2021 Edition

Nuclear Science Workbook

The Basics

ICENS

THE INTERNATIONAL CENTRE FOR ENVIRONMENTAL AND NUCLEAR SCIENCES

Section 01

Chemistry

01 Chemistry

Quick Notes

An atom has a nucleus and 1 or more electron(s)

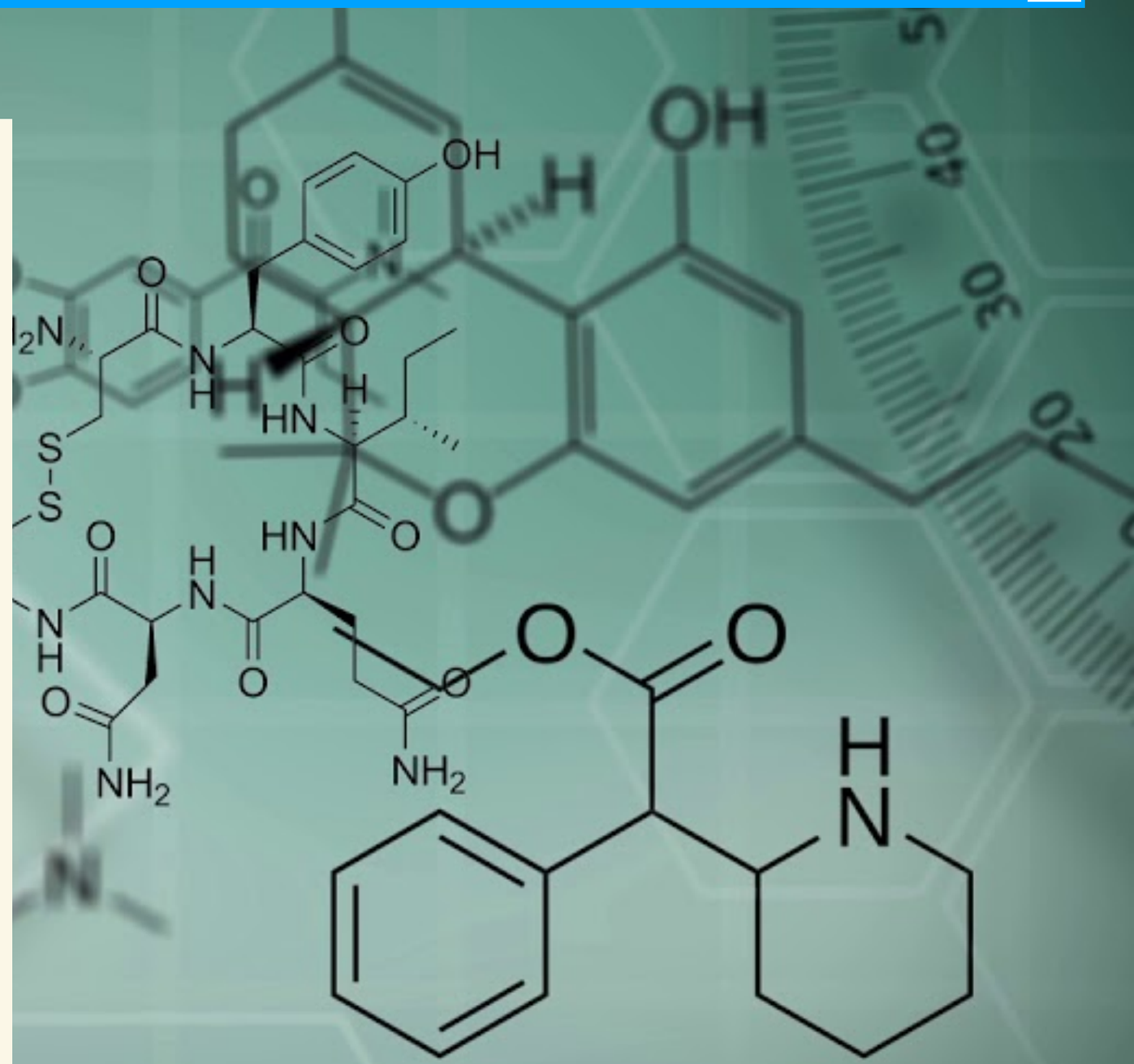
Elements on the periodic table vary by their atomic number (Z). This number is also the same number of protons in the atom.

