Delta Science Education

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# HKDSE CHEMISTRY

## Section 2: Microscopic World I

## Part 1

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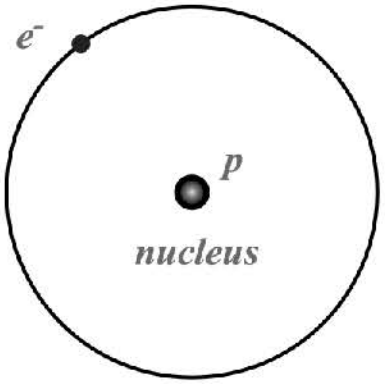
# 1. Atomic Structure

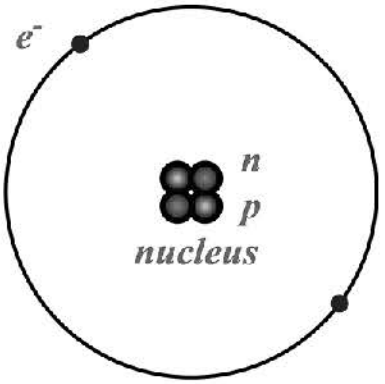
## A. Basic structure of an atom

- **Atom**: the smallest [ ] particle that can still recognize what the [ ] is.
- An atom consists of 3 types of subatomic particles:

| Subatomic particles | Proton, $p^+$ | Neutron, $n$ | Electron, $e^-$ |
|---|---|---|---|
| **Relative mass** | 1 | 1 | ≈ 0 (1/1837) |
| **Relative charge** | +1 | 0 | -1 |
| **Position** | Stationary in the nucleus | | In the electron cloud, revolving round the nucleus |



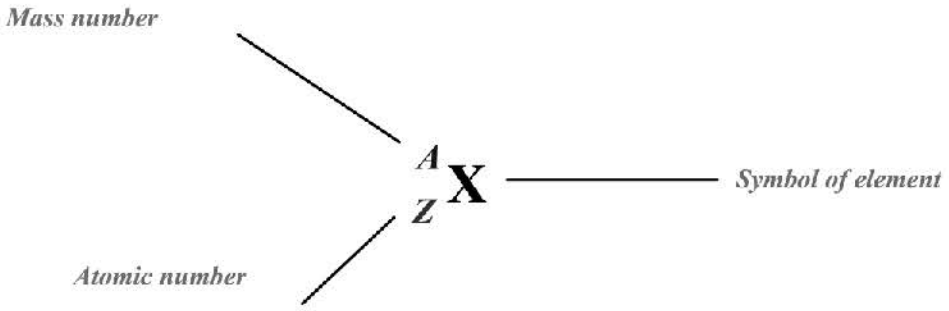

*Hydrogen atom*




*Helium atom*

- **Atomic number** of an atom = number of [ ]
  - Each element has a **UNIQUE** atomic number:
    e.g. Li must be 3 and 3 must be Li; Cl must be 17 and 17 must be Cl
- **Mass number** of an atom = number of [ ] + number of [ ]
- Note:
  1. The size of an atom is mainly governed by the [ ].
  2. Most of the space of an atom is the electron cloud and is actually [ ].
  3. An atom MUST be [ ], since the [ ].

- Notation of an atom:




## Examples that you must fully understand

1. Fill in the table below:

| | $^{23}_{11}Na$ | $^{65}Cu$ | | $^{238}U$ |
|---|---|---|---|---|
| # of $p^+$ | | | 18 | |
| # of $e^-$ | | 29 | | |
| # of $n$ | | | 22 | |

2. The atomic number of an element W is 20 and the mass number of it is 41. The atom has

   **A. *20 protons, 21 neutrons, 20 electrons***

   **B. *20 protons, 21 neutrons, 21 electrons***

   **C. *20 protons, 41 neutrons, 20 electrons***

   **D. *41 protons, 20 neutrons, 41 electrons***

   **E. *21 protons, 20 neutrons , 21 electrons***

3. Which of the following species contains the same number of neutrons as $^{20}_{9}F$ ?

   **A.** $^{26}_{12}Mg$

   **B.** $^{21}_{10}Ne$

   **C.** $^{33}_{16}S$

   **D.** $^{29}_{14}Si$

4. An atom must contain

   **(1) *proton***

   **(2) *neutron***

   **(3) *electron***

5. You are provided with the following stable atoms as reference:

$$^{1}_{1}H \quad ^{3}_{2}He \quad ^{12}_{6}C \quad ^{14}_{7}N \quad ^{206}_{82}Pb$$

Which of the following atoms is/are impossible or not stable or not correct?

**(1)** $^{12}_{7}C$ **(2)** $^{14}_{6}N$ **(3)** $^{4}_{2}He$

**(4)** $^{10}_{6}C$ **(5)** $^{16}_{6}C$ **(6)** $^{15}_{7}N$

**(7)** $^{2}_{1}H$ **(8)** $^{164}_{82}Pb$ **(9)** $^{238}_{82}Pb$

## B. Isotopes

- [ ] are different [ ] of the same [ ]. Isotopes have the same number of [ ] but different number of [ ].

- Below shows the two isotopes of Chlorine:

$^{35}_{17}Cl$ **Cl-35** $^{37}_{17}Cl$ **Cl-37**


- Isotopes have exactly the same [ ] properties, since [ ].

