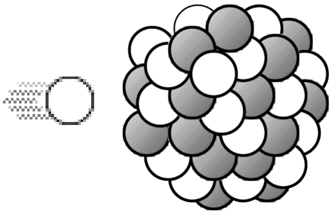
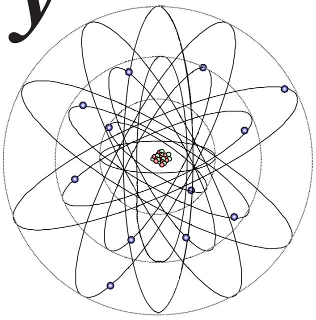
# National 5 Chemistry

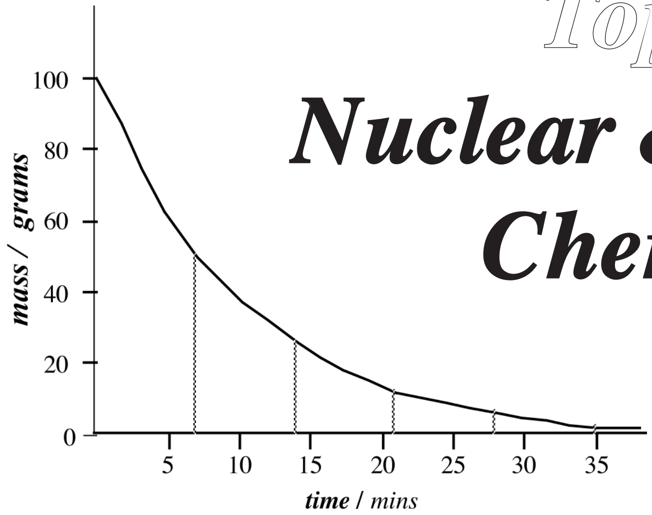


## Unit 1:



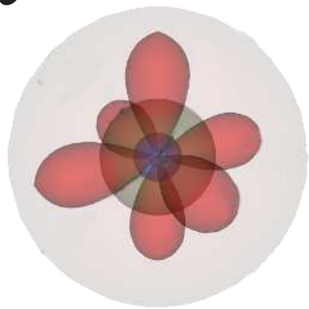
## Chemical Changes & Structure

Student:



## Topic 2

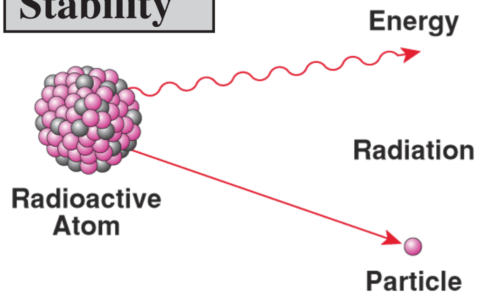
# Nuclear & Electron Chemistry



| Topics | | Sections | Score | Done | Checked |
|---|---|---|---|---|---|
| 2.1 **Radioactivity** | 1. | Stability | | | |
| | 2. | Emissions | | | |
| | 3. | Nuclear Equations | | | |
| | | ***Self -Check Questions 1 - 8*** | Score: / | | |
| 2.2 **Nuclear Chemistry** | 1. | Radioactivie Decay | | | |
| | 2. | Using Radioisotopes | | | |
| | 3. | Nuclear Energy | | | |
| | | ***Self -Check Questions 1 - 5*** | Score: / | | |
| 2.3 **Electron Arrangements** | 1. | Electron Shells | | | |
| | 2. | Electrons & The Periodic table | | | |
| | 3. | Electrons & Bonding Powers | | | |
| | | ***Self -Check Questions 1 - 8*** | Score: / | | |
| **Consolidation Work** | | Consolidation A | Score: / | | |
| | | Consolidation B | Score: / | | |
| | | Consolidation C | Score: / | | |
| | | Consolidation D | Score: / | | |
| *End-of-Unit Assessment* | | Score: % | Grade: | | |

# 2.1 Radioactivity

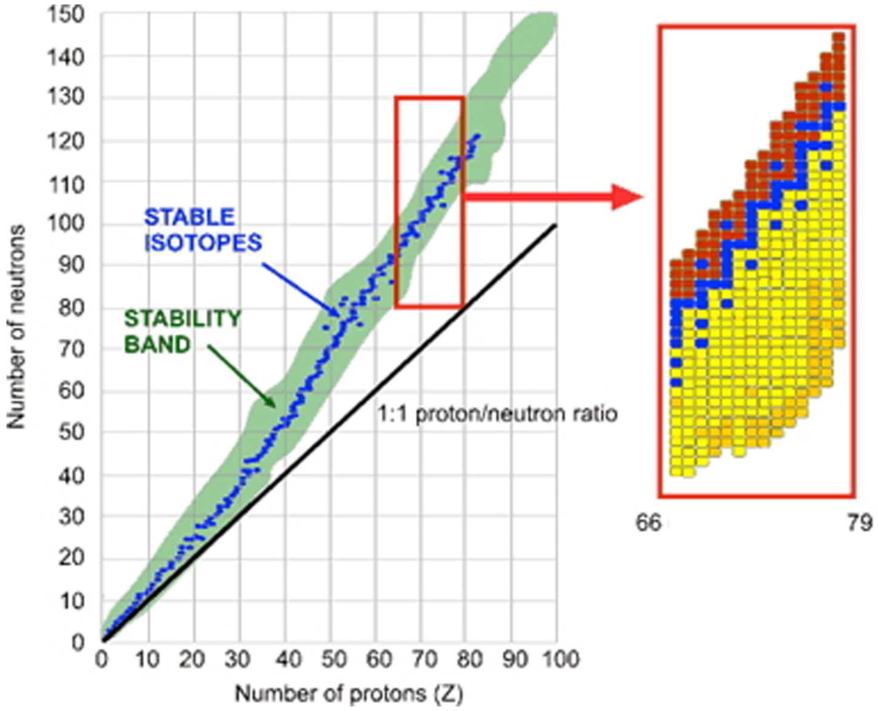
## Stability



Most elements have ***iso*** , most of which are ***unsta*** .

Radioactivity is the result of ***unsta nuc*** *rearranging* to form ***sta nuc*** - ***ene*** is released and, often, a ***particle*** is also ***emi*** .

The stability of a nucleus depends on its ***pro neut balance***;



There are different ways of representing ratios.

In this course we will often convert our ratios into ***fractions***:

eg neutron : proton ratio

= ***neutron / proton***

eg $^{24}_{12}\text{Mg} = \frac{12}{12} = 1$

$^{115}_{50}\text{Sn} = \frac{\phantom{00}}{\phantom{00}} =$

$^{200}_{80}\text{Hg} = \frac{\phantom{00}}{\phantom{00}} =$

✶ ***sma nuclei*** usually 'prefer' ***equ numbers***:- *neutron : proton ratio = 1*

***unsta nuc*** usually have *too many* ***neut*** , so a ***neut*** changes into a ***pro*** and an ***elec*** . The ***elec*** is ***emi*** as a β-*particle*.

$$^{1}_{0}\text{n} \longrightarrow {}^{1}_{1}\text{p} + {}^{0}_{-1}\text{e}$$

e.g. $$^{14}_{6}\text{C} \longrightarrow {}^{14}_{7}\text{N} + {}^{0}_{-1}\text{e}$$

✶ ***larg nuclei*** 'need' ***mo neut*** :- *neutron : proton ratio = 1.5*

***unst nuc*** usually have *too much mass*, so an α-*particle*is ***emi*** to *reduce mass* and ***impr*** the *proton:neutron ratio*.

e.g. $$^{232}_{90}\text{Th} \longrightarrow {}^{228}_{88}\text{Ra} + {}^{4}_{2}\text{He}$$

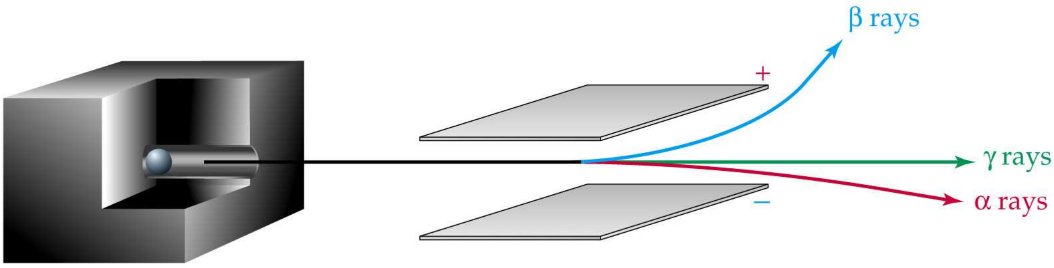
✶ above atomic number 83 almost all isotopes are unstable.