The mass number (A) is equal to the number of protons (Z) plus the number of neutrons (N).

$$A = Z + N$$

An element can be written in the following format:

$${}^{A}_{Z}X$$ where X is the symbol for the element



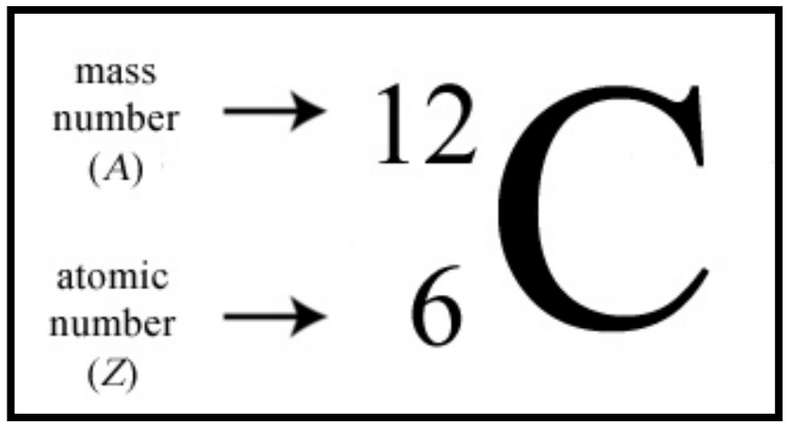
01 Chemistry

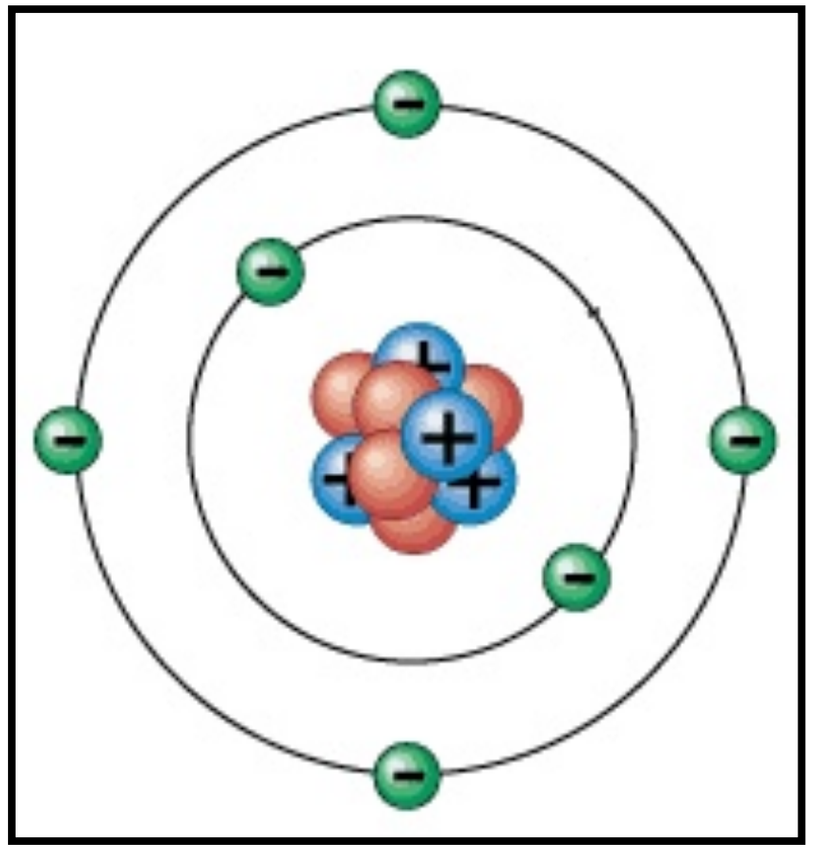
All about the elements

Test your knowledge of the periodic table. Fill in the blanks in the table below.

Symbol	Name
Ca	_____
___	Sodium
___	Oxygen
K	_____
Zn	_____
U	_____
___	Copper
Pb	_____
___	Carbon

01 Chemistry





How many neutrons are there? _____

How many electrons are there in this atom? _____

Since oxygen (O-16) has 8 protons, 8 neutrons and 8 electrons, draw and label the atom for oxygen.

01 Chemistry

What makes something radioactive?

Atoms can either be stable or unstable. The atoms discussed earlier, are all stable atoms. This means that the forces among the particles that make up the nucleus are balanced. When they are unbalanced, the atom is then considered unstable or radioactive.

What causes this instability?

The instability of an atom's nucleus may be due to an increase in the number of protons or neutrons. When this happens, the nucleus has an excess of internal energy. As a result, the radioactive atom will continue to try and lose or eject the neutrons and protons until it becomes stable. During this process, it is also emitting radiation. The rate at which this happens is determined by the half-life (this is discussed in the next section).

What happens after?