- Isotopes have different [ ] properties. e.g. mass, mp, bp, radioactivity, as they have different mass.

- Isotopes can only be separated by [ ].

## Examples that you must fully understand

1. There are a few atoms below:

| Atom | Atomic no. | Mass no. | # of $e^-$ |
|---|---|---|---|
| V | | 40 | 20 |
| W | 18 | 40 | |
| X | 20 | 40 | |
| Y | | 44 | 20 |
| Z | | 96 | 44 |
| F | 42 | 96 | 42 |

Which of the following pairs are isotopes?

**A. V & X** **B. W & X** **C. W & Z**

**D. X & Y** **E. Y & Z** **F. Z & F**

2. There are three naturally occurring isotopes of the element Carbon:

| | Relative / % / natural abundance | Radioactive? |
|---|---|---|
| $^{12}_{6}C$ | 98.9% | Stable |
| $^{13}_{6}C$ | 1.1% | Stable |
| $^{14}_{6}C$ | Very few | Radioactive |

**(a) What are isotopes?**

Isotopes are atoms of the [ ] which have the same number of [ ] but different number of [ ].

**(b) What is relative abundance?**

Relative abundance describes the [ ] of isotopes of an element in nature.

**(c) Is it possible to separate the three isotopes by chemical reaction?**

**(d) $^{14}_{6}C$ is radioactive. One of the neutron in its nucleus emits an electron and becomes a proton, write an equation describing it.**

## C. Relative isotopic mass and Relative atomic mass

- **Carbon-12 scale**: the mass of a $^{12}_{6}C$ atom is defined to have a relative mass of [ ].
- **Relative isotopic mass** of a particular [ ] of an element is defined as the mass of one atom of that isotope on the $^{12}C = 12.00$ scale.

*Relative isotopic mass of an isotope ≈ [ ] of the isotope*

- **Relative atomic mass** of an [ ] is the weighted average mass of all naturally occurring isotopes of that element on the $^{12}C = 12.00$ scale.
- Below shows the two naturally occuring isotopes of Chlorine:

| **Isotopes** | $^{35}_{17}Cl$ **Cl-35** | $^{37}_{17}Cl$ **Cl-37** |
|---|---|---|
| **Relative abundance** | 75% | 25% |
| **Relative isotopic mass** | | |
| **Relative atomic mass of Chlorine** | | |

- Note:
  1. Relative isotopic mass is roughly an integer.
  2. Relative atomic mass is usually NOT an integer.
  3. Both of them have NO unit.

### Examples that you must fully understand

1. Which of the following statements is / are correct?

   ***(1) On $^{12}C = 12.00$ scale, the relative isotopic mass of carbon-14 is 14.0 g.***

   ***(2) The magnitude of the relative isotopic mass of an isotope is roughly equal to the mass number of that isotope.***

   ***(3) The relative isotopic mass of an isotope is equal to the number of neutrons in the isotope.***

2. Fill in the blanks of the table below:

| Element | Atomic number | Isotope (Relative abundance) | Relative atomic mass |
|---|---|---|---|
| H | 1 | $^{1}H$ (99.985%) | |
| | | $^{2}H$ (0.015%) | |
| | | $^{3}H$ (Trace) | |
| He | 2 | $^{3}He$ (0.000137%) | |
| | | $^{4}He$ (99.999863%) | |
| B | 5 | $^{10}B$ ( %) | 10.81 |
| | | $^{11}B$ ( %) | |
| Mg | 12 | $^{24}Mg$ (78.99%) | |
| | | $^{25}Mg$ (10%) | |
| | | Mg (11.01%) | |
| Cl | 17 | $^{35}Cl$ (3) | |
| | | $^{37}Cl$ (1) | |

3. Element X occurs in nature as two isotopes, $^{79}X$ and $^{81}X$. If the relative atomic mass of X is 79.9, which of the following statements is / are correct?

   **A. *The isotopes can be separated by chemical methods.***

   **B. *The abundance of $^{79}X$ is more than the abundance of $^{81}X$.***

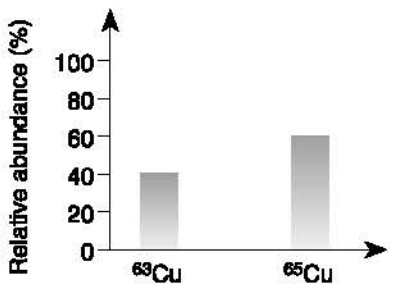
   **C. *The relative atomic mass is 79.9 g.***

4. An element has 3 naturally occurring isotopes $^{20}X$, $^{21}X$ and $^{22}X$. The ratio of abundance of $^{20}X$ and $^{22}X$ is 2 to 1 and the relative atomic mass of X is 20.86. Calculate the % abundance of each isotope of X.

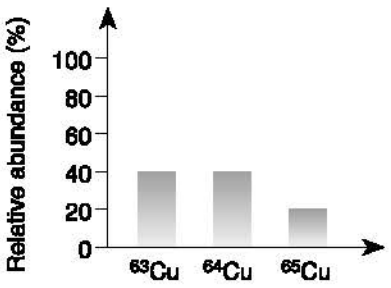
   Therefore, the % abundance of ☐

5. The relative atomic mass of a natural sample of copper is 63.6. Which of the following graphs shows the relative abundance of the isotopes?

