Name: ____**TG:** ______ **Date:** ___________

Chapter 17: Radioactivity

Content:

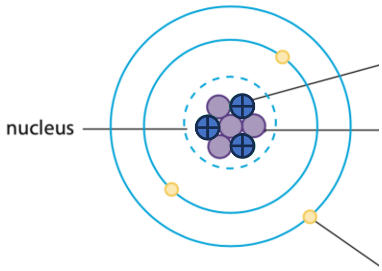
- The composition of the atom
- Radioactive decay
- Dangers and uses of radioactivity

Learning Outcomes:

Candidates should be able to:

	✓
(a) describe the composition of an atom in terms of a positively charged nucleus (with protons and neutrons) and negatively charged electrons	
(b) use the terms proton (atomic) number Z, nucleon (mass) number A and isotope	
(c) use and interpret the term nuclide and use the nuclide notation ${}^{A}_{Z}X$	
(d) show an understanding that nuclear decay is a random and spontaneous process whereby an unstable nucleus loses energy by emitting radiation	
(e) show an understanding of the nature of alpha (α), beta (β), and gamma (γ) radiation (including ionising effect and penetrating power) [β-particles are assumed to be β– particles only]	
(f) show an understanding of background radiation	
(g) use the term half-life in simple calculations, which might involve information in tables or decay curves	
(h) state the applications (e.g. medical and industrial uses) and hazards of radioactivity.	

17.1 What is the composition of an atom?



Proton : positively charged

Neutron : does not carry any charge.

Electron : negatively charged

Figure 17.1 Structure of a lithium atom

- Subatomic particles: protons, neutrons and electrons
- Are held together by: strong attractive forces
- **Positively charged** nucleus and **negatively charged** electrons.

Table 17.1 The relative charges of subatomic particles

Subatomic Particle	Relative Charge
electron	-1
proton	+1
neutron	0

- **Nuclide Notation:**

Nucleon (mass) number :

Total number of neutrons and protons in the nucleus of an atom

$^{A}_{Z}X$

Chemical symbol of the nuclide

Proton (atomic) number :

Number of protons or Number of electrons in an atom

To find number of neutrons *N*,

N = Nucleon Number A – Proton Number Z in a nucleus

Example 1 (17A):

The nucleus of a radioactive element is represented by $^{235}_{92}U$.
(a) How many protons does the neutral atom contain?
(b) How many neutrons does the nucleus contain?

(a) No. of protons = 92
(b) No. of neutrons = 235 – 92 = 143

Example 2 (Let's Practise 17.1)

1 The following statement describes the nucleus of an atom X.
The proton number Z of atom X is 84. Its nucleon number is 209.
(a) How many protons are in the atom X?
(b) How many electrons are in the atom X?
(c) How many neutrons are in the nucleus of atom X?
(d) What is the nuclide notation of the atom?

(a) 84 protons
(b) 84 electrons (atom is neutral)
(c) No. of neutrons = 209 - 84 = 125

(d) $$^{209}_{84}X$$

Isotopes

Isotopes are atoms of the same element that have the same number of protons but different numbers of neutrons.

- Isotopes of the same element have identical chemical properties.

17.2 What is radioactivity?

Nuclear Decay

Nuclear decay is a random process by which an unstable atomic nucleus loses its energy by emission of electromagnetic radiation or particle(s)

Nuclear decay is also known as *radioactive decay* or *radioactivity*.

The instability of the atomic nuclei is because the **nuclear forces** within the nuclei are **not enough** to bind the nucleons together.

- A material is radioactive when: it contains unstable nuclei
- Radiation emitted is spontaneous and random in direction.

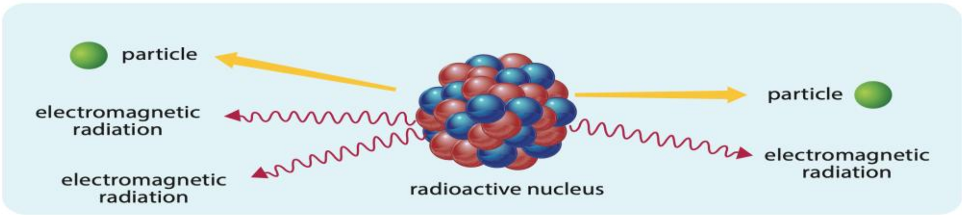
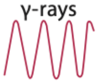


Figure 17.5 The radiation or particles emitted from a radioactive nucleus can occur anytime and in any direction.