As the nucleus emits radiation, the atom changes into a nuclide. This process is called radioactive decay and will continue until the forces in the nucleus are balances and the atom is stable.

01 Chemistry Review

Using the words below, fill in the blanks for each sentence.

Atomic Number, Electrons, Isotopes, Mass Number, Nucleus, Neutrons, Protons

1. _____ have a positive charge and are found in the nucleus of an atom
2. _____ have a negative charge and are found around the nucleus
3. _____ have no charge and are found inside the nucleus
4. The _____ of an element equals the number of protons in an atom of that element
5. The _____ is the sum of the _____ and _____ in the nucleus of an atom
6. _____ are atoms of the same element that have different numbers of neutrons (and different mass numbers) but the same _____
7. _____ have zero charge
8. The center of an atom is known as the _____

Bonus

What is the difference between a stable atom and an unstable atom?

_____

_____

_____

_____

_____

Section 02

Radiation

Radiation is energy that travels as particles or waves.

02 Radiation

Quick Notes

Radiation is all around us, in the air, water, food, soil and in us among all other living things. Radiation can exist naturally and can be created with instruments like a nuclear reactor.

There are two main types of radiation:

Ionizing Radiation

This type of radiation can change the structure of an atom by removing electrons from them through a process called ionization. This type of radiation includes those from X-rays and nuclear reactors.