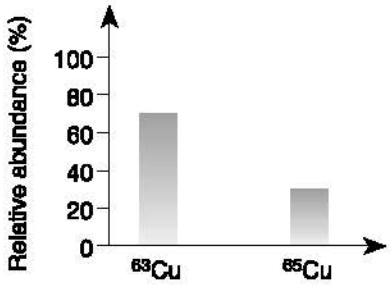
**A.**



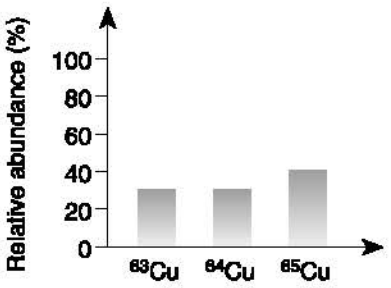

**B.**




**C.**

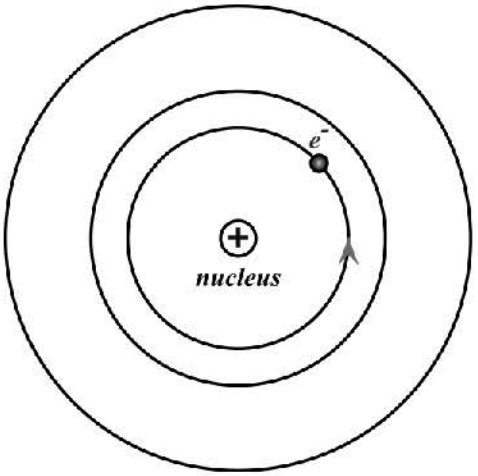



**D.**



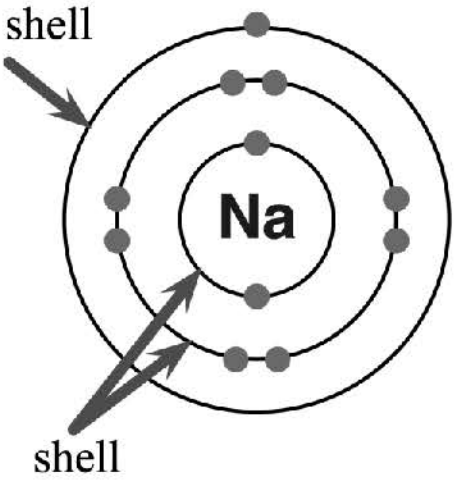
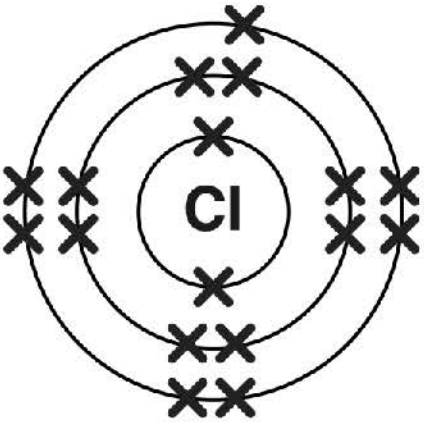
## D. Electronic arrangements of atoms

- Electrons move round the nucleus in electron shell.




*hydrogen atom*

- Electronic arrangement = the way that the electrons in an atom is arranged

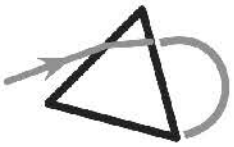
| Sodium atom, atomic no. = 11 | Chlorine atom, atomic no. = 17 |
|---|---|
|  |  |



*Electron diagram*

- Maximum number of electrons in each electron shell = ☐

| Electron shell (n) | Max number of $e^-$ |
|---|---|
| First (n = 1) | |
| Second (n = 2) | |
| Third (n = 3) | |
| Forth (n = 4) | |



- Electronic arrangement of the first 20 elements:

| Element | Symbol | Atomic number | $e^-$ number | Electronic arrangement |
|---|---|---|---|---|
| Hydrogen | | 1 | 1 | |
| Helium | | 2 | 2 | |
| | | | | |
| Lithium | | 3 | 3 | |
| Beryllium | | 4 | 4 | |
| Boron | | 5 | 5 | |
| Carbon | | 6 | 6 | |
| Nitrogen | | 7 | 7 | |
| Oxygen | | 8 | 8 | |
| Fluorine | | 9 | 9 | |
| Neon | | 10 | 10 | |
| | | | | |
| Sodium | | 11 | 11 | |
| Magnesium | | 12 | 12 | |
| Aluminium | | 13 | 13 | |
| Silicon | | 14 | 14 | |
| Phosphorus | | 15 | 15 | |
| Sulphur | | 16 | 16 | |
| Chlorine | | 17 | 17 | |
| Argon | | 18 | 18 | |
| | | | | |
| Potassium | | 19 | 19 | |
| Calcium | | 20 | 20 | |

## Examples that you must fully understand

1. In early 19th century, an English scientist, John Dalton, proposed the Atomic Theory. Which of the idea(s) of his atomic theory is / are known to be incorrect by the current scientific knowledge?