Three types of nuclear emission

Table 17.2 The three types of nuclear emissions

Nuclear Emission	Nature	Relative Ionising Effect	Relative Penetrating Ability
α-particles  ${}^{4}_{2}\alpha$	An α-particle consists of two protons and two neutrons tightly bound together. It is identical to a *helium nucleus.*	Highest	• Least • They are easily absorbed by a piece of paper, a thin aluminium foil or human skin.
β-particles ⊖ ${}^{0}_{-1}\beta$	An β-particle is a fast-moving *electron* ejected from a radioactive nucleus.	Medium	• Medium • They are absorbed by a piece of aluminium that is a few millimetres thick.
γ-rays 	A γ-ray is *electromagnetic radiation* emitted by a nucleus with excess energy.	Lowest	• Highest • They pass through most materials easily. They are absorbed by lead that is a few centimetres thick or very thick concrete.

Example 3

1. Three radioactive sources are available.
   Source A emit alpha particles. Source B emit beta particles. Source C emit gamma radiation.

   a. State what is an alpha particle.
   b. State the nuclide notation of an alpha, beta and gamma radiation.
   c. State and explain the materials that can be used to contain source C.

   (a) An alpha particle consists of two protons and two neutrons tightly bound together.
   (b)

   (c) Source C can be contained by lead that is a few centimetres thick or very thick concrete because they can pass through most materials easily.

Background Radiation and GM counter

- Ionising radiation: **Ionising radiation** is radiation with high energies that can knock off electrons from atoms to form ions.

- Background radiation: **Background radiation** refers to nuclear radiation in an environment where no radioactive source has been deliberately introduced. We encounter background radiation every day.

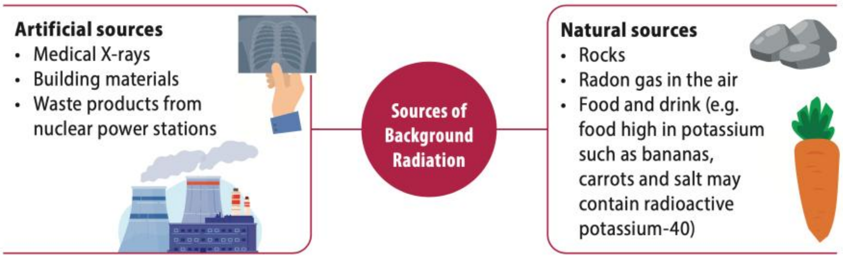


Figure 17.8 Examples of artificial and natural sources of background radiation

- Geiger-Muller Counter (GM Counter) measures number of times a radioactive atoms decay (count).

- SI unit: **Becquerel (Bq)**

- One becquerel (1 Bq) is equal to 1 disintegration per second.
-

To measure background radiation:	
Step 1:	Remove all known radioactive sources.
Step 2	Start the counter and the stopwatch.
Step 3:	Stop the counter after 10 minutes and record the number of counts. Number of counts per minute = $\frac{\text{number of counts in 10 minutes}}{10}$
Step 4:	Repeat your measurement at least once and calculate an average value.

Example 4 (17B)

(a) A scientist is using a radiation detector connected to a counter to measure the ionising nuclear radiation from a radioactive source. Briefly describe what the scientist should do.

(b) The number of counts from the detector when placed in front of a radioactive source for 30 seconds is 1500. What is the count rate in counts/s?

(c) The background count rate is 18 counts/min. What is the corrected count rate for the radioactive source in counts/min?

Half-life

The **half-life** of a radioactive nuclide is ____

____.

Example 5 (17C)

The amount of radioactivity of sample X is 600 Bq. If the half-life of sample X is six hours, determine the amount of radioactivity of sample X after 18 hours.

Example 6 (17D)

Figure 17.11 shows the decay curve of a radioactive nuclide.

(a) What is meant by *half-life*?

(b) The half-life of the radioactive nuclide is 27 years. How long will 2 g of the radioactive nuclide take to reduce to 0.25 g?