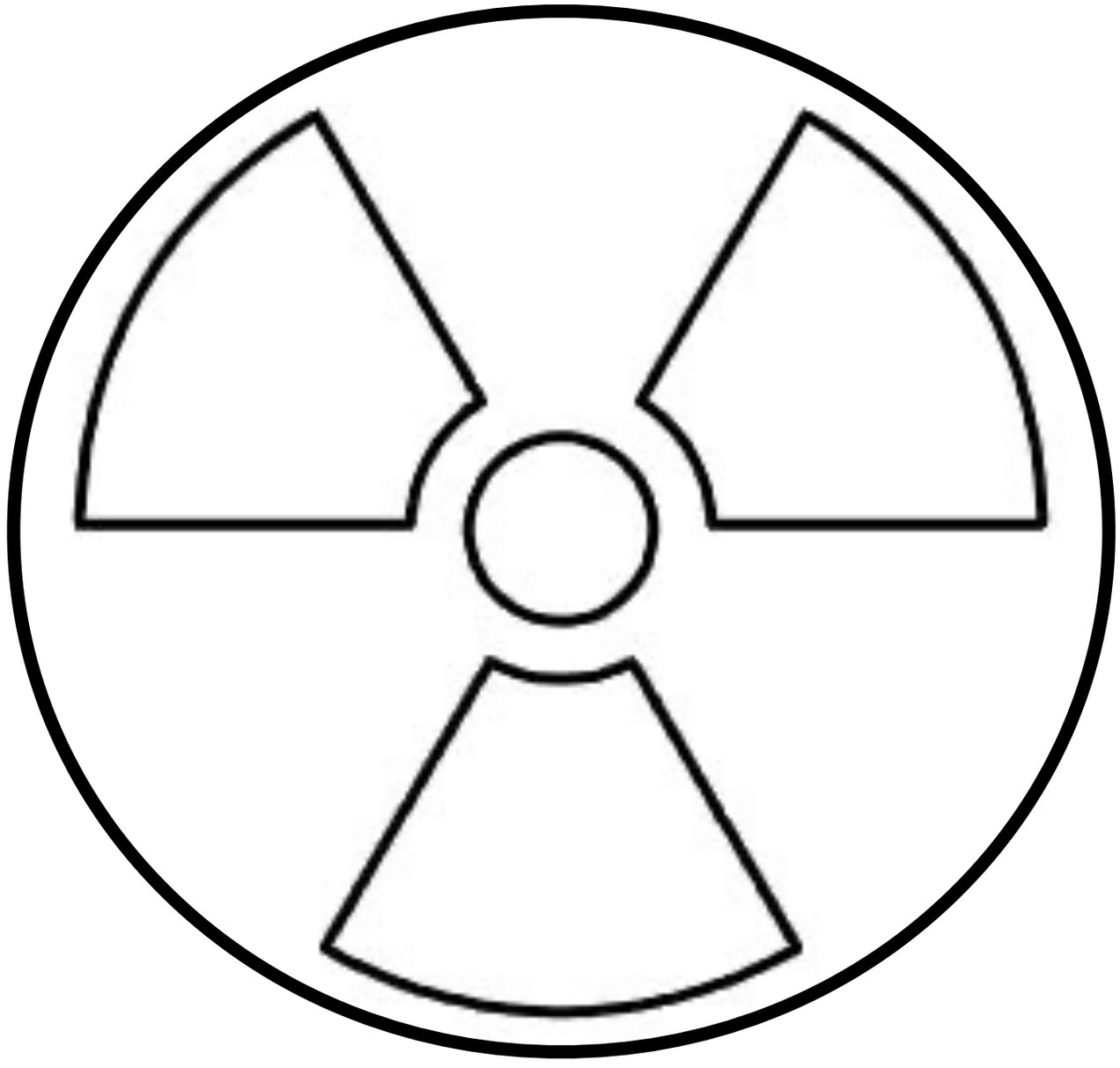
Non-Ionizing Radiation

This type of radiation has enough energy to exit atoms thus allowing them to move at a fast rate. This type of radiation includes those from microwaves and cellular phones.

Identifying Ionizing Radiation

As mentioned, ionizing radiation is a type of high energy that can change the structure of an atom. The symbol on the right is used to indicate the presence of ionizing radiation.

Do you know the correct colours? Go ahead and fill in the appropriate colours for this symbol.



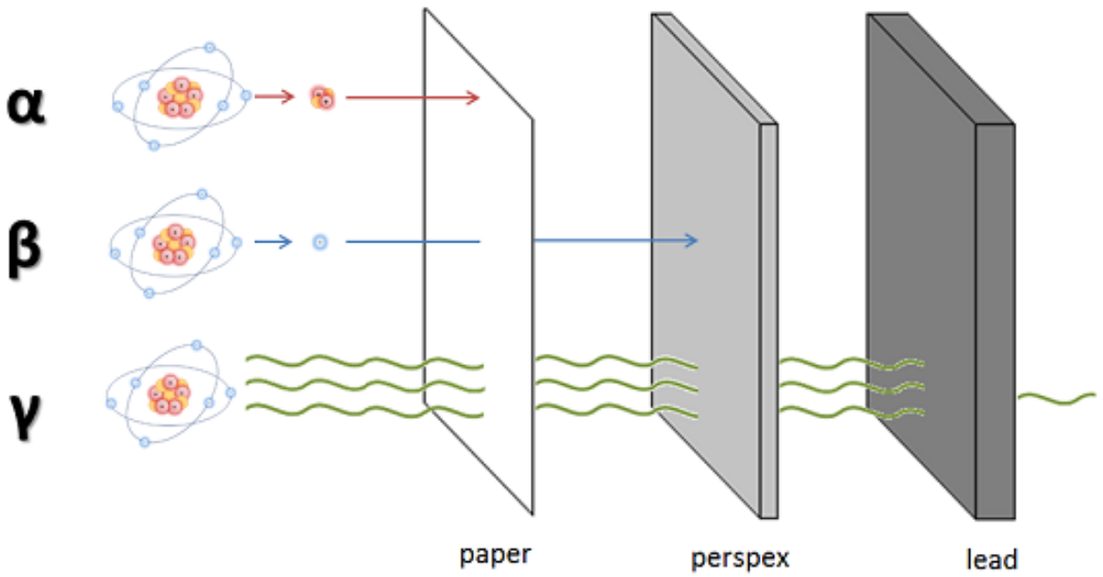
Quick Tip

The trefoil symbol is used to label radioactive material and can be found in areas where you may be exposed to radiation. Some areas where the symbol may be found include:

- ☑ **Hospitals (imaging and x-ray machines)**
- ☑ **Research facilities that use nuclear materials (eg: ICENS)**
- ☑ **Airports (x-ray machines)**

Keep an eye out next time you visit any of these places to see if you spot the symbol.

02 Radiation



A radioactive nuclei can emit three types of ionizing radiation as they decay. These are alpa, beta and gamma.

Alpha decay occurs when a nucleus emits a particle identical to a helium nucleus containing 2 protons and 2 neutrons with a positive (+2) charge.

Beta decay occurs when a neutron in the nucleus changes into a proton thus turning it into an entirely different element. It also releases a neutrino which is basically a particle with no mass.

Gamma decay occurs when a nucleus emits radiation without experiencing a change in its composition. The radiation emitted contains high amounts of energy and can easily penetrate varying surfaces.

02 Radiation

Half-Life

The half-life of something is the time taken for it to lose half of its effects. When we consider radioactive substances, it refers to the time taken for half of the radioactive atoms for a particular isotope to decay. It is important so that you can determine how long a particular isotope will remain radioactive.

For example:

Carbon-14 has a half-life of 5730 years. Therefore, if we started with 100 grams of C-14 today, in 11460 years we would have 25 grams remaining.