Other processes such as '*electron capture*' , '*neutron capture*' and '*proton emission*' are possible but the main processes are the ***emission*** of α-*particles* and β-*particles*.

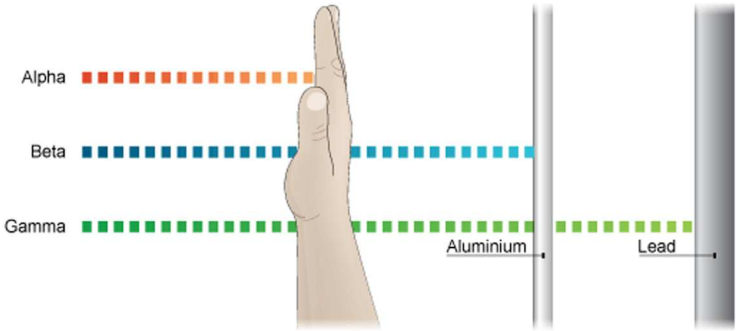
## Emissions

α-particles
β-particles
γ-rays

Most radioactivity involves the ***emi*** of - and -particles but ***en*** , in the form of *high frequency electromagnetic radiation* is also released.These γ-rays are the same as other ***electro radia*** such as *radio-waves*, *visible light* and *x-rays* but are of ***hig ene*** and, therefore, ***more dang*** .



| ***Property*** | ***Type of emission*** | | |
|---|---|---|---|
| | α-***particle*** | β-***particle*** | γ-***rays*** |
| ***nature*** | 2 ***pro*** , 2 ***neut***<br>(He nucleus) | ***elec***<br>( n → p + e) | high ***frequ***<br>radiation |
| ***charge*** | | | 0 |
| ***mass*** | | | 0 |
| ***stopped by*** | ***pap*** | ***alum*** foil | ***le*** sheet |
| ***electric field*** | *slightly* towards<br>***neg*** plate | *greatly* towards<br>***pos*** plate | no<br>effect |



All 3 types of ***rad*** are capable of knocking ***ele*** off any atoms they ***coll*** with so are sometimes referred to as ***ionising rad*** .

The ***ionising*** effect of the ***rad*** is used to both ***det*** and ***cou*** radiation - each particle entering the *detector* triggers an ***ele*** and the ***flow of electrons*** (*current*) determines the ***am*** .

The ***ion*** effect of the ***rad*** can lead to ***har*** changes in ***human tissue*** - hence the protective clothing.

## Nuclear Equations

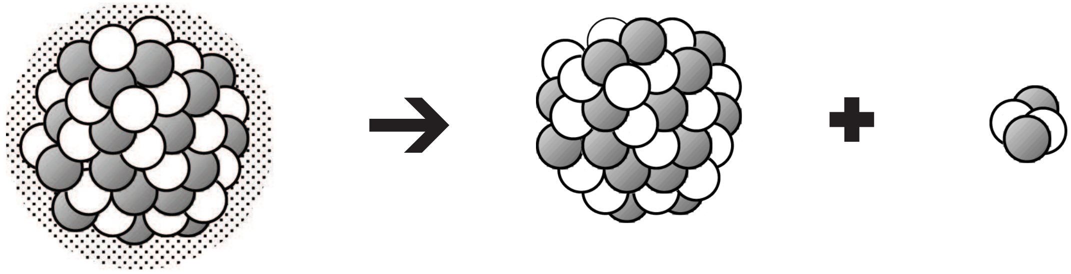
*With the exception of γ-rays, all nuclear reactions involve particles with mass and charge so we can continue to write equations to represent these processes.*

***mass*** → 206
***charge*** → 82

$$^{206}_{82}\mathrm{Pb}$$

Most atoms continue to be represented by their usual ***sym*** except that ***ma     numbers*** are now *essential* and the ***'ato number'*** now represents the *'charge on the particle'*

***For example:***



an ***unsta*** *polonium* nucleus a ***sta*** *lead* nucleus an α*-particle*

$^{210}_{84}\mathrm{Po}$ $^{206}_{82}\mathrm{Pb}$ $^{4}_{2}\mathrm{He}$

Other particles that need to be learnt are:-

| | | |
|---|---|---|
| $^{4}_{2}\mathrm{He}$ | α **- *particles*** | ( strictly speaking $^{4}_{2}\mathrm{He}^{2+}$ ) |
| $^{0}_{-1}\mathrm{e}$ | β **- *particles*** | ( slow moving electrons emitted from the nucleus. ) |
| $^{1}_{0}\mathrm{n}$ | ***neutrons*** | |
| $^{1}_{1}\mathrm{p}$ | ***protons*** | ( sometimes represented as $^{1}_{1}\mathrm{H}^{+}$ since a hydrogen ion is just a proton ) |

As with all other ***equa***        , these must be ***bal***          . This means that the *overall mass* on both sides must be the ***sa***      and the *overall charge* on both sides must be the ***sa***     .

e.g. $^{14}_{6}\mathrm{C} \longrightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}\mathrm{e}$

*mass* = *mass* = + =

*charge* = *charge* = + =

*Typical processes include:-*

***Alpha decay*** $^{230}_{92}\mathrm{U} \longrightarrow \qquad\qquad + \; ^{4}_{2}\mathrm{He}$

***Beta decay*** $^{216}_{84}\mathrm{Po} \longrightarrow \qquad\qquad + \; ^{0}_{-1}\mathrm{e}$

***Gamma decay*** *this is the emission of energy so no equation possible*

***Neutron capture/ Proton emission***

*this reaction occurs naturally in the uppper atmosphere triggered by cosmic rays*

$$^{14}_{7}\mathrm{N} + \; ^{1}_{0}\mathrm{n} \longrightarrow \qquad\qquad + \; ^{1}_{1}\mathrm{p}$$

***Electron capture***

*sometimes isotopes have too few neutrons so capture an electron from their first shell and convert a proton into a neutron*

$$^{37}_{18}\mathrm{Ar} + \; ^{0}_{-1}\mathrm{e} \longrightarrow$$

***Nuclear Fusion***

*in suns, at temperatures of about 10 million K, small atoms can fuse together*

$$^{2}_{1}\mathrm{H} + \; ^{3}_{1}\mathrm{H} \longrightarrow \qquad\qquad + \; ^{1}_{0}\mathrm{n}$$

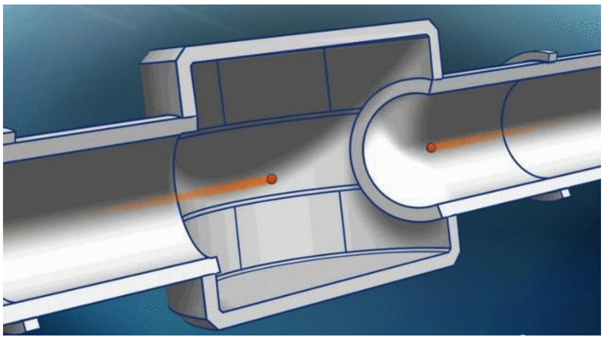
*'Man-made' processes include:-*

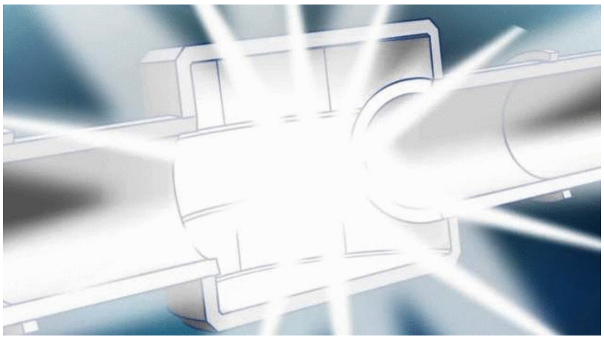
***Nuclear Fission***

*in power stations atoms are bombarded with neutrons to form unstable nuclei which then split apart to form smaller atoms*

$$^{235}_{92}\mathrm{U} + \; ^{1}_{0}\mathrm{n} \longrightarrow \qquad\qquad \longrightarrow \; ^{140}_{54}\mathrm{Xe} + \qquad\qquad + \; 2\,^{1}_{0}\mathrm{n}$$

*The development of high energy particle accelerators means that just about any particle can be fired into an atom leading to a variety of methods for producing various unstable nuclei -**radioisotopes***





### Q1. H

Phosphorus-32 and strontium-89 are two radioisotopes used to study how far mosquitoes travel.

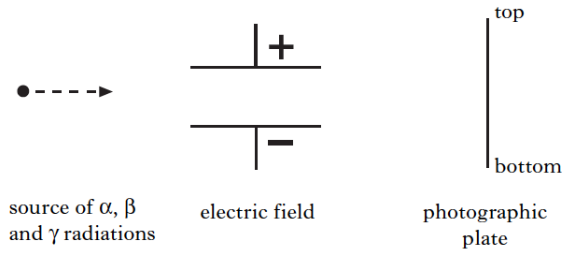
Strontium-89 decays by emission of a beta particle.