   ***(1) All atoms of the same element are identical.***

   ***(2) Different elements have different types of atoms.***

   ***(3) Atoms are indivisible.***

   ***(4) Atoms of one element always differ in mass from those of another element.***

   ***(5) All atoms of the same element have the same properties. Chemical? Physical?***

   ***(6) Chemical reactions occur when atoms are rearranged.***

   ***(7) Atoms of one element cannot be converted to atoms of another element.***

2. This question is about Lithium, Sodium and Potassium.

   **(a) State one difference between their electronic structures.**

   The have different number of ☐

   **(b) State one similarity in their electronic structures.**

   The have the same number of outermost electron shell.

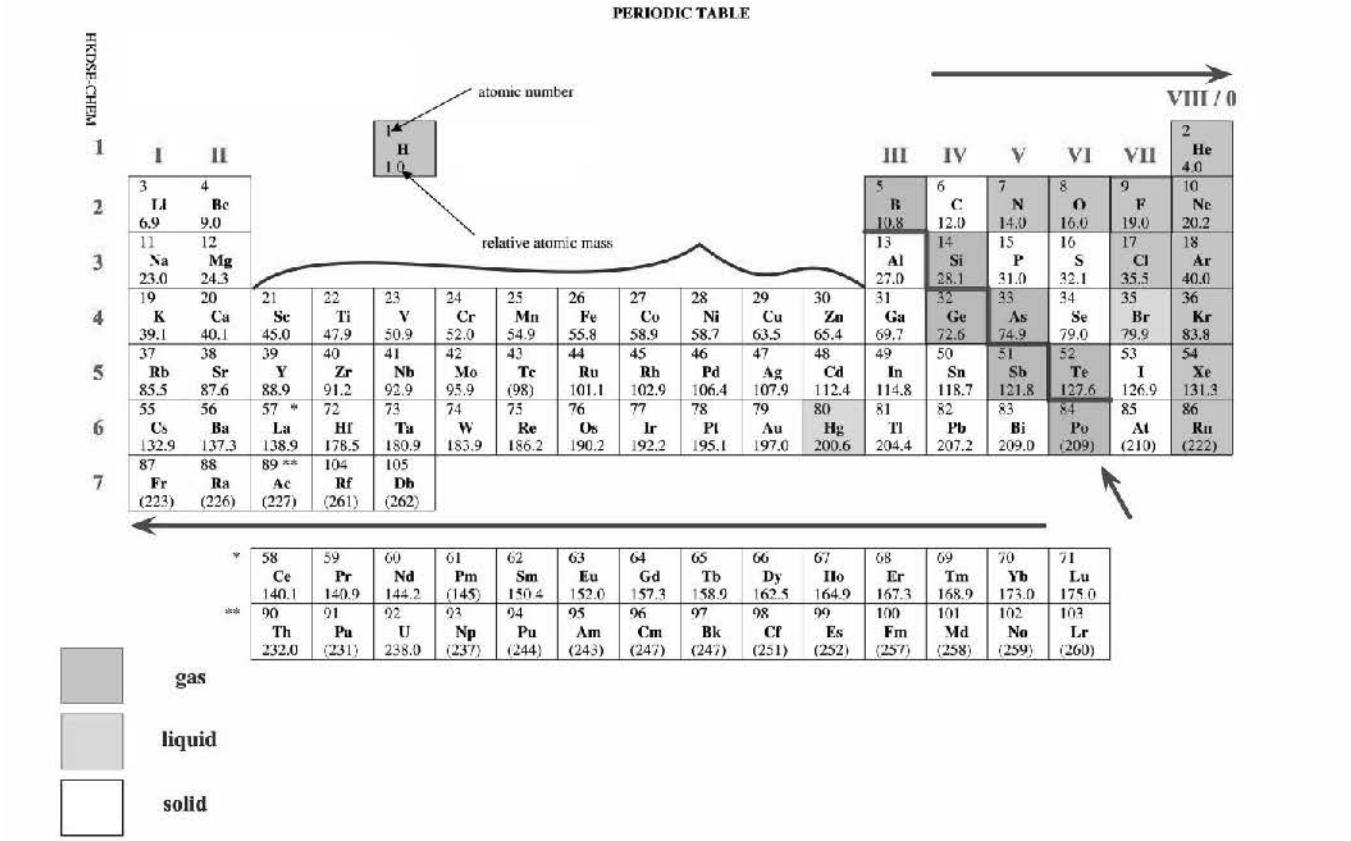
   **(c) Explain why the electronic arrangement of Potassium is 2,8,8,1 instead of 2,8,9.**

3. Write down the electronic arrangements for the following elements:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | **He** |
| **Li** | **Be** | **B** | **C** | **N** | **O** | **F** | **Ne** |
| **Na** | **Mg** | **Al** | **Si** | **P** | **S** | **Cl** | **Ar** |
| **K** | **Ca** | | | | | | |

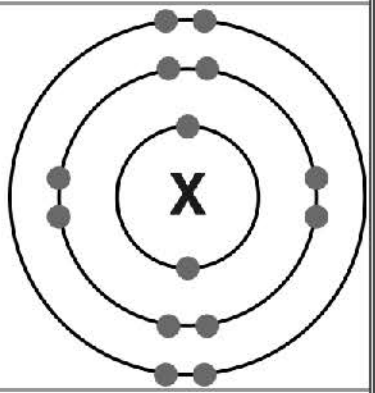
# 2. Periodic Table

- The elements are arranged in order of increasing [ ]
- Periodic similarity in the properties of elements will be observed.