Tip: remaining mass = $(1/2^n)$ x original mass

****where n is the number of half-lives****

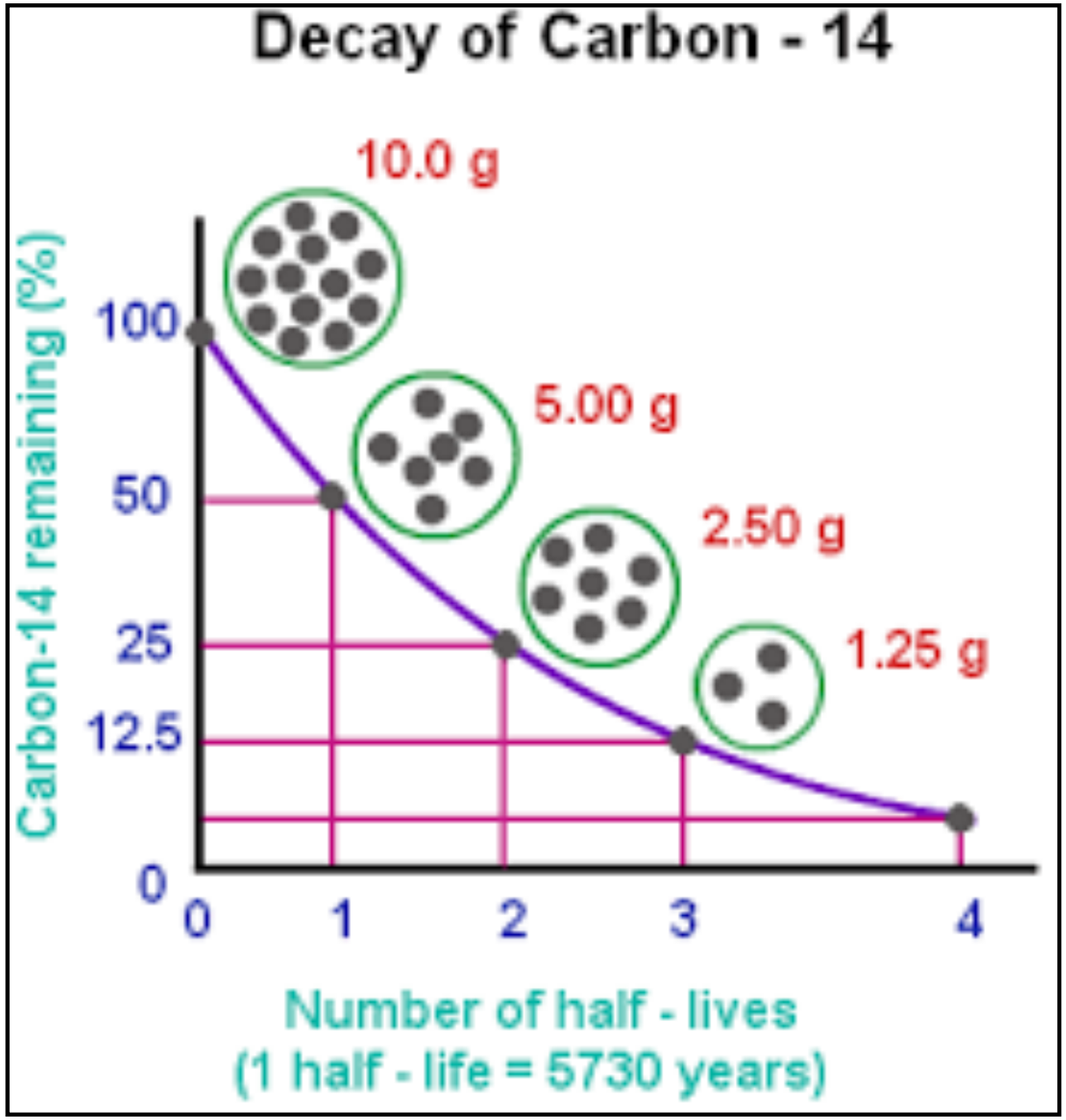
Quick Challenge

The half-life of thorium-227 is 18.72 days. After 37.44 days how many grams remain if the initial mass is 88 grams?

_____

The half-life of radium-224 is 3.66 days. What was the initial mass of radium-224 if 40 grams remains after 14.64 days?

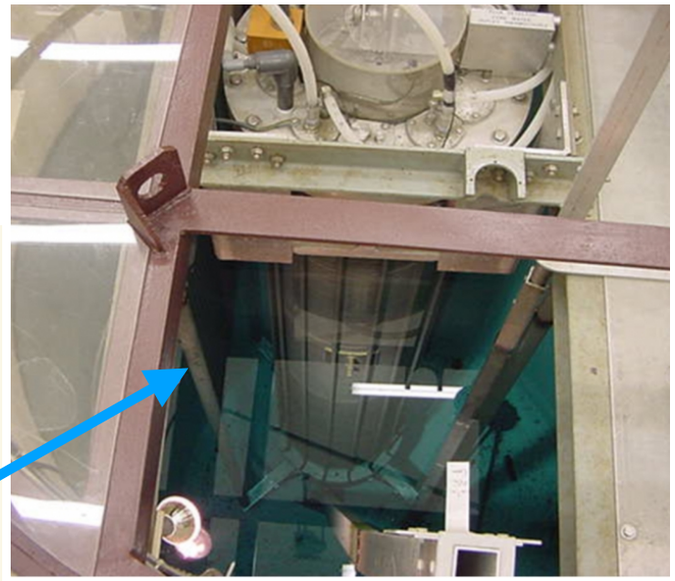
_____



02 Radiation

Nuclear Applications

Nuclear science is applied in various fields to improve our lives and the environment. It is used to diagnose and treat cancer, to make food safer, to study the impact of climate change and even to generate electricity.



Did you know?

Jamaica has the ONLY nuclear reactor in the English-speaking Caribbean.

It was built in 1984 and is located at the University of the West Indies Mona Campus.

The reactor is a 20 kW SLOWPOKE-2 reactor used to conduct research.

Check out the picture on the right to see how we use nuclear techniques in Jamaica.

02 Radiation

List 3 things that are <u>naturally radioactive</u>

1. _____
2. _____
3. _____

Did you know?

Radiation in space is called cosmic radiation.

When you take a flight from Jamaica to any country in the world, you get closer to outer space and so you are exposed to more cosmic radiation than when you are standing on the ground.

The amount of cosmic radiation that you are exposed to, will vary based on the altitude (how high the plane goes) and the length of the flight.

If you travel from Kingston to New York, you will be exposed to more cosmic radiation than if you traveled from Kingston to Montego Bay.

Don't worry, the radiation that you are exposed to on a round trip from Kingston to New York is about same as the radiation dose from a single chest x-ray.

02 Radiation Review

Fill in the table below.

	ALPHA PARTICLES	BETA PARTICLES	GAMMA RAYS
SYMBOL			
WHAT CAN BE USED TO BLOCK IT?			

Section 03

Puzzle Time

03 Puzzle Time

Word Search

ACCELERATOR
ALPHA
ATOMIC
BETA
DETECTOR
ELECTRON
ELEMENT
FISSION
FUSION
GAMMA RAY
HALF LIFE
IONIZING
IRRADIATE
ISOTOPE
NEUTRON
NUCLEAR
PROTON
RADIATION
RADIONUCLIDE
REACTOR
RESEARCH
SOURCE
XRAY

T V K N A Y V G G J T J Z R V X A T L V
N J D K O A N A E F I L F L A H R B P Q
E O Y S B I M C A L K U E V P E A A V P
M D U Y Z M S I Y I N E X L L L L O Y G
E X X I A E Z U R E S E A R C H G C K G
L C N R C L P B F N P X N Q D B I U U D
E O A Q T D O J W G O R C K C P Y K R N
I Y L W N B F E Z V A I X K M U Y Z G G
N N B Z G S V A O D E E T G O V H X D R
E O S Z H G T A I J T L E A N P R M O K
U T Z T T O C O G Z A E H C I Z E T A L
T O O R M B N X R Z I C H V D D C I J M
R R T I D U S Q U V D T Z S Y A A J M B
O P C R C E F D O W A R L N E P F R B W
N H M L P V T I A V R O I R E C R U O S
J L I K C R T E S E R N B J O N E A N R
Q D B E T A D C C S I S O T O P E V Z U
E F E T G X I G H T I I U T Z T F T U K
D K T T P R B V V D O O T Z X J U Y E P
R O T A R E L E C C A R N H V J N C U M