Complete the nuclear equation for the decay of strontium-89.

$${}^{89}\text{Sr} \rightarrow$$

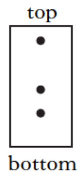
### Q2. H

Alpha, beta and gamma radiation is passed from a source through an electric field onto a photographic plate.

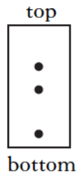


Which of the following patterns will be produced on the photographic plate?

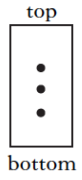
**A**



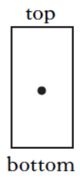
**B**



**C**



**D**



### Q3. H

From which of the following could ${}^{32}_{15}\text{P}$ be produced by neutron capture?

**A** ${}^{33}_{15}\text{P}$

**B** ${}^{32}_{16}\text{S}$

**C** ${}^{31}_{15}\text{P}$

**D** ${}^{31}_{16}\text{S}$

### Q4. H

Carbon-13 NMR is a technique used in chemistry to determine the structure of organic compounds.

Calculate the neutron to proton ratio in an atom of carbon-13.

### Q5. H

Which particle will be formed when an atom of ${}^{211}_{83}\text{Bi}$ emits an α-particle and the decay product then emits a β-particle?

**A** ${}^{207}_{82}\text{Pb}$

**B** ${}^{208}_{81}\text{Tl}$

**C** ${}^{209}_{80}\text{Hg}$

**D** ${}^{210}_{79}\text{Au}$

### Q6. H

The element iodine has only one isotope that is stable. Several of the radioactive isotopes of iodine have medical uses. Iodine-131, for example, is used in the study of the thyroid gland and it decays by beta emission.

***a)*** why are some atoms unstable?

________________________________________

________________________________________

***b)*** complete the balanced nuclear equation for the beta decay of iodine-131.

$${}^{131}_{53}\text{I} \rightarrow$$

### Q7. H

Thorium-227 decays by alpha emission.

***a)*** Complete the nuclear equation for the decay of thorium-227.

$${}^{227}\text{Th} \rightarrow$$

***b)*** A sample of thorium-227 was placed in a wooden box. A radiation detector was held 10 cm away from the box.

Why was alpha radiation not detected?

________________________________________

________________________________________

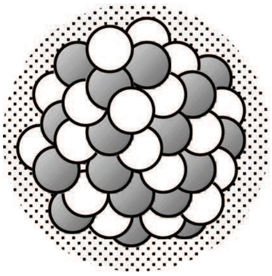
### Q8. H

An atom of ${}^{227}\text{Th}$ decays by a series of alpha emissions to form an atom of ${}^{211}\text{Pb}$. How many alpha particles are released in the process?

________________________________________

# 2.2 Nuclear Chemistry

## Radioactive Decay



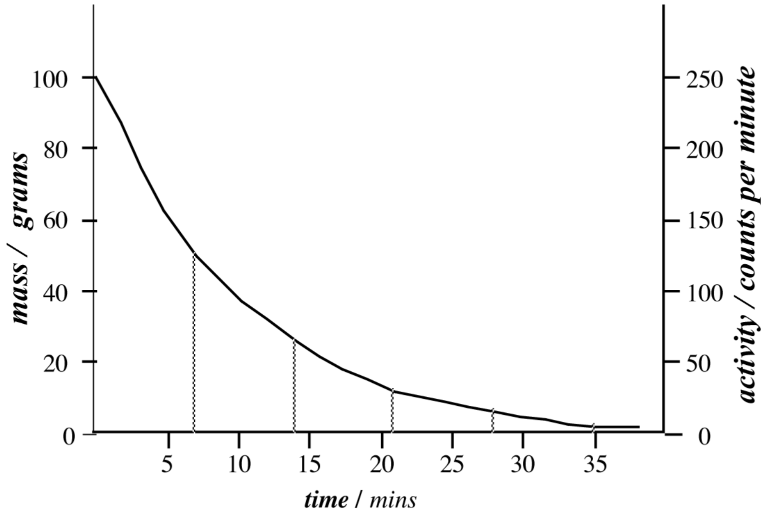
The breakdown of the ***nuc*** of ***unsta*** atoms is known as ***decay***.

It is a totally ***rand*** process, i.e it is ***impo*** to predict exactly when a *particular* ***nuc*** will break apart.

It is also a purely ***nuc*** reaction i.e. it is not affected by most of the factors that affect normal chemical reactions such as:-

| | |
|---|---|
| *state* | solid , liquid, gas, solution, lump, powder etc. makes no difference |
| *temperature* | do not decay faster when hot |
| *form* | atoms, ions, single or in molecules makes no difference |
| *pressure* | has no effect |
| *catalysts* | have no effect |

Though ***ran*** , the ***dec*** will still follow a ***predi*** ***patt*** .

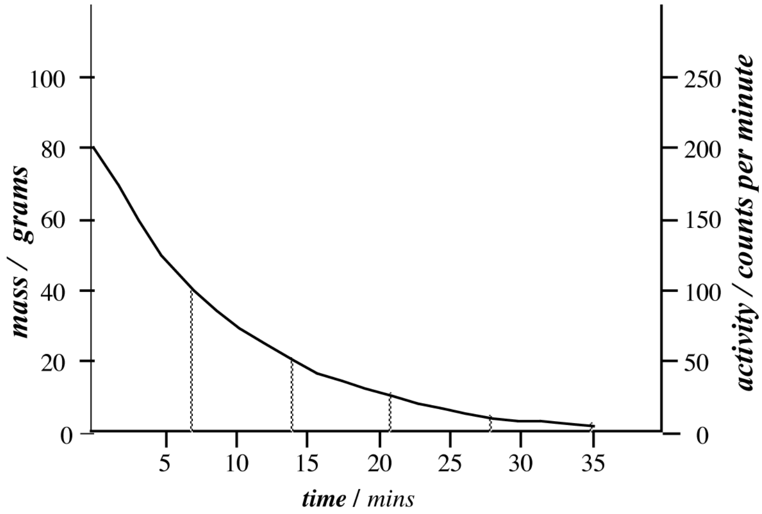


Starting with g of radioactive material, a ***gei*** ***counter*** could detect particles being ***emi*** every minute.

The ***ma*** of radioactive material ***decr*** , as does the ***act*** .

The ***decr*** is not ***cons*** , (i.e. not a ***stra*** ***line***), but it does follow a ***patt*** .

After a *certain time* the ***ma*** of radioactive material will fall to *half its original value*. The ***act*** will also be *halved*. It will then take the *same length of time* for the ***ma*** , and the ***act*** , to *half again*. This time is known as the ***half-life*** ( $t_{½}$ ). In the example above, the half-life, $t_{½}$ , = minutes.



Starting with a ***diff*** ***mass***, **80**g, of radioactive material, a ***gei*** ***counter*** would detect a *lower* ***act*** ,only particles being ***emi*** every minute.

However the ***half-life*** remains at minutes.

The ***patt*** for the ***dec*** remains the same *regardless of the mass you start with*.

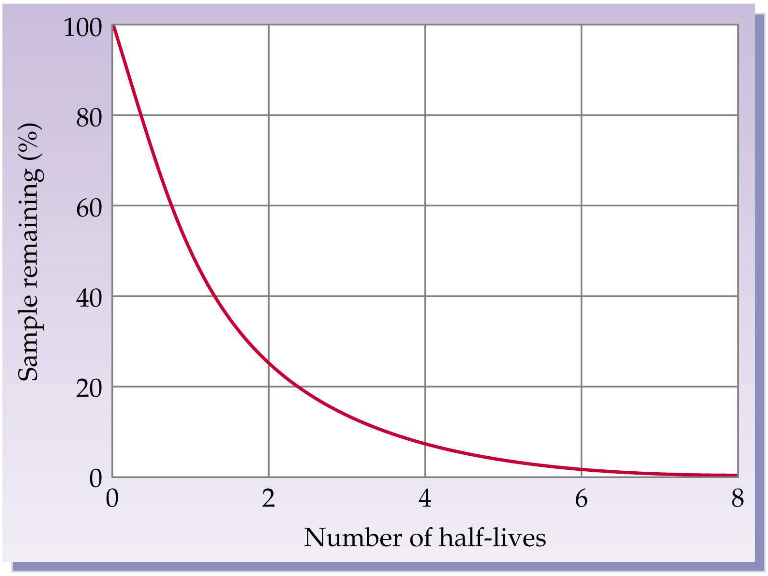
***Diff*** *isotopes* ***dec*** at *different* ***rates*** but all show this pattern:-

some have a *very* ***sho*** half-life e.g $^{220}$Ra $t_{½}$ = 55 seconds

others have a *very* ***lo*** half-life e.g $^{238}$U $t_{½}$ = 4.51 x $10^9$ years

| **Radioisotope** | **Symbol** | **Radiation** | **Half-Life** | **Use** |
|---|---|---|---|---|
| Tritium | $^{3}_{1}$H | $\beta^-$ | 12.33 years | Biochemical tracer |
| Carbon-14 | $^{14}_{6}$C | $\beta^-$ | 5730 years | Archaeological dating |
| Phosphorus-32 | $^{32}_{15}$P | $\beta^-$ | 14.26 days | Leukemia therapy |
| Potassium-40 | $^{40}_{19}$K | $\beta^-$ | $1.28 \times 10^9$ years | Geological dating |
| Cobalt-60 | $^{60}_{27}$Co | $\beta^-, \gamma$ | 5.27 years | Cancer therapy |
| Technetium-99*m*[*] | $^{99m}_{43}$Tc | $\gamma$ | 6.01 hours | Brain scans |
| Iodine-123 | $^{123}_{53}$I | $\gamma$ | 13.27 hours | Thyroid therapy |
| Uranium-235 | $^{235}_{92}$U | $\alpha, \gamma$ | $7.04 \times 10^8$ years | Nuclear reactors |