## Examples that you must fully understand

1. Below shows the electron diagram of an atom of element X. Which of the following statements concerning X is / are correct?




***(1) This atom contains 14 protons.***

***(2) X in a period 3 element.***

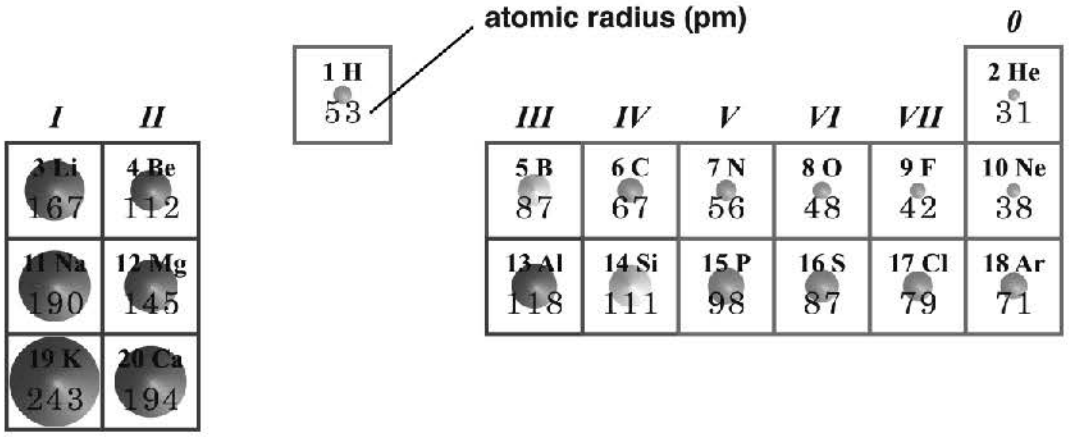
***(3) X is in group IV.***

***(4) The mass number of this atom is 14.***

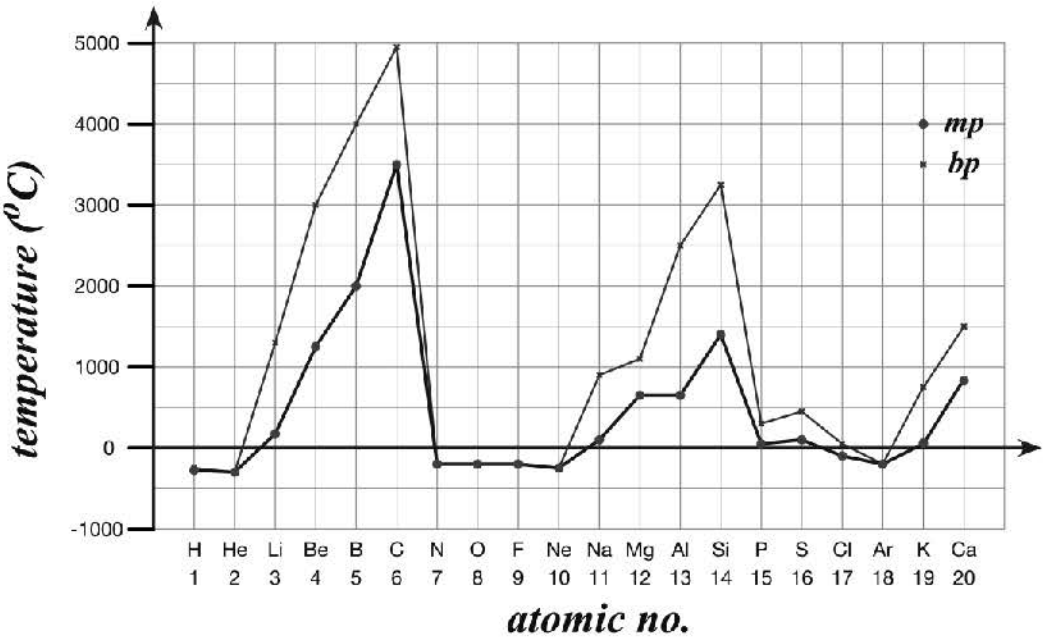
2. The atomic number of iodine is 53. Deduce the electronic arrangement of it.

## A. Period

- **Period** (horizontal row) number = **number of** [ ].
- Change in physical properties of elements across a period (from left to right):
  - **Metals >> Semi-metals >> Non-metals**
  - **Atomic radius** [ ]
    - As nuclear charge increases across a period, **the** [ ] **between the nucleus and the electron cloud** [ ].




  - **Melting point and boiling point:**




  - **Electronegativity increases**
    - **As atomic radius decreases, stronger attraction between** [ ] **and the nucleus**

## B. Group

- **Group** (vertical column) number = equal to the [ ]
- Elements in a group show similar chemical properties:
  - The [ ] properties of an element mainly depend on [ ]
  - Elements in the same group have the same no. of outermost $e^-$, so they have [ ] chemical properties.
  -
- Group names:

| Group | Name |
|---|---|
| I | |
| II | |
| VII | |
| VIII/0 | |

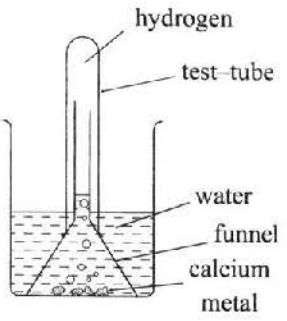
- Change in physical properties of elements across a group (down the group):
  - **Metallic character increases**
  - **Atomic radius increases**
    - Due to increases in the number of [ ]
  - **Melting point and boiling point**
    - Group I and II: [ ] down the group
    - Group VII and VIII/0: [ ] down the group
  - **Electronegativity decreases**

## C. Group I, Alkali Metals

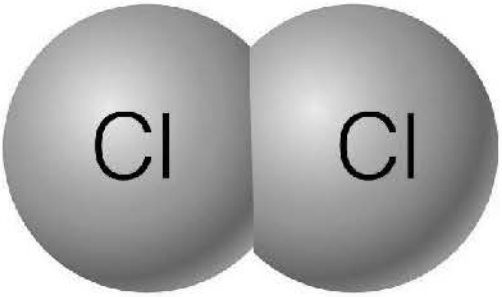
| | Lithium (Li) | Sodium (Na) | Potassium (K) | Rubidium (Rb) | Caesium (Cs) |
|---|---|---|---|---|---|
| **Electronic arrangement** | 2,1 | 2,8,1 | 2,8,8,1 | 2,8,18,8,1 | 2,8,18,18,8,1 |
| **Appearance** | Shiny when freshly cut but soon [ ] in air. | | | | |
| **Soft** | Can be cut by a **knife**. | | | | |
| **Lower mp, bp than other metals** | • Lower mp and bp when compared with other metals.<br>• [ ] down the group. | | | | |
| **Low density** | Low. **Li, Na and K can float on water**. | | | | |
| **Highly reactive** | • **Highly reactive**, must be stored in **paraffin oil** to avoid reaction with air or water<br>• **Reactivity** [ ] down the group<br>➢ Reason:<br>▪ Metals react by [ ]<br>• as **atomic size increases** down the group<br>• **distance** between the **outermost shell $e^-$ and nucleus** [ ]<br>• [ ] **attraction** between the outermost shell $e^-$ and nucleus<br>• [ ] **tendency** to lose electron<br>• More reactive<br>• More reactive than alkaline earth metals (Group II) | | | | |
| **Reaction with water** | React vigorously with **water** to give [ ] and **metal** [ ] **solution**.<br>$Na(s) + H_2O(l) \longrightarrow$ | | | | |
| | Metal floats; Hissing sounds; Colourless gas bubbles | Metal floats; Metals melt into a silvery ball; Hissing sounds; Colourless gas bubbles; Metals burn, Na >> Golden yellow flame<br>K >> Lilac flame | Explosive reaction | | |
| **Reaction with halogens** | React with halogens to form salts<br>$Na(s) + Cl_2(g) \longrightarrow$ | | | | |

## D. Group II, Alkaline Earth Metals

| | Beryllium (Be) | Magnesium (Mg) | Calcium (Ca) | Strontium (Sr) | Barium (Ba) |
|---|---|---|---|---|---|
| **Electronic arrangement** | 2,2 | 2,8,2 | 2,8,8,2 | 2,8,18,8,2 | 2,8,18,18,8,2 |
| **Appearance** | Shiny when fresh but will **tarnish** in air. | | | | |
| **Higher mp, bp than Group I** | • [ ] down the group<br>• But still lower than other metals | | | | |
| **Denser than Group I** | All [ ] in water | | | | |
| **Less reactive than Group I** | • Reactivity [ ] down the group<br>• Less reactive than [ ]<br>➢ Reason:<br>▪ Metals react by **losing** electron<br>▪ As atomic size [ ] from group I to group II<br>• **distance** between the **outermost shell $e^-$ and nucleus decreases**<br>• [ ] **attraction** between the outermost shell $e^-$ and nucleus<br>• [ ] to lose electron<br>▪ Also, group II needs to lose [ ] outermost $e^-$ instead of [ ] in group I<br>▪ Less reactive | | | | |
| **Reaction with water** | Only Ca, Sr and Ba can react with water to give [ ] and **metal** [ ] solution.<br>$Ca(s)+H_2O(l)\longrightarrow$<br>Metal dissolves; Colourless gas bubbles | | | | |
| **Reaction with halogens** | React with halogens to form salts $Mg(s)+Cl_2(g)\longrightarrow MgCl_2(s)$ | | | | |