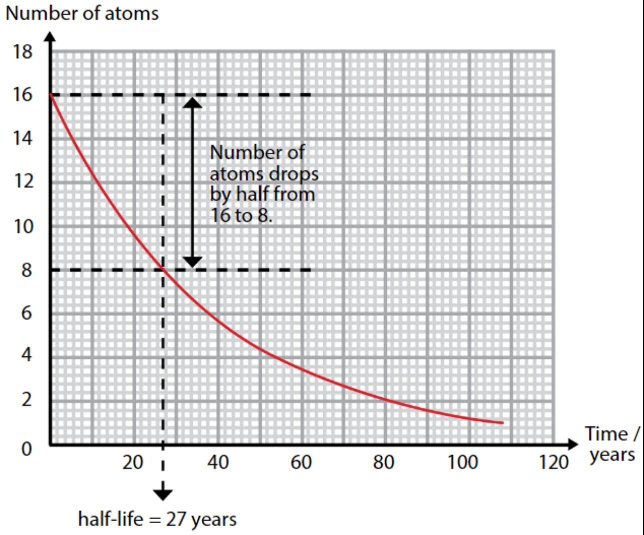


Figure 17.11

Example 7 (Let's Practise 17.2)

2 The amount of radioactivity of a sample decreases from 252 Bq to 63 Bq in 14 days. What is the half-life of the sample?

3 In a paper rolling mill, the thickness of the paper is monitored by passing beta radiation through the paper. The beta radiation passing through the paper is detected by the detector.

(a) Explain why beta radiation is used.

(b) Would the beta source have a long or short half-life? Explain.

17.3 What are the uses and hazards of radioactivity? (Self-Study)

- Uses related to damages to the cells.

	Radiation	Use
Medical	γ-rays	• • Isotope has short half-life (6 hours) so it does not remain in body for too long.
	β-particles	• • Destroy the thyroid cells including cancer cells. • Short half-life (8 days) so does not remain in body for too long.
	γ-rays	• Gamma knife radiosurgery, γ-rays are directed at brain to destroy brain tumours. •
Safety	γ-rays	• γ-rays used to kill microbes so that food is safe of consumption and last longer. •
	γ-rays	• • Isotope has long half-life (a few years). It takes long time for it to decay so only small quantity is needed over a long time.

- Uses related to radioactive decay and half-life.

	Radiation	Use
Geology	α-rays	•

Geology is the study of physical structure of Earth.

		• Isotope decays to stable isotope, lead-206. Age of rock can be known by determining relative amounts of uranium-238 and lead-206 in a sample. •

- Uses related to penetrating abilities and ionising effects.

	Radiation	Use
Safety	α-particles	• • . • Flow of current is disrupted and triggers detector's alarm.
Industrial	β-particles or γ-rays	• Measure the thickness of materials and ensure material is of uniform thickness. • • • • •

Hazards of Radioactivity

- Energy carried by ionising radiation can kill cells, cause mutation and cancer.