[*] The *m* in technetium-99*m* stands for *metastable*, meaning that it undergoes γ emission but does not change its mass number or atomic number.



We consider that an ***iso*** is ‘safe’ when the level of its ***act*** falls to the level of normal ***background radiation***.

Generally it takes about 6 to 8 half-lives.

We are all exposed to ***radi*** all the time. About 85% of this is natural due to radioisotopes in rocks and radiation from the sun.

About 15% is man-made resulting from ***med*** ***uses*** and, *more controversially*, from *leakages* from ***nuc*** ***power stations*** and the ***disposal of nuc*** ***waste***.

## Using Radioisotopes

*There are very many uses for radioisotopes, these are a few.*

***Medical*** ***examining body tissues or organs***

e.g $^{132}$I and $^{125}$I are used to test the health of the ***thy*** gland

***cancer treatments***

e.g $^{60}$Co is a powerful γ-emitter used to treat deep-seated ***tum***

$^{32}$P is a weak β-emitter which can be applied directly to treat ***sk cancer***

wires of $^{198}$Au can be placed inside ***tum*** to dose them with radiation

***Industrial*** ***detecting flaws***

e.g $^{60}$Co can be used to take 'X-ray pictures' of ***wel*** and castings

***measuring engine wear***

e.g. engine/oil makers used ***pist rings*** with a thin layer of radioactive material on the surface to monitor wear without ***disma*** the engine

***detecting cracks in jet engines***

e.g γ-radiation from $^{192}$Ir is used to detect ***cra*** in jet turbines

***domestic smoke detectors***

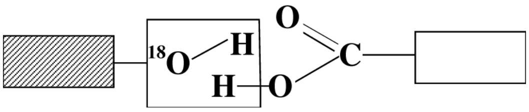
e.g. $^{241}$Am emits α-particles that even a small amount of ***smo*** blocks

***measuring thickness/checking contents***

e.g. the thickness of ***ste*** sheet or the level of ***be*** in a can can be monitored

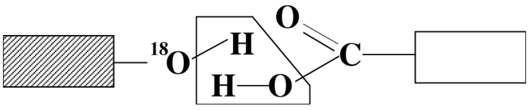
***Scientific*** ***reaction pathways - using isotopic labelling***

e.g $^{18}$O was used to determine the *mechanism* of the ***esteri*** reaction



*predicted mechanism*

*radioactive $^{18}$O should have been part of the $H_2O$ molecule formed*



*actual mechanism*

*in fact, $^{18}$O remained as part of the ester molecule.*

e.g $^{32}$P was used to follow the routetaken through plants by ***phos***

ADP → ATP etc

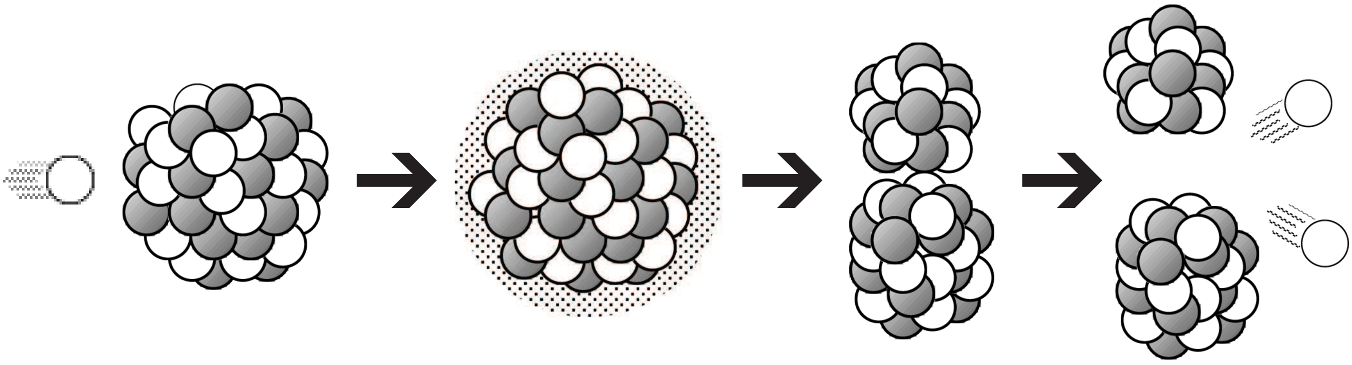
***dating***

e.g. $^{14}$C is produced naturally in the upper ***atmo*** . While alive, ***pla*** and ***ani*** have a constant ratio of $^{12}$C:$^{14}$C. Once they die the $^{14}$C ***dec*** . The half-life for $^{14}$C is about 5,600 years so the age of any object made from a living organism can be ***estim*** by comparing it with a similar object today.

## Nuclear Energy

*Both the **fusion** (smashing together) and the **fission** (splitting apart) of atoms provide potential for generating large amounts of energy.*

### *Nuclear Fission*



One of the possible reactions that could take place in a ***nuc*** power station is:-

$$^{1}_{0}n \quad + \quad ^{235}_{92}U \longrightarrow \qquad\qquad \longrightarrow \; ^{140}_{54}Xe \quad + \qquad\qquad + \quad 2\,^{1}_{0}n$$

A slow moving ***neut*** is ***cap*** by a ***Ura*** atom which then ***spl*** apart to produce two smaller *'daughter'* atoms. The ***two*** neutrons produced can then go on to react with other ***Ura*** atoms leading to a ***chain reaction***.

A mole of Uranium, g, yields as much energy as 60 tonnes of high quality coal which would also release 220 tonnes of $CO_2$ into the ***atmos*** . Nuclear power stations could replace conventional ***foss fuel*** power stations but....

***Advantages***

- no '***gree*** ' gases emitted
- no $SO_2$ to add to '***ac rain***'
- safer ***min*** uranium than ***min*** coal
- uranium reserves will last longer than ***foss fuel*** reserves
- less ***vis*** impact than coal- or oil-fired power stations or wind farms etc
- fewer ***stat*** needed

***Diadvantages***

- possibility of ***disas*** accident
- increase in '***back*** ' radiation
- problems ***stor*** long term waste
- slow to change output levels to respond to peaks of demand
- ***plut*** produced may lead to increase in nuclear ***wea***
- much more ***expe*** to build
- more ***expe*** to decommission

### *Nuclear Fusion*

This is many peoples hope for the ***fut*** . The main ***raw mat*** would be ***hydr*** atoms extracted from ***wat*** and it would produce no ***dang*** ( long $t_{½}$ ) ***radio*** products. It would replicate one of the main reaction that powers a ***st*** .

$$^{2}_{1}H \quad + \quad ^{3}_{1}H \quad \longrightarrow \qquad\qquad + \quad ^{1}_{0}n$$

The major difficulty is bringing ***nuc*** together (*enormous* ***repul*** ) long enough to ***fu*** together. Very ***expe*** devices are being tested but, so far, no-one has achieved ***fus*** for more than a few seconds or succeeded in producing ***more ene*** than was needed to achieve ***fus*** .

In ***sta*** and ***neb*** , ***temp*** of several ***mill*** degrees Celcius are attained and ***ato*** possess so much ***ene*** that ***fus*** can occur and larger ***nuc*** can be formed.

$$3\ {}^{4}_{2}\mathrm{He} \longrightarrow$$

$${}^{12}_{6}\mathrm{C} + {}^{4}_{2}\mathrm{He} \longrightarrow$$

In the *heaviest*, ***ho*** stars, even heavier ***ele*** can be produced. These heavier ***ele*** form the *core* of the ***st*** . Once iron is formed, too much energy is ***abs*** in the core and eventually the star will go *supernova* and ***expl*** . This disperses the ***ele*** causing new *suns* and *planets* to form. All *naturally-occuring* ***ele*** have been formed in this way over ***bill*** of years.