03 Puzzle Time

Crossword

Down

1. process of splitting an unstable nucleus

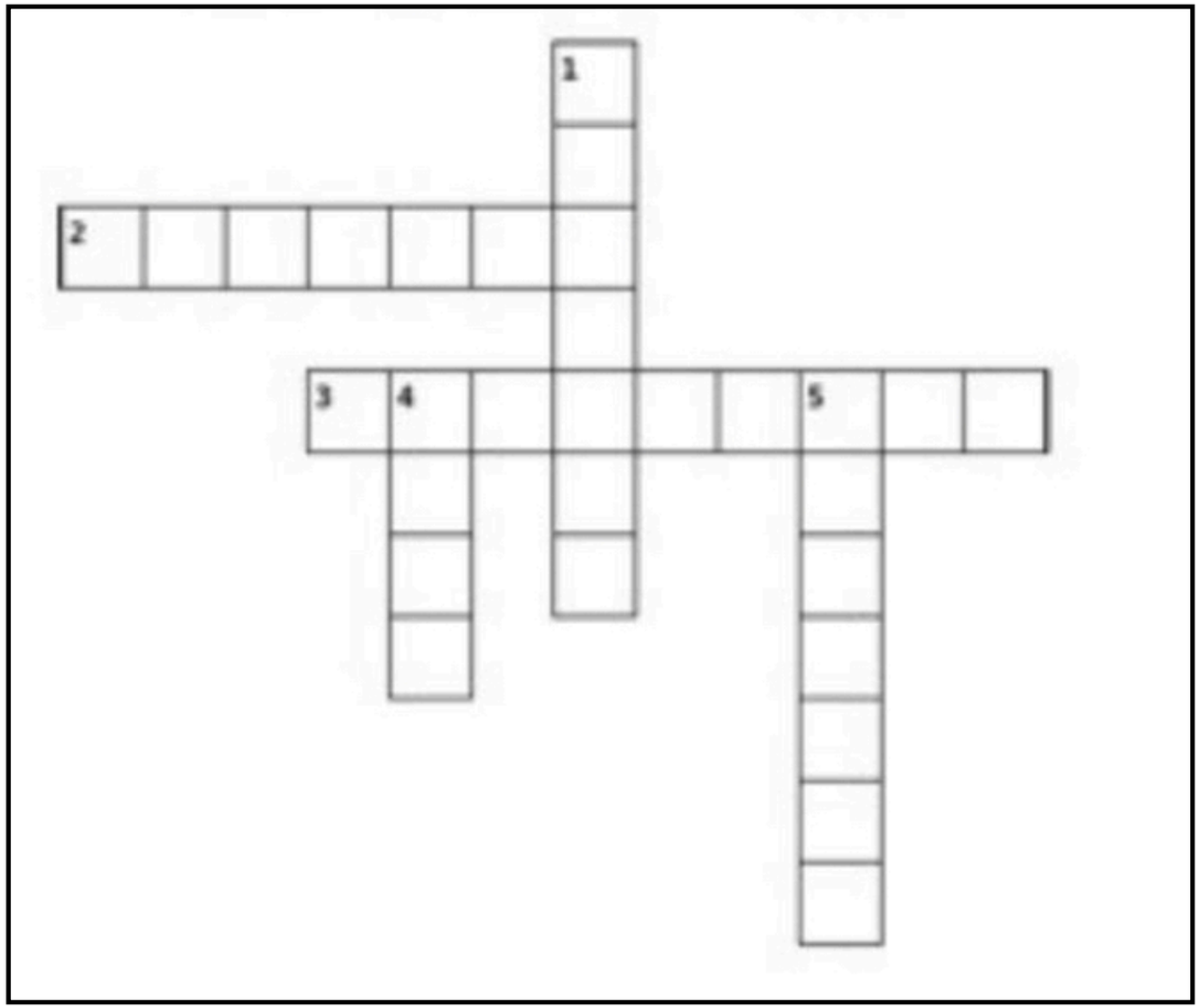
4. the basic unit of structure for all matter

5. equal protons but a different number of neutrons

Across

2. core of an atom

3. energy that travels as particles or waves



Section R

Resources

R1 Glossary

ACCELERATOR: a machine that accelerates charged particles at high speeds and focuses them onto a target

ALPHA: a particle consisting of two protons plus two neutrons

ATOM: the smallest portion of an element that can exist and still retain the properties of that element

BETA: an electron that is released from the nucleus of a radionuclide

DECAY: the process that allows for the transformation of a radionuclide from an unstable state to a more stable state

DETECTOR: a device used to measure ionizing radiation

ELECTRON: a particle with low mass that is usually found in the shells surrounding the nucleus

ELEMENT: a substance with atoms of the same atomic number that cannot be broken down into simpler substances

FISSION: the process where a nucleus splits into two or more lighter nuclei and energy is released. This process occurs in nuclear reactors like the one at the ICENS in Jamaica.

