons	$3s^1$	$3s^2$	$3s^23p^1$	$3s^23p^2$	$3s^23p^3$	$3s^23p^4$	$3s^23p^5$
Atomic radius	Decreases across a period.						
First Ionization energy	The general trend is an increase across the period.						
Electro-negativity	Increases across the period.						
Melting and boiling point	Increases to silicon and then decreases to argon.						
Electrical conductivity	Increases from sodium to aluminium. Silicon is a semi-conductor. The rest are insulators.						

Note that we have left argon ($^{40}_{18}$Ar) out. Argon is a noble gas with electron configuration: $[Ne]3s^23p^6$. Argon does not form any compounds with oxygen or chlorine.

3 CHEMICAL PROPERTIES OF THE GROUPS

In some groups, the elements display very similar chemical properties and some of the groups are even given special names to identify them. The characteristics of each group are mostly determined by the electron configuration of the atoms of the elements in the group. The names of the groups are summarised in Figure 3.

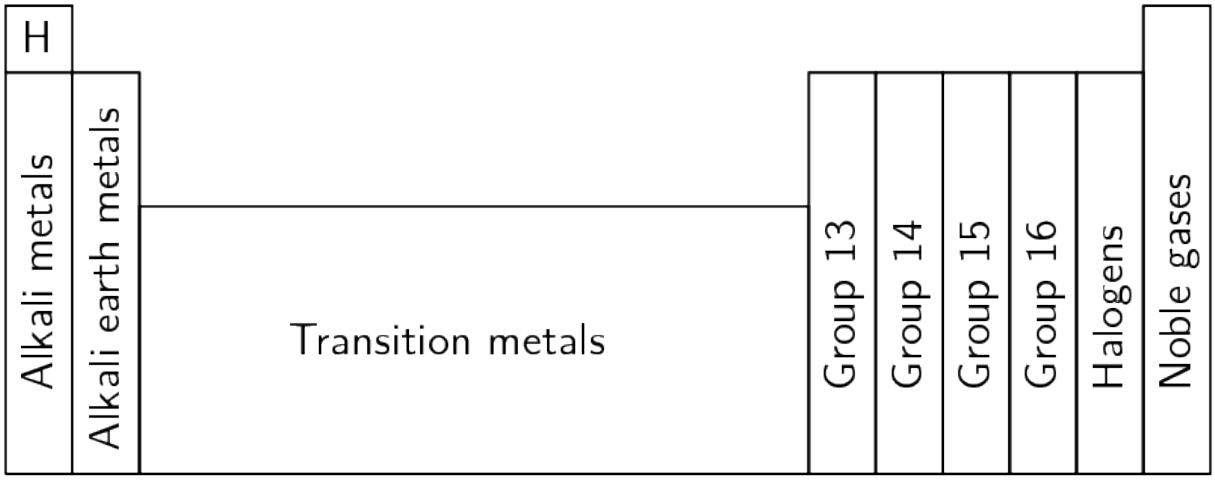

Figure 3: Groups on the periodic table.

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A few points to note about the groups are:

- Although hydrogen appears in group 1, it is not an alkali metal.
- Group 15 elements are sometimes called the pnictogens.
- Group 16 elements are sometimes known as the chalcogens.
- The **halogens** and the **alkali metals** are very reactive groups.
- The **noble gases** are *inert* (unreactive).

The following diagram illustrates some of the key trends in the groups of the periodic table:

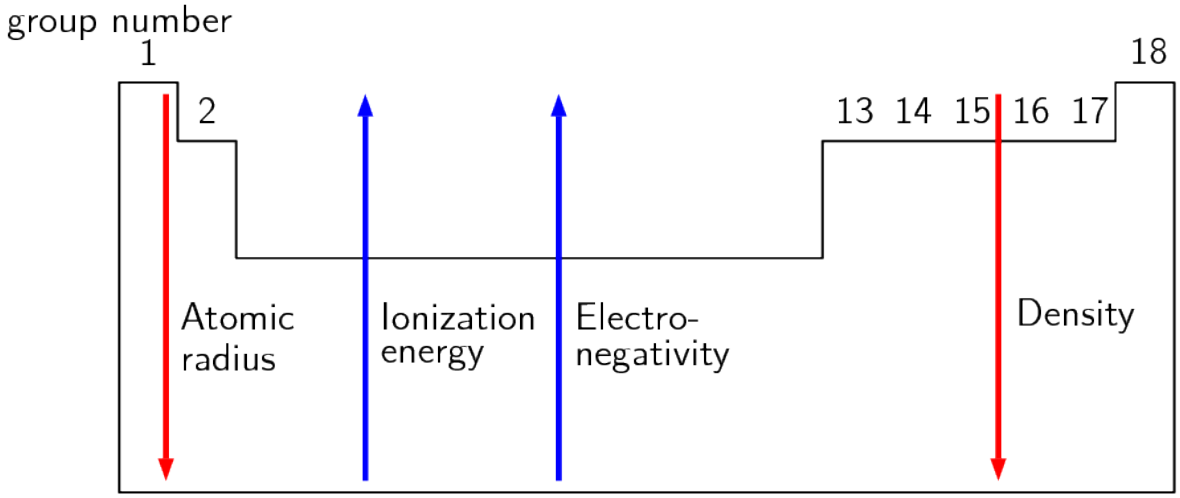

Figure 4: Trends in the groups on the periodic table.

Table 2 summarises the patterns or trends in the properties of the elements in group 1. Similar trends are observed for the elements in the other groups of the periodic table. We can use the information in Table 2 to predict the chemical properties of unfamiliar elements. For example, given the element Francium (Fr) we can say that its electronic structure will be $[\text{Rn}]7s^1$, it will have a lower first ionisation energy than caesium (Cs).

One general trend that is not shown is the melting and boiling points. For the metals (groups 1 to 13) the melting and boiling points increase as you go up the group. For the non-metals the melting and boiling points decrease as you go up the group.

You should also recall from chapter Chapter 2 that the metals are found on the left of the periodic table, non-metals are on the right and metalloids are found on the zig-zag line that starts at boron.

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Table 2: Summary of the trends in group 1

Element	$^{3}_{7}$Li	$^{23}_{11}$Na	$^{39}_{19}$K	$^{86}_{37}$Rb	$^{133}_{55}$Cs
Electron structure	[He]$2s^1$	[Ne]$3s^1$	[Ar]$4s^1$	[Kr]$4s^1$	[Xe]$5s^1$
Group 1 chlorides	LiCl	NaCl	KCl	RbCl	CsCl
	Group 1 elements all form halogen compounds in a 1:1 ratio				
Group 1 oxides	Li_2O	Na_2O	K_2O	Rb_2O	Cs_2O
	Group 1 elements all form oxides in a 2:1 ratio				
Atomic radius	Increases as you move down the group.				
First ionisation energy	Decreases as you move down the group.				
Electronegativity	Decreases as you move down the group.				
Melting and boiling point	Decreases as you move down the group.				
Density	Increases as you move down the group.				

4 CHAPTER SUMMARY

- Elements are arranged in periods and groups on the periodic table. The elements are arranged according to increasing atomic number.
- A **group** is a column on the periodic table containing elements with similar properties. A **period** is a row on the periodic table.
- The atomic radius is a measure of the size of the atom.
- The first ionisation energy is the energy needed to remove one electron from an atom in the gas phase.
- Electronegativity is the tendency of atoms to attract electrons.
- Across a period the ionisation energy and electronegativity increase. The atomic radius decreases across a period.
- The groups on the periodic table are labelled from 1 to 18. Group 1 is known as the alkali metals, group 2 is known as the alkali earth metals, group 17 is known as the halogens and the group 18 is known as the noble gases. The elements in a group have similar properties.
- The atomic radius and the density both increase down a group. The ionisation energy, electronegativity, and melting and boiling points all decrease down a group.

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5 EXERCISES

5.1 Exercise 1

1. Provide a definition for the atomic radius.
2. What is first ionisation energy?
3. Define electron affinity.
4. Define electronegativity.
5. What represents a group on the periodic table?
6. What represents a period on the periodic table?
7. What represents the total number of energy levels on the periodic table?
8. Which of the following statements regarding atomic radius is correct?
   (i) Increase across a group
   (ii) Increase across a period
   (iii) Decrease across a period
   (iv) Decrease across a group
9. Which of the following compound is possible between phosphorus and chlorine?
   (i) $PC\ell_5$
   (ii) $PC\ell_4$
   (iii) $FC\ell_5$
   (iv) $FC\ell_4$
10. The valence electrons for silicon are:
    (i) $3s^2 3p^2$
    (ii) $2s^2 2p^2$
    (iii) $3s^2 3p^1$
    (iv) $2s^2 2p^1$

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11. Which one is NOT a possible oxide?

    (i) SiO_2

    (ii) $A\ell_2O_3$

    (iii) MgO

    (iv) NaO

12. Which one of the following is a possible chloride?

    (i) $NC\ell$

    (ii) $NC\ell_2$

    (iii) $NC\ell_3$

    (iv) $N_2C\ell$

13. Which elements cannot form chlorides?

    (i) O_2, F_2, Ne

    (ii) Li, Be, B

    (iii) C, N, O_2

    (iv) Li, B, N

14. Which elements can form oxides?

    (i) C, N, F

    (ii) Li, Be, B

    (iii) Li, Be, F

    (iv) Be, N, F

15. Describe the trend with regards to melting points across periods.

16. Describe the trend with regards to electrical conductivity across periods.

17. Which element will have an ionisation energy of 1307

    (i) Hydrogen

    (ii) Oxygen

    (iii) Fluoride

    (iv) Chloride

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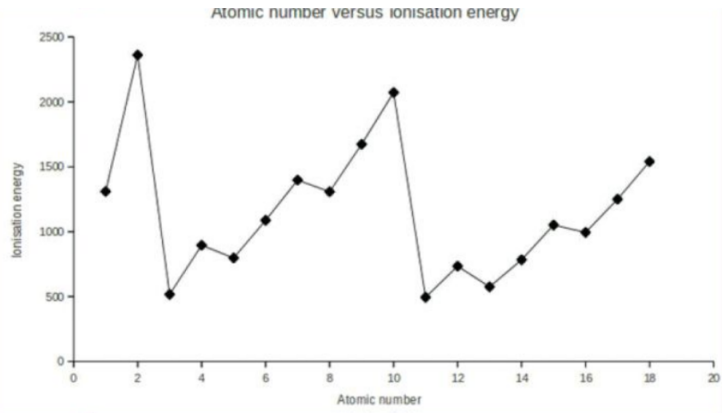
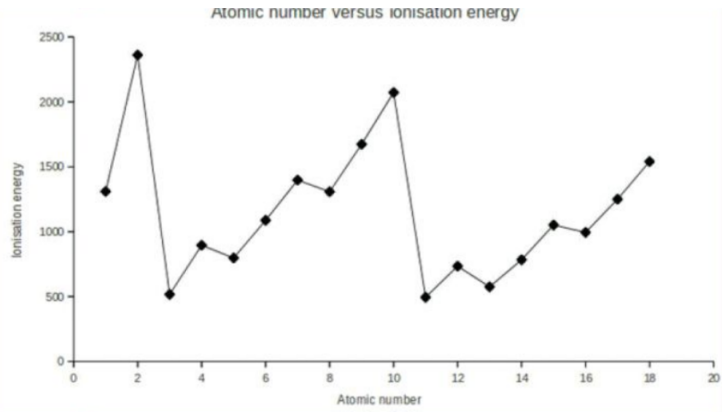
18. Refer to the graph below to answer the following question:



Describe the general trend with regards to ionisation energy across the periodic table.

19. Refer to the graph below to answer the following question:



Why does Z = 2 have a higher ionisation energy than Z = 1?

20. The energy needed to remove one electron from an atom increase when:

A	The atomic number increases
B	The number of electrons increase
C	The number of protons decrease
D	The number of electrons decrease

(i) B and D

(ii) C and D

(iii) A, B, C and D

(iv) A and B

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21. What is the name of Group 1 elements?
22. What is the name of Group 2 elements?
23. What is the name of Group 7 elements?
24. The following group is very reactive:
    (i) Alkali earth metals
    (ii) Noble gases
    (iii) Halogens
    (iv) None of the above
25. Transition metals are found between which groups?
26. What is the energy needed to remove one electron from an atom called?
27. What do you call a horizontal row on the periodic table?
28. What do you call a vertical column on the periodic table?
29. What group is very very reactive and is missing just one electron?
30. Which comparison for $^{80}_{35}Br$ and $^{35}_{17}C\ell$ is true?
    (i) Chlorine has a larger atomic radius as bromine
    (ii) Bromine has a larger atomic radius than chlorine
    (iii) Bromine has a higher electronegativity as Chlorine
    (iv) Brominels electrons are further away from the nucleus as chlorines
31. Give the electron structure of calcium.
32. Which element will have the lowest first ionisation energy?
    (i) Ba
    (ii) Sr
    (iii) Ca
    (iv) Mg
33. Which element will have the highest Boiling point?
    (i) I
    (ii) Br
    (iii) F