## Q1. H

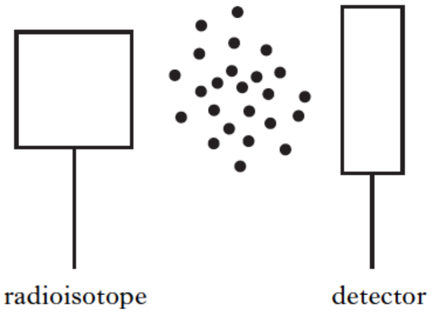
$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

The above process represents

**A** nuclear fusion
**B** nuclear fission
**C** neutron capture
**D** proton capture

## Q2. H

Some smoke detectors make use of radiation which is very easily stopped by tiny smoke particles moving between the radioactive source and the detector.



The most suitable type of radioisotope for a smoke detector would be

**A** an alpha-emitter with a long half-life
**B** a gamma-emitter with a short half-life
**C** an alpha-emitter with a short half-life
**D** a gamma-emitter with a long half-life.

## Q3. H

Phosphorus-32 and strontium-89 are two radioisotopes used to study how far mosquitoes travel.

In an experiment, 10 g of strontium-89 chloride was added to a sugar solution used to feed mosquitoes.

*a)* The strontium-89 chloride solution was fed to the mosquitoes in a laboratory at 20 °C. When the mosquitoes were released, the outdoor temperature was found to be 35 °C.

What effect would the increase in temperature have on the half-life of the strontium-89?

________________________________________

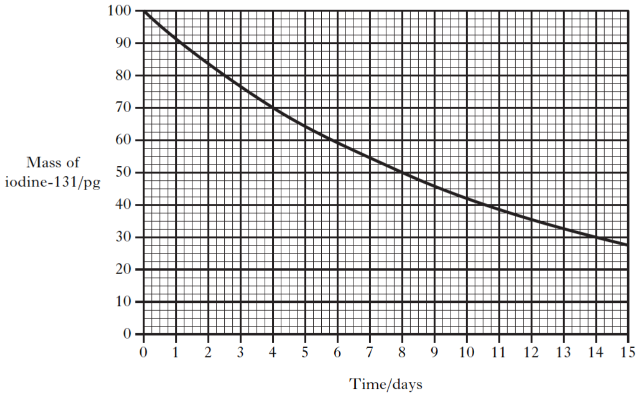
*b)* A mosquito fed on a solution containing phosphorus-32 is released. Phosphorus-32 has a half-life of 14 days.

When the mosquito is recaptured 28 days later, what fraction of the phosphorus-32 will remain?

________________________________________

## Q4. H

The graph shows how the mass of iodine-131 in a sample changes over a period of time.



What is the half-life of this isotope?

__________________

## Q5. H

Positron emission tomography, PET, is a technique that provides information about biochemical processes in the body.

Carbon-11, $^{11}C$, is a positron-emitting radioisotope that is injected into the bloodstream.

A positron can be represented as $^{0}_{1}e$

*a)* Complete the nuclear equation for the decay of $^{11}C$ by positron-emission.

$$^{11}C \rightarrow$$

*b)* A sample of $^{11}C$ had an initial count rate of 640 counts min$^{-1}$. After 1 hour the count rate had fallen to 80 counts min$^{-1}$.

Calculate the half-life, in minutes, of $^{11}C$.

____________ minutes

*c)* $^{11}C$ is injected into the bloodstream as glucose molecules ($C_6H_{12}O_6$). Some of the carbon atoms in these glucose molecules are $^{11}C$ atoms.

The intensity of radiation in a sample of $^{11}C$ is compared with the intensity of radiation in a sample of glucose containing $^{11}C$ atoms. Both samples have the same mass.

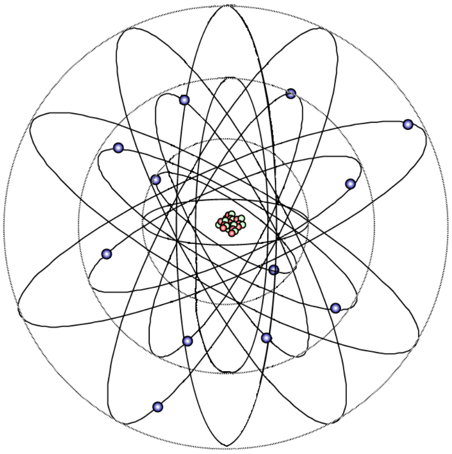
Which sample has the higher intensity of radiation? Give a reason for your answer.

________________________________________

________________________________________

# 2.3 Electron Arrangement

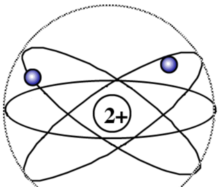
## Electron Shells



***Charge*** - ***el*** are ***ch*** particles. They carry one unit of ***ne*** charge.

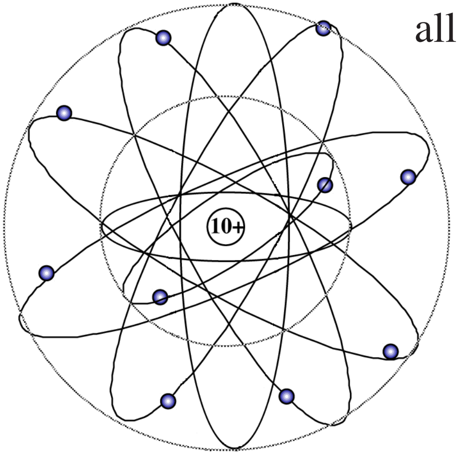
***Position*** - they are found in the ***space*** around the ***nu*** in *regions* called ***orbitals***

***Mass*** - they are extremely ***sm and li*** . (About 1/2000th as heavy as a ***pr*** ).



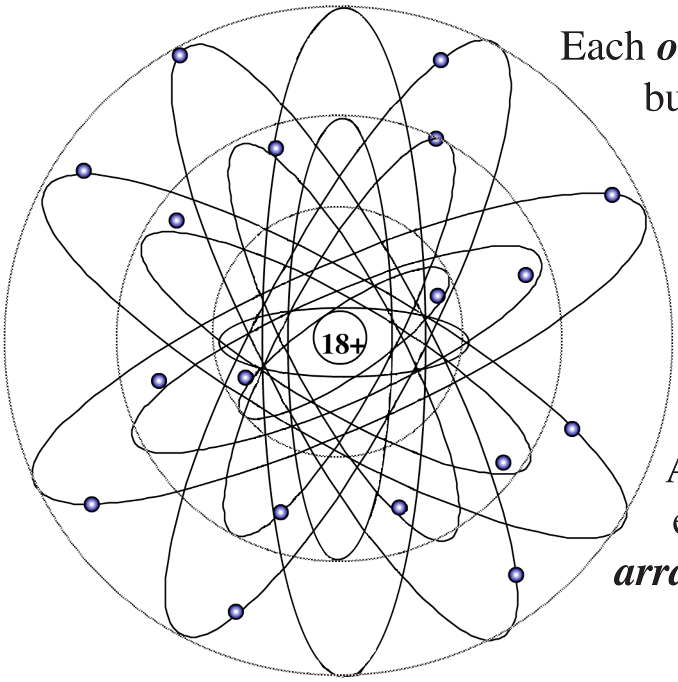
Some of the ***el*** are found quite close to the ***nu*** in what we call the ***F Shell***. These electrons have ***least en*** .

There is only room for electrons in the ***F Shell***, ( the repulsive forces between the ***el*** are too strong to allow any more).



The next group of electrons are found ***fu*** out from the nucleus in what we call the ***S*** Shell. These electrons have ***more en*** .

There is room for electrons in this shell. There are possible paths ( ***or*** ) that the electrons can follow.



Each ***or*** is able to hold electrons, but they will not '***pa up***' until there are no more ***em*** orbitals available. i.e. after electrons.

The ***T Shell*** is even ***fu out*** from the nucleus. These electrons have even ***more en*** .