FUSION: the process where energy is released by merging atoms together. It is the same process by

R1 Glossary

GAMMA RAY: electromagnetic energy that is released from the nucleus of a radionuclide

HALF-LIFE: the time taken for the activity of a radionuclide to lose half its value

IONIZING RADIATION: radiation that produces ionization in matter and can cause damage to DNA

IRRADIATION: process by which something is exposed to radiation

ISOTOPE: these are nuclides with the same number of protons but a different number of neutrons

RADIATION: energy that travels as waves or particles

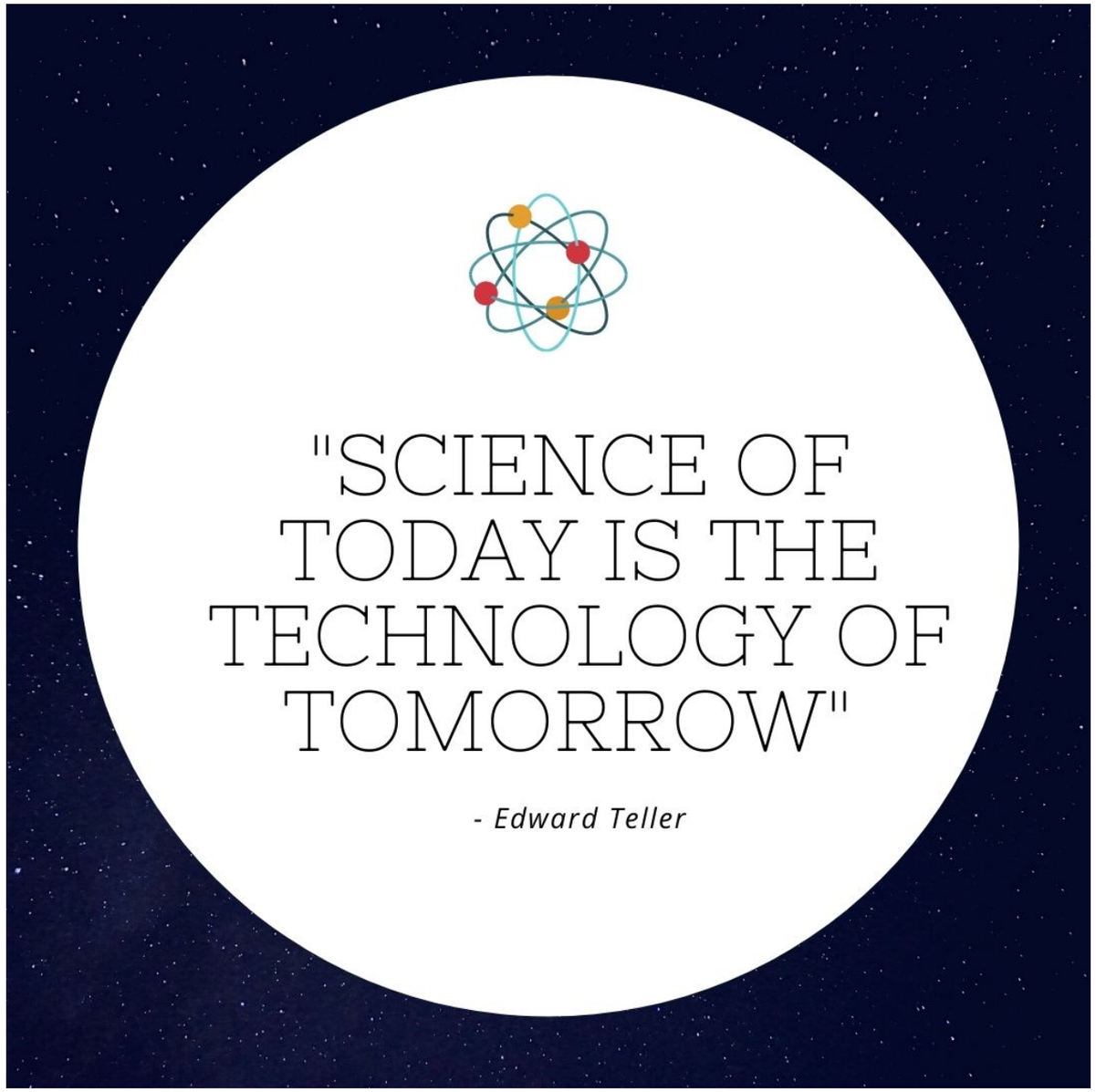
RADIONUCLIDE: an unstable nuclide that emits ionizing radiation

REACTOR: a device in which nuclear fission can occur

STABLE [NUCLIDE/ISOTOPE]: an isotope or nuclide whose half-life is longer than the age of the universe

UNSTABLE [NUCLIDE/ISOTOPE]: an isotope or nuclide whose half-life is less than the age of the universe (<13.7 billion years)

R2 Resources



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  - International Centre for Environmental and Nuclear Sciences
- Via the International Atomic Energy Agency: www.iaea.org

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