## E. Group VII, Halogens

| | Fluorine (F) | Chlorine (Cl) | Bromine (Br) | Iodine (I) | Astatine (At) |
|---|---|---|---|---|---|
| **Electronic arrangement** | 2,7 | 2,8,7 | 2,8,18,7 | 2,8,18,18,7 | 2,8,18,32,18,7 |
| **Diatomic molecule** | All of them are [ ] **molecules** = [ ] atoms join together to be [ ]<br>  | | | | |
| **Appearance (All coloured)** | Pale yellow gas | Yellowish green gas | Dark red / brown liquid | Black / purple solid | Black solid |
| **Toxic** | They are all **toxic (poisonous)** and smelly. | | | | |
| **Quite low mp, bp** | Mp and bp [ ] down the group. | | | | |
| **Density** | Density **increases** down the group | | | | |
| **Reactivity** | • Reactivity [ ] down the group<br>➢ Reason:<br>▪ Halogens react by [ ] electron<br>▪ As atomic size **increases** down the group<br>• **distance** between the **incoming $e^-$ and nucleus** [ ]<br>• [ ] **attraction** between the incoming $e^-$ and nucleus<br>• [ ] **likely** to gain the incoming electron<br>• Less reactive | | | | |
| **Reaction with sodium sulphite solution** | All of the halogens react with sodium sulphite to give colourless products.<br>$I_2(aq) + SO_3^{2-}(aq) + H_2O(l) \longrightarrow SO_4^{2-}(aq) + 2I^-(aq) + H^+(aq)$ | | | | |

## F. Group VIII/0, Noble gases

| | Helium (He) | Neon (Ne) | Argon (Ar) | Krypton (Kr) | Xenon (Xe) |
|---|---|---|---|---|---|
| **Electronic arrangement** | 2 | 2,8 | 2,8,8 | 2,8,18,8 | 2,8,18,18,8 |
| | Duplet structure | Octet structure | | | |
| **Reactivity** | • They are all **inert / very unreactive / very stable** due to their [ ] [ ]<br>• They generally DO NOT react with other elements.<br>• | | | | |
| **Monatomic molecules** | All of them are [ ] **molecules** = [ ] **atom is already enough to be stable** | | | | |
| **Appearance** | All are **colourless gases**. | | | | |
| **Very low mp, bp** | Mp and bp **increases** down the group. | | | | |
| **Density** | • Density **increases** down the group<br>• **He and Ne are less dense than air.**<br>• Ar, Kr and Xe are **denser** than air. | | | | |

| | Helium (He) | Neon (Ne) | Argon (Ar) |
|---|---|---|---|
| **Uses** | To fill airship, weather balloon | To fill neon lamp in advertising sign | To fill light bulb |
| |  |   |  |
| **Reason** | as He has a density lower than air and it is non-flammable | as Ne can produce an unmistakable bright reddish-orange light in an electric discharge tube | as Ar non-oxidizing and relatively abundant in air compared to other noble gases |

## Examples that you must fully understand

1. Name the element(s) in the Periodic Table which is / are

**(a) Liquid:**

**(b) Gas:**

**(c) Metal (one):**

**(d) Semi-metal (one):**

**(e) Non-metal (one):**

**(f) Yellow solid:**

**(g) Needed to be stored under paraffin oil (one):**

**(h) Needed to be stored under water:**

**(i) Used to make lilac fireworks:**

**(j) Metal that can float on water:**

**Diatomic molecules (one):**

**(l) Monatomic molecules (one):**

**(m) Having stable electronic arrangement:**

**(n) That needs to gain $e^-$ and become stable (one):**

**(o) That needs to lose $e^-$ and become stable (one):**

**(p) Toxic (one):**

**(q) Non-metal that conduct electricity:**

**(r) Soft metal that can be cut by a knife (one):**

**(s) Used to fill airship:**

**(t) Having the highest boiling point across period 2:**

**(u) The most reactive when they react together (two elements):**

2. When move across a period, which of the following properties increase?

***(1) Electronegativity***

***(2) Ability to attract an electron***

***(3) Number of outermost shell $e^-$***

***(4) Size of an atom***

***(5) Reactivity***

***(6) Electrical conductivity***

***(7) Melting point and boiling point***

***(8) Metallic character***

3. When move down a group, which of the following properties increase?

***(1) Electronegativity***

***(2) Ability to attract an electron***

***(3) Number of outermost shell $e^-$***

***(4) Number of electron shell in an atom***

***(5) Size of an atom***

***(6) Reactivity***

***(7) Electrical conductivity***

***(8) Melting point and boiling point***

***(9) Metallic character***

4. Which of the following statements concerning noble gases is / are correct?

***(1) All noble gases are inert because they have octet structure.***

***(2) All of them will never react with other elements.***

***(3) Their relative atomic masses increase down the group.***

***(4) They have a stable electronic arrangement.***

***(5) Their reactivity increases down the group.***

***(6) Their boiling point increases down the group.***

***(7) Some noble gases are coloured.***

***(8) They are diatomic molecules.***

5. Which of the following statements about the Periodic Table is correct?

***(1) In any group, the atomic size of elements increases with the increasing atomic number.***

***(2) All Group 0 elements are non-metals and all elements with one outermost shell electrons are metals.***

***(3) In any periods (except Period 1), the metallic character of the elements increases with increasing atomic number.***

***(4) All Period 3 elements contain three filled electron shells.***

***(5) Melting point of elements increases across Period 2.***

***(6) Elements in a group have the same number of outermost shell electrons.***

***(7) Elements in the Periodic Table are arranged according to increasing atomic weight.***

6. Mg and Ca have similar properties because

***A. their atoms have the same atomic structure.***

***B. their atoms have the same number of electron shells.***

***C. their atoms have the same number of electrons in their outermost shells.***

***D. their atoms have the same electronic arrangement.***

7. This question is about Caesium (Cs).

**(a) Which is more reactive? Cs or K? Explain briefly.**

Both Cs and K belong to Group I. Reactivity of Group I elements [ ].
As Cs is [ ] K, Cs is more [ ].