Again, there are ***or*** and room for electrons in total. We write this ***electron arrangement*** as:-

**2, ,**

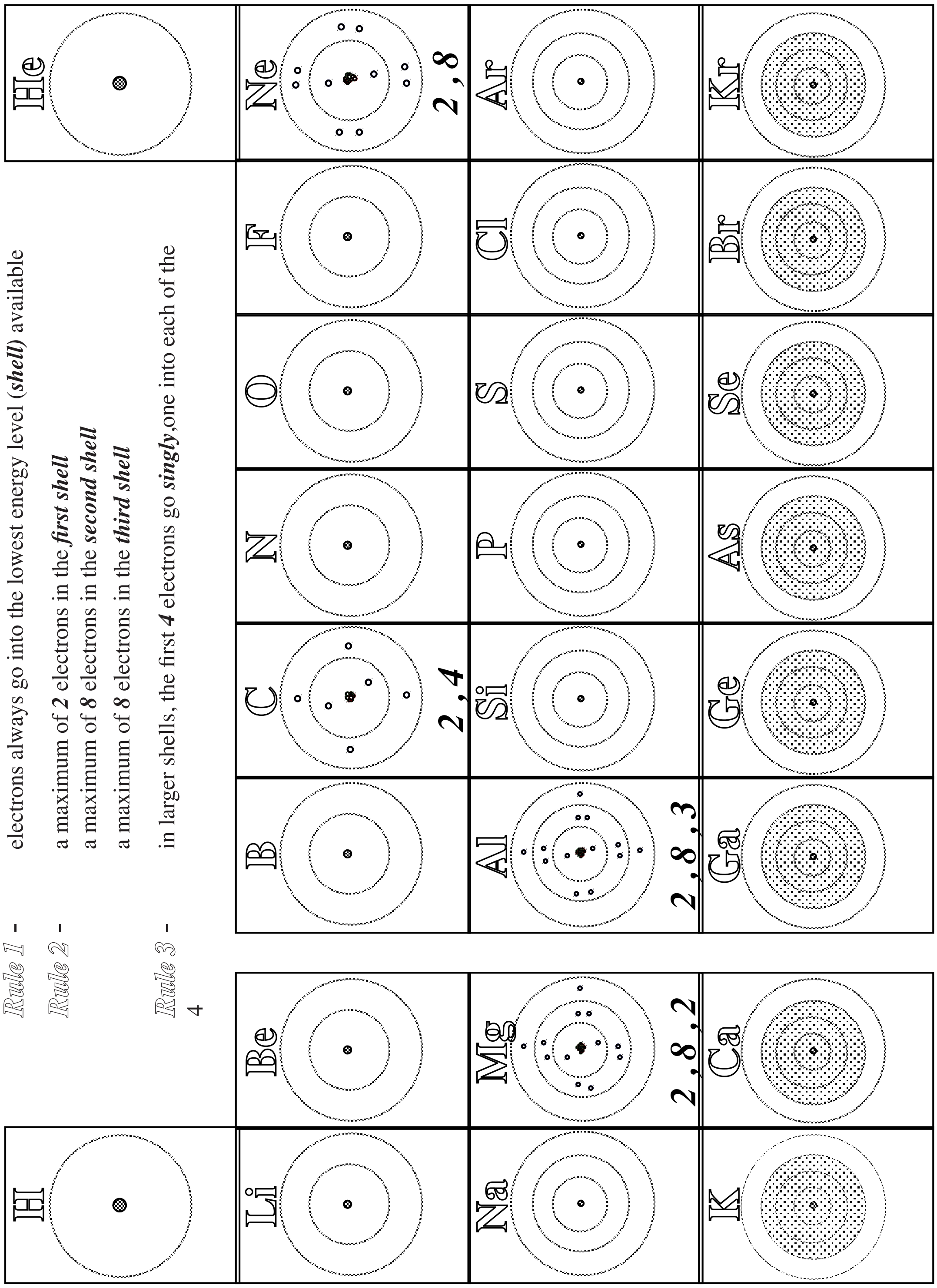
## Electrons & The Periodic Table

### Electron Arrangements

*Rule 1* - electrons always go into the lowest energy level (***shell)*** available

*Rule 2* - a maximum of ***2*** electrons in the ***first shell***
a maximum of ***8*** electrons in the ***second shell***
a maximum of ***8*** electrons in the ***third shell***

*Rule 3* - in larger shells, the first ***4*** electrons go ***singly***,one into each of the
4



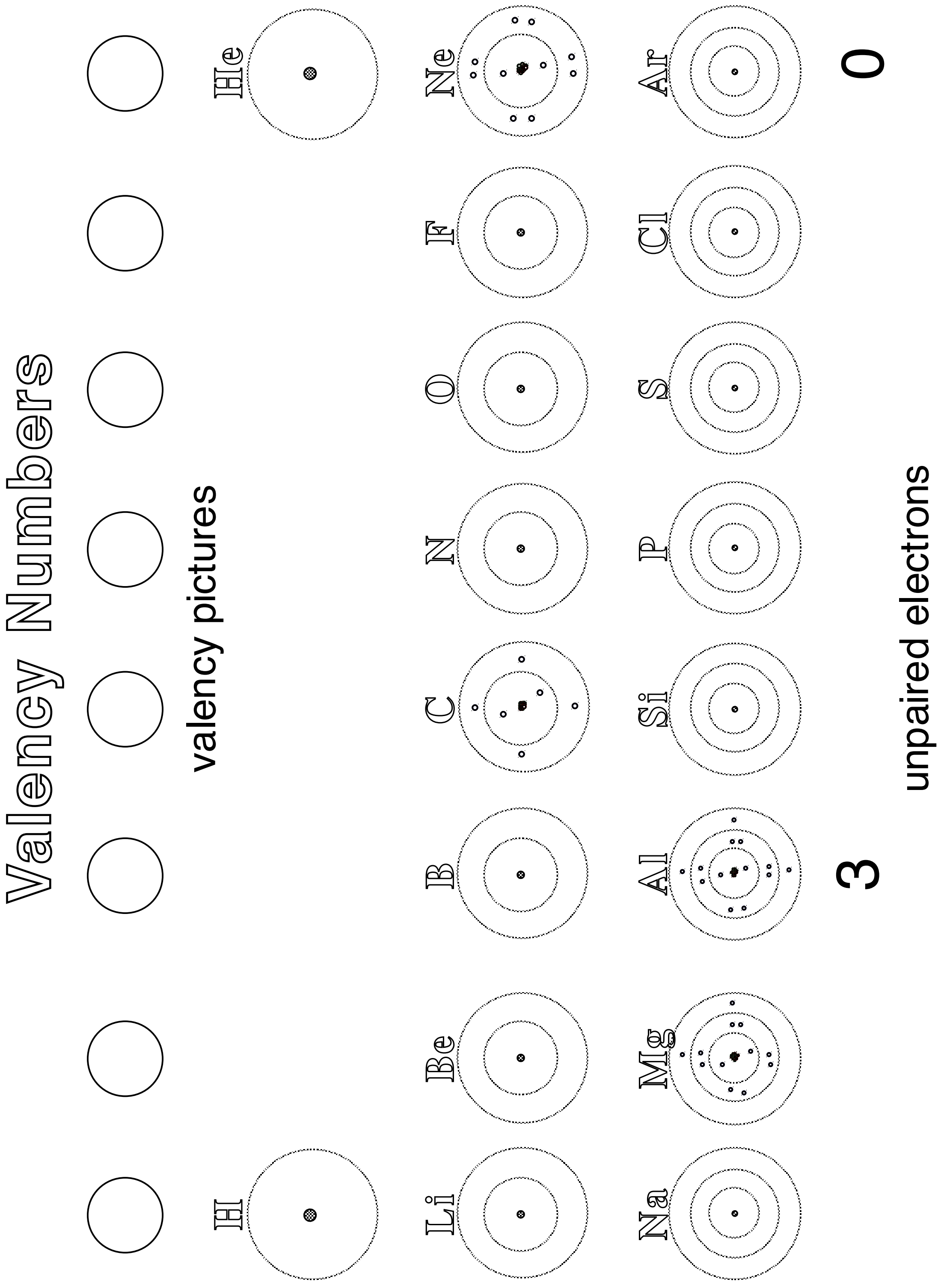
Each new row ( ***Pe*** ) in the ***Periodic Table*** represents the start of a new ***sh*** . As you move from ***le*** to ***ri*** the ***sh*** is being ***fi*** , and the elements change from ***me*** to ***n*** ***-metals***.

The ***Al*** ***metals*** all have electron in their ***ou*** ***shell***. The ***Ha*** all have , while the ***No*** ***gases*** all have a ***fu*** ***outer shell***. Elements which are in the ***same Gr*** will have the ***same nu*** ***of el*** in their ***ou*** ***shell*** and will have ***very similar pro*** .

# Electrons & Bonding Powers

When ***at*** get involved in ***re*** they have to physically touch, (***col*** with), each other. This really only affects the ***el*** in the ***ou shell***. Not surprisingly then, the ***nu of el*** an atom has in its ***ou shell*** is all important.

There are various methods for learning ***For Wri*** but most involve some idea of ***Bon Po*** (*Valency Number*) which is determined by the ***nu of el*** in the ***ou shell***.