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(iv) $C\ell$

34. Which statement concerning these two elements are true? $^{24}_{11}Mg$ and $^{20}_{40}Ca$

A	Calcium is larger
B	Magnesium has more energy levels
C	Calcium has higher first ionisation energy than magnesium
D	Magnesium has a higher boiling point

(i) A only

(ii) A and D

(iii) A and C

(iv) A and B

35. Which element belongs to Group 1?

(i) Neon

(ii) Chlorine

(iii) Lithium

(iv) Carbon

36. Which element is a halogen?

(i) Oxygen

(ii) Neon

(iii) Chlorine

(iv) Lithium

37. Which element is a noble gas?

(i) Oxygen

(ii) Neon

(iii) Lithium

(iv) Carbon

38. Which element is an alkali metal?

(i) Lithium

(ii) Neon

(iii) Chlorine

(iv) Calcium

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39. Which element has an atomic number of 12?

    (i) Chlorine
    (ii) Oxygen
    (iii) Neon
    (iv) Carbon

40. Which element has 4 neutrons in the nucleus?

    (i) Calcium
    (ii) Lithium
    (iii) Helium
    (iv) Borium

41. Which element contains electrons in the 4^{th} energy level?

    (i) Oxygen
    (ii) Lithium
    (iii) Calcium
    (iv) Neon

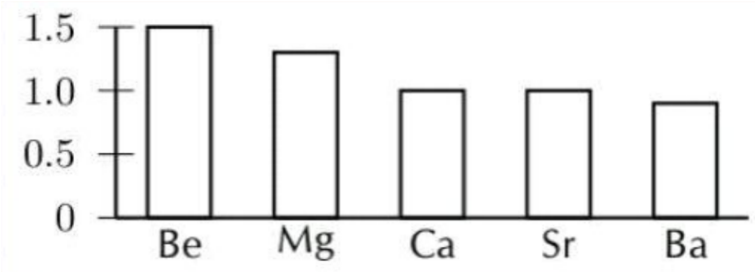
42. Which element has all the orbitals filled?

    (i) Carbon
    (ii) Oxygen
    (iii) Calcium
    (iv) Neon

43. Which elements would have similar chemical properties?

    (i) O and C
    (ii) Mg and Ca
    (iii) C and Be
    (iv) Ne and F

44. What trend does this graph represent?



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45. What trend does this graph represent?

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6 ANSWERS TO EXERCISES

6.1 Exercise 1

1. It is the measure of the size of an atom.
2. It is the energy needed to remove one electron from an atom in the gas phase.
3. How much an element wants an electron.
4. The tendency of atoms to attract electrons.
5. Vertical column in the periodic table.
6. Horizontal row in the periodic table.
7. The period number
8. iii - Decrease across a period
9. i - $PC\ell_5$
10. i - $3s^2 3p^2$
11. iv - NaO
12. iii - $NC\ell_3$
13. i - O_2, F_2, Ne
14. ii -Li, Be, B
15. Increase to C and the decrease to Ar
16. Increase to boron and then decreases
17. ii - Oxygen
18. Increase across the period
19. Z = 2 has a full outer shell
20. iv - A and B
21. Alkali metals
22. Alkali earth metals
23. Halogens

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24. iii - Halogens
25. 2 and 3
26. First ionisation energy
27. period
28. Group
29. Group 17
30. ii - Bromine has a larger atomic radius than chlorine
31. $[Ar]4s^2$
32. i - Ba
33. i - I
34. ii - A and D
35. iii - Lithium
36. iii - Chlorine
37. ii - Neon
38. i - Lithium
39. iv - Carbon
40. ii - Lithium
41. iii - Calcium
42. iv - Neon
43. ii - Mg and Ca
44. Electronegativity
45. Density against atomic number

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