**(b) Write down the equation when Cs reacts with water.**

**(c) Which is more reactive? Cs or Barium (Ba)?**

Reactivity of Group I elements is [ ] than the Group II elements in the same period.
Therefore, Cs, as a Group I element is [ ] than Ba which is in Group II.

**(d) Which has a higher melting point? Cs or Li?**

**(e) Where should Cs be stored?**

Cs should be stored in [ ].

8. Astatine is a Group VII element below iodine in the Periodic Table. Which of the following statements concerning astatine is incorrect?

   **A. *Astatine is a solid under room conditions.***

   **B. *Astatine has 7 outermost electrons.***

   **C. *Astatine is colourless.***

   **D. *Astatine reacts with sodium.***

   **E. *Astatine molecule is diatomic.***

9. Below shows magnified figures of some substances. Describe the figures with the help of the following terms:

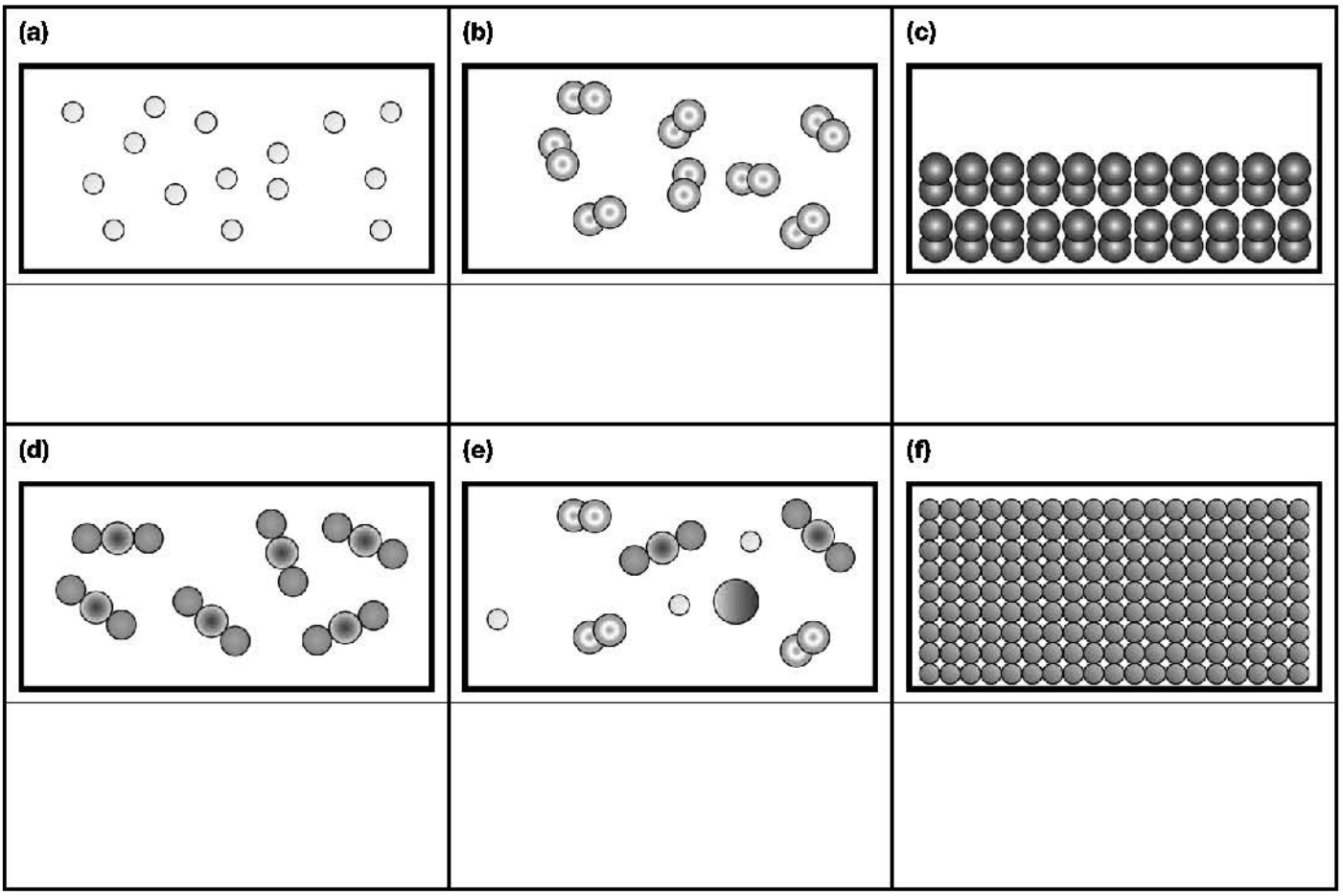
   **(i) *atom, monatomic molecule, diatomic molecule, polyatomic molecule***

   **(ii) *element, compound, mixture***

   **(iii) *solid, gas***

   **(iv) *metal, non-metal***

   **(v) *give examples***




10. How many elements does ammonium dichromate [$(NH_4)_2Cr_2O_7$] consist of?