Only ***un*** ***electrons*** in the ***ou*** ***shell*** of an atom can get involved in reactions, and form ***bo*** with other atoms.

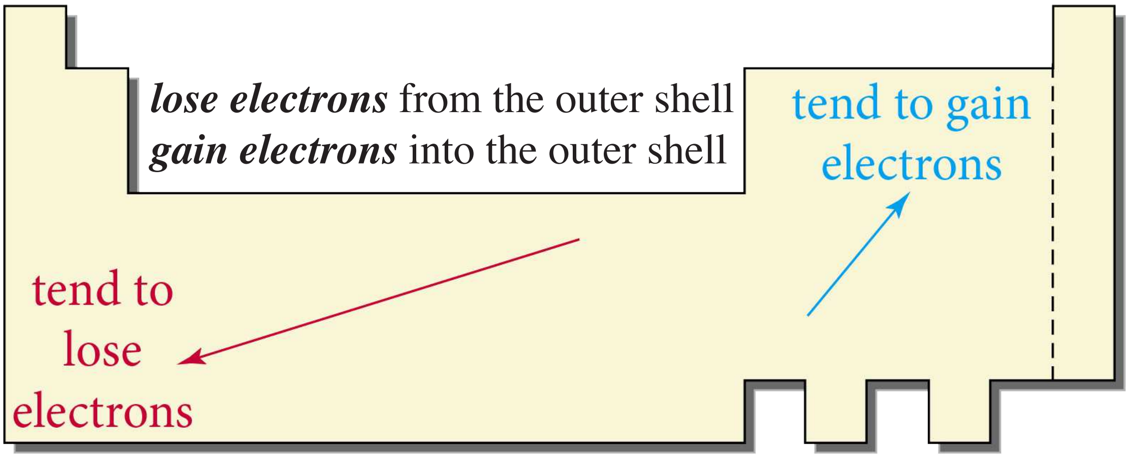
The ***No*** ***gases*** are very ***unr*** because they have no ***un*** ***electrons***.

One of the *driving forces* behind ***bon*** will be the *advantages* that can be gained by achieving a ***sta*** ***ele*** ***arr*** , like the ***No*** ***gases***. The 'easiest' way of doing this is to either:

***lose electrons*** from the outer shell

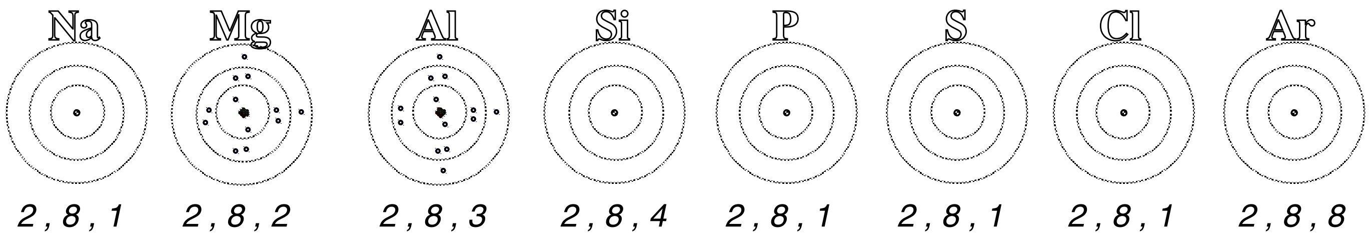
or:

***gain electrons*** into the outer shell



***Me*** atoms tend to form ***pos*** ***ions*** by ***giv*** ***away*** their ***outermost elec*** to achieve the ***same electron arrangement*** as the nearest ***no*** ***gas***.

***N*** ***-metal*** atoms tend to form ***neg*** ***ions*** by ***gai*** extra ***outermost elec*** to achieve the ***same electron arrangement*** as the nearest ***no*** ***gas***.



**Na** **$Mg^{2+}$** **Al** *Silicon and carbon find it too difficult to form ions* **P** **S** **Cl** **Ar**

valency pictures

The ***size of the ch*** on an ***ion*** depends on the ***num*** ***of electrons*** given away or gained.

The ***ch*** ***number*** on an *ion* is the same as its ***val*** ***number***.

### Q1. Int2

Which of the following numbers is the same for lithium and oxygen atoms?

**A** Mass number

**B** Atomic number

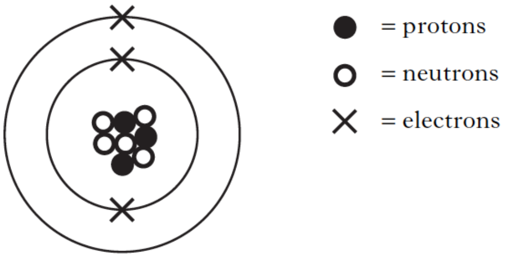
**C** Number of outer electrons

**D** Number of occupied energy levels

### Q2. Int2

Elements are made up of atoms.

An atom of an element is represented by the diagram below



**a)** explain why this atom is electrically neutral

______________________________

**b)** name the ***family*** of elements to which this atom belongs.

______________________________

### Q3. SC

Identify the ***two*** elements which can form ions with the same electron arrangement as argon.

**A** oxygen

**B** potassium

**C** phosphorus

**D** aluminium

**E** fluorine

**F** bromine

### Q4. SC

Identify the particle which has the same electron arrangement as neon.

**A** $^{23}_{11}\text{Na}$

**B** $^{18}_{8}\text{O}$

**C** $^{40}_{19}\text{K}^{+}$

**D** $^{24}_{12}\text{Mg}^{2+}$

**E** $^{35}_{17}\text{Cl}^{-}$

**F** $^{16}_{8}\text{O}$

### Q5. SG

Identify the ***two*** elements which have similar chemical properties

**A** gold

**B** magnesium

**C** carbon

**D** nitrogen

**E** calcium

**F** iodine

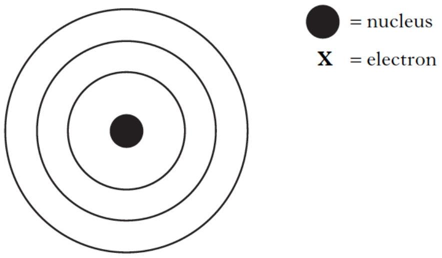
### Q6. Int2

Atoms contain particles called protons, neutrons and electrons. Electrons are arranged in energy levels.

The nuclide notation of the sodium atom is shown.

$$^{24}_{11}\text{Na}$$

**a)** complete the diagram to show how the electrons are arranged in a sodium atom.



**b)** explain what holds the negatively charged electrons in place around the nucleus.

______________________________

______________________________

### Q7. Int2

Atoms of an element form ions with a single positive charge and an electron arrangement of 2, 8.

The element is

**A** fluorine

**B** lithium

**C** sodium

**D** neon

### Q8. SG

Identify the symbol for the element which has similar chemical properties to oxygen.

The element is

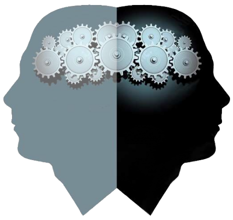
**A** Mg

**B** N

**C** S

**D** F

# Knowledge Met in this Topic



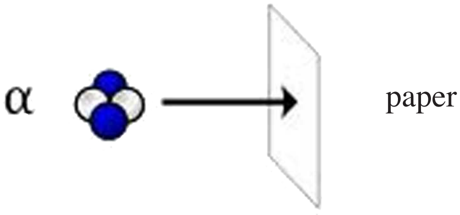
## *Stability*

- Radioactive decay involves changes in the ***nuclei*** of atoms
- Unstable nuclei (***radioisotopes***) are transformed into more stable nuclei by the ***emission*** of small particles and the ***release of energy***.
- The stability of nuclei depend on the ***neutron: proton ratio*** which can be calculated as

  ***neutrons / protons***
- As you go through the Periodic Table larger numbers of neutrons are needed and the ***neutron : proton ratio increases*** from 1 to 1.5.