Protecting ourselves from Radioactive Materials

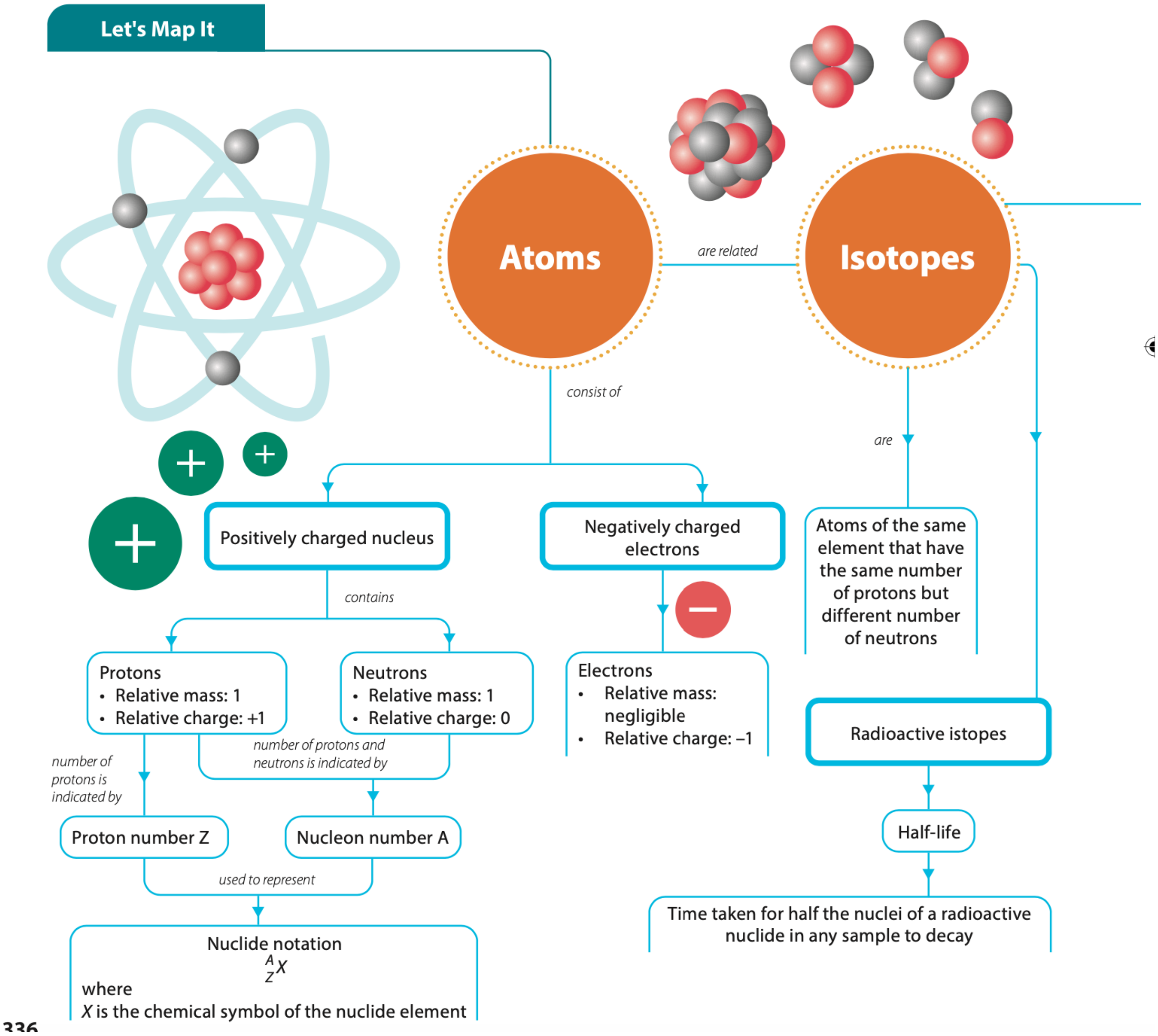
Limit Contamination	• Leave immediate area quickly. • Remove outer layer of clothing. • Wash all exposed parts with soap and lukewarm water.

Reduce Exposure	• Carry out experiment with radioactive materials in designated locations.

Example 8 (Let's Practise 17.3)

Let's Practise 17.3

1 State **one** application of each of the three types of radiation — α-particles, β-particles and γ-rays.
2 State **two** safety measures when handling radioactive materials.
3 State **three** ways to control exposure to ionising radiation.