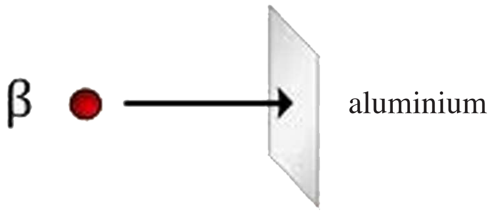
## *Emissions*

- There are 3 main types of emissions referred to as ***alpha** (α) particles*, ***beta** (β) particles* and ***gamma** (γ) rays*
- ***alpha** (α) particles* -



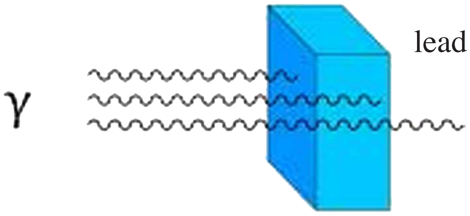
*nature* - like a helium nucleus
*symbol* - $^{4}_{2}He^{2+}$
*mass* - 4
*charge* - positively charged
*deflection* - towards negative plate
*penetration* - low

- ***beta** (β) particles* -



*nature* - high energy electron
*symbol* - $^{0}_{-1}e^{-}$
*mass* - 0
*charge* - negatively charged
*deflection* - towards positive plate
*penetration* - medium

- ***gamma** (γ) rays* -



*nature* - electromagnetic radiation
*symbol* - ∿
*mass* - 0
*charge* - 0
*deflection* - not deflected
*penetration* - high

## Nuclear Equations

- ***Balanced*** nuclear equations can be written involving:

neutrons - $^{1}_{0}n$
protons - $^{1}_{1}p$
$\alpha$ particles - $^{4}_{2}He$
$\beta$ particles - $^{0}_{-1}e$

- During nuclear reactions:

overall ***mass*** is conserved
overall ***charge in nuclei*** is conserved

## Radioactive Decay

- The decay of individual nuclei within a sample is ***random*** and is ***independent of chemical or physical state***.
- ***Nuclear*** chemistry is not affected by the same factors as 'normal' (*electron*) chemistry such as:
*temperature, concentration, particle size, atom or ion, physical state, etc*
- The ***half-life*** is the time taken for the *activity* or *mass* of a radioisotope to halve
- Given the values of two of these variables, the value of the other can be ***calculated***:

*quantity of radioisotope*,
*half-life*,
*time elapsed*.

## Using Radioisotopes

- ***Radioisotopes*** are used in:

| | |
|---|---|
| ***medicine*** | - tracers, cancer treatments, imaging *etc* |
| ***industry*** | - tracers, measuring, imaging, energy *etc* |
| ***science*** | - tracers, measuring, imaging, dating *etc* |

- ***Radioisotopes*** with ***long half-lives*** give 'constant' readings over large time periods but can require expensive arrangements for disposal / storage.
- ***Radioisotopes*** with ***short half-lives*** should decay to 'safe' levels quickly.
- ***Radioisotopes*** with ***low penetration*** are easier to shield and can be used within a person with little risk of exposure for people coming into contact.
- ***Radioisotopes*** with ***high penetration*** are useful for imaging and treatments from outside the body, but have to be carefully screened.

## Nuclear Energy

- ***Nuclear fission*** inolves creating unstable nuclei by neutron bombardment which then '***split***' to produce smaller '*daughter*' nuclei
- During nuclear fission, neutrons are produced which can lead to a '***chain reaction***' and, if not controlled, a nuclear explosion or meltdown.
- Nuclear fuels and fossil fuels can be compared in terms of *safety*, *pollution* and use of *finite resources*.
- Elements are created in the stars from simple elements by ***nuclear fusion***.
- All naturallv occuring elements, including those found in our bodies, originated in the stars.
- Nuclear fusion has the potential to be a safe, non-polluting source of energy but there are enormous engineering problems to be overcome.

## Electron Shells

- Electrons are arranged in special layers (called ***shells***) around each nucleus. ***Electron arrangements*** are given in the data booklet.
- ***Electron arrangements*** for the first 20 elements in the Periodic Table can be worked out on the basis of

  ***first shell*** - maximum **2** electrons
  ***second shell*** - maximum **8** electrons
  ***third shell*** - maximum **8** electrons
- Larger shells are divided into *regions* called ***orbitals*** which can each hold a ***pair*** of electrons
- *Each* orbital in a shell must have one electron before any ***pairing*** of electrons takes place

## Electrons & The Periodic Table

- Each row (***Period***) represents a new shell, and the shell is gradually filled as we move across the ***period***.
- As we move across the period, ***properties gradually change*** from '*typically metallic*' to '*typically non-metallic*'.
- Elements in the same column (***Group***) have the ***same number of outer electrons*** and have ***similar chemical properties***.

## Electrons & Bonding

- The ***number of outer electrons*** determines the ***bonding power*** of an atom.
- Atoms can become more stable by ***losing*** or ***gaining electrons*** to form ***ions***.
- The ***number of outer electrons*** determines the ***charge on the ion*** most likely to be formed from a particular atom.

# CONSOLIDATION QUESTIONS A

## Q1. Int2

Which of the following is the electron arrangement for an alkali metal?

(You may wish to use your Data Book to help)

**A** 2 , 1

**B** 2 , 2

**C** 2 , 3

**D** 2 , 4

## Q2.

*a)* Complete each line below by providing the correct symbol and electron arrangement for each ***atom***.

(You may wish to use your Data Book to help)

e.g sodium atom Na 2,8,1

oxygen atom

lithium atom

chlorine atom

sulphur atom

magnesium atom

nitrogen atom

aluminium atom

*b)* Complete each line below by providing the correct symbol and electron arrangement for each ***ion***.

e.g sodium ion $Na^+$ 2,8

oxygen atom

lithium atom

chlorine atom

sulphur atom

magnesium atom

nitrogen atom

aluminium atom

*c)* What do you notice about the electron arrangements of these ions ?

______________________________

______________________________

## Q3. H

Xenon-144 is a radioisotope.

What is the proton to neutron ratio in an atom of this isotope?

A 0.38

B 1.00

C 1.34

D 2.67

What is the neutron to proton ratio in an atom of this isotope?

A 0.38

B 0.76

C 1.00

D 1.34

## Q4. H

Give the symbol for each of these particles

alpha particle

beta particle

neutron

proton

electron

Which two particles are the same ?

______________________________

## Q5. H

Which of the following equations represents nuclear fusion ?

**A** $^{40}_{19}K + ^{0}_{-1}e \longrightarrow ^{40}_{18}Ar$

**B** $^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$

**C** $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{90}_{38}Sr + ^{144}_{54}Xe + 2\,^{1}_{0}n$

**D** $^{14}_{7}N + ^{1}_{0}n \longrightarrow ^{14}_{6}C + ^{1}_{1}p$

# CONSOLIDATION QUESTIONS B

**Q1.** Int2

The table shows information about an ion.

| *Particle* | *Number* |
|---|---|
| protons | 16 |
| neutrons | 17 |
| electrons | 18 |

The charge on the ion is

**A** - 2

**B** - 1

**C** + 1

**D** + 2

**Q2.** Int2

Which of the following particles contains a different number of electrons from the others?

**A** $Cl^{-}$

**B** $O^{2-}$

**C** Ne

**D** $Na^{+}$

**Q3.** Int2/H

Atoms and ions contain particles called protons, neutrons and electrons.

The nuclide notation of a phosphide ion is shown.

$$^{32}_{15}P^{3-}$$

***a)*** Complete the table to show the number of each type of particle in this phosphide ion.

| *Particle* | *Number* |
|---|---|
| *electron* | |
| *proton* | |
| *neutron* | |

***b)*** Phosphorus-32 decays by beta-emission. Write the nuclear equation for the decay of phosphorus-32.

**Q4.** Int2

In which of the following compounds do ***both*** ions have the same number of electrons as neon?

**A** calcium fluoride

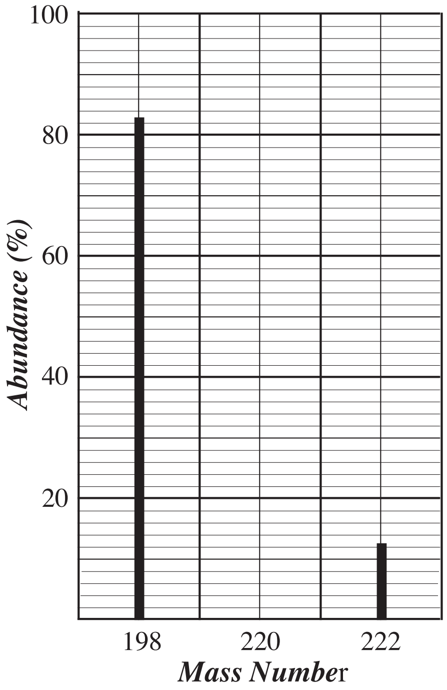
**B** magnesium chloride

**C** sodium oxide

**D** aluminium bromide

**Q5.** H

The chart was obtained from a 24-day old sample of an α-emitting radioisotope of Radon.



***a)*** What is the half-life of the isotope?

**A** 2 days

**B** 4 days

**C** 8 days

**D** 12 days

***b)***

$$^{222}_{86}Rn \longrightarrow {}^{a}_{b}X + {}^{4}_{2}He$$

Identify element **X** and the values of ***a*** and ***b***.

***c)*** Radon-222 can be produced from another radioisotope after ***six*** ***α-emissions*** amd ***two*** ***β-emissions***. Identify the starting radiosisotope.

_______________