Let's Map It
Atoms
are related
Isotopes
consist of
are
Positively charged nucleus
Negatively charged electrons
Atoms of the same element that have the same number of protons but different number of neutrons
contains
Protons
• Relative mass: 1
• Relative charge: +1
Neutrons
• Relative mass: 1
• Relative charge: 0
Electrons
• Relative mass: negligible
• Relative charge: –1
Radioactive istopes
number of protons is indicated by
number of protons and neutrons is indicated by
Proton number Z
Nucleon number A
Half-life
used to represent
Time taken for half the nuclei of a radioactive nuclide in any sample to decay
Nuclide notation
$^{A}_{Z}X$
where
X is the chemical symbol of the nuclide element
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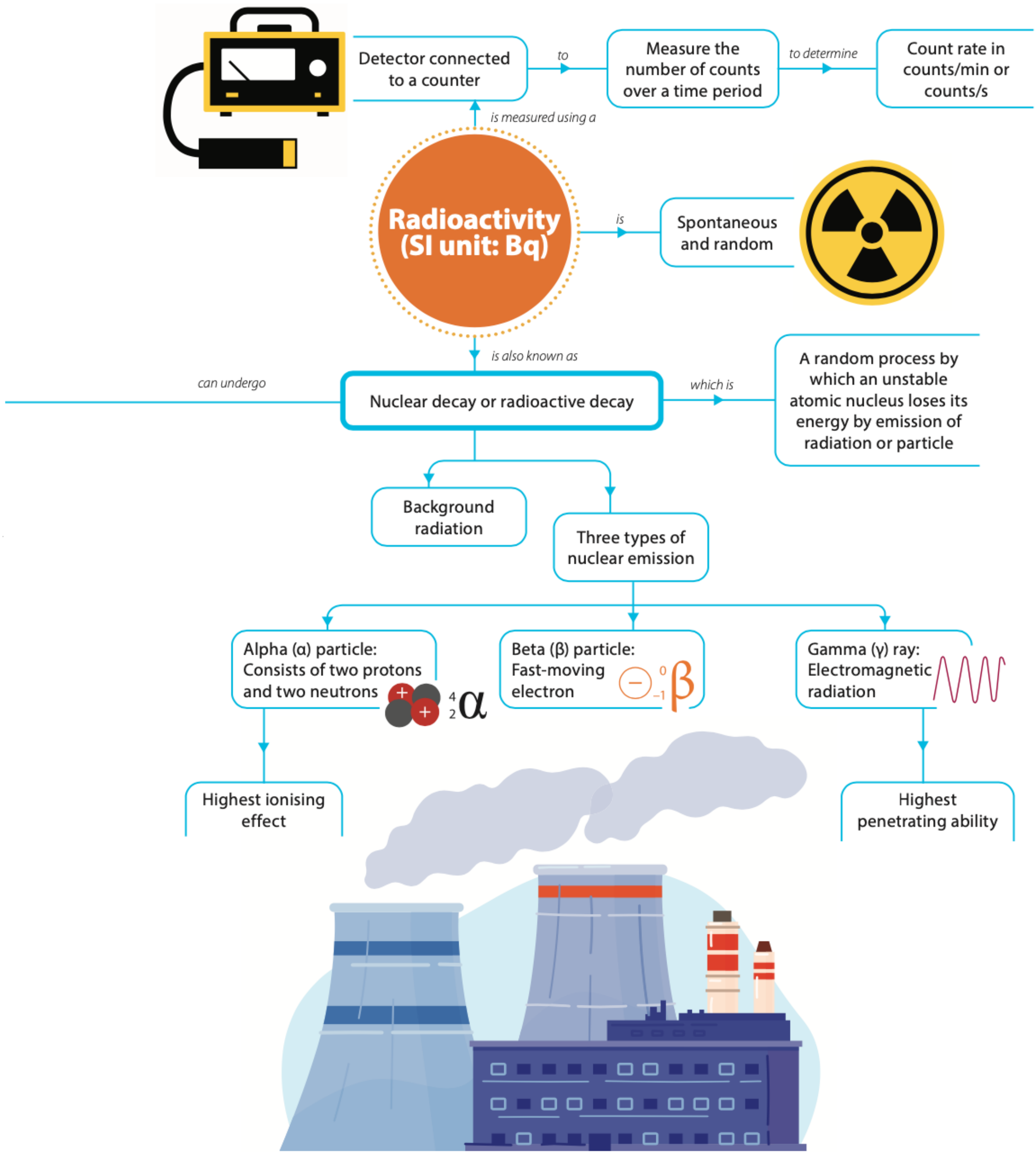
Radioactivity (SI unit: Bq)
is measured using a
Detector connected to a counter
to
Measure the number of counts over a time period
to determine
Count rate in counts/min or counts/s
is
Spontaneous and random
is also known as
Nuclear decay or radioactive decay
which is
A random process by which an unstable atomic nucleus loses its energy by emission of radiation or particle
can undergo
Background radiation
Three types of nuclear emission
Alpha (α) particle: Consists of two protons and two neutrons
$^4_2\alpha$
Beta (β) particle: Fast-moving electron
$^{0}_{-1}\beta$
Gamma (γ) ray: Electromagnetic radiation
Highest ionising effect
Highest penetrating ability

Notes: