Topic 1 - Fundamentals

by Molly via cheatography.com/30516/cs/9102/

Aim of radiation therapy

To deliver a precise radiation dose to a defined volume of abnormal tissue, or tumour, while minimising dose to the surrounding normal tissue.

Basic Radiation Units

POWERS OF TEN			
Factor	Name	Prefix	Symbol
10^{18}	Quintillion	Exa-	E
10^{15}	Quadrillion	Peta-	P
10^{12}	Trillion	Tera-	T
10^{9}	Billion	Giga-	G
10^{6}	Million	Mega-	M
10^{3}	Thousand	Kilo-	k
10^{2}	Hundred	Hecto-	h
10^{1}	Ten	Deca-	da
10^{-1}	One Tenth	Deci-	d
10^{-2}	One Hundredth	Centi-	c
10^{-3}	One Thousandth	Milli-	m
10^{-6}	One Millionth	Micro-	μ
10^{-9}	One Billionth	Nano-	n
10^{-12}	One Trillionth	Pico-	p
10^{-15}	One Quadrillionth	Femto-	f
10^{-18}	One Quintillionth	Atto-	a

SI units

Energy: joule (J) (kilogram-metre2 per second2)

we use an energy unit based on a single (positive) electron charge when experiencing a voltage of 1 V, and this is referred to as the **electron volt (eV).**

Radiation Exposure: coulomb per kilogram (C/kg) (Previously roentgen (r))

Absorbed Dose: Gray (Gy) (one joule per kilogram) (Previously rad, 1 Gy =100 rads)

Radioactivity: rate of decay of a radioactive material, becquerel (Bq) (one decay per second)

Exponential Function

$$A_t=A_0e^{-\lambda t}$$

Decay of a radioactive material

A0 is the initial activity (at time t = 0) and At is the activity after time t. λ is a constant that is specific to the radioactive material under consideration.

Nomenclature

$${}^{A}_{Z}X_{N}$$

Nomenclature

Z is the atomic number (i.e. the number of protons, determines the **element**)

N is the number of neutrons

A is the mass number (Z + N)

Inverse Square Law

The intensity of a point source of radiation decreases as the distance from the source is increased. The amount of decrease is inversely proportional to the square of the distance.

Fundamental Particles

Quarks: points of matter that exist with other quarks as a pair or triplet.

Bound together by gluons

Collections of quarks are hadrons. A triplet of quarks is known as a baryon.

A Meson is one quark, and one anti-quark. The most commonly encountered meson is the pion, formed by anti-matter, extremely unstable.

Six quarks - up, down, top, bottom, strange and charm; there are also six anti-quarks.

Leptons: point particles that can exist in isolation

Much lower mass than a quark

May carry a negative unit charge (-1) or have no charge (0).

Six leptons. The three charged leptons are electrons, muons and tau. The three uncharged leptons are neutrinos.

Fundamental Particles (cont)

The special antimatter anti-lepton is the positron.

All known matter in the universe is made up of: The up and down quark; The electron lepton; The three uncharged neutrinos and the three uncharged anti-neutrinos

All interactions are made up of forces between these particles. Four forces: 1. The strong force or nuclear force, mediated by gluons; 2. The electromagnetic force, mediated by photons; 3.The weak force, mediated by the W-bosons and the Z-boson; 4. Gravity, for which the force carrier particle still eludes detection

The Atom

Smallest unit in the composition of matter

Composed of a central nucleus surrounded by one or more orbiting electrons

The nucleus consists of two types of hadrons: **Protons** positively charged (+1), **Neutrons** neutrally charged

Nucleons: protons and neutrons

The nucleus is held together by the residual strong force, which occurs between quarks of neighbouring nuclei.

Nucleons are about 2000 times heavier than electrons

Atoms combine to form molecules and chemical compounds

The **size of the atom** (its diameter) is about 10^{-10} m, whereas the nucleus has a diameter of 10^{-14} m, a factor of 10,000 smaller.

The atom is largely unoccupied space which has an enormous bearing on interactions of radiation with matter, including human tissue.

The Electron Position

Heisenberg's Uncertainty Principle: the exact momentum (energy) and the exact position can't be known simultaneously

Observing something alters it

Wave-Particle Duality

We can consider the atomic entity as either a: 1. **particle** (the localised 'billiard ball' approach) with particle diameter (d) and mass (m) 2. **wave** (an extended and vibrating phenomenon) with energy (E), wavelength (λ), and frequency (f).

$E = mc^2$

Energy here is in J and must be converted into MeV.

Atomic Mass Unit (u)

One atomic mass unit is 1/12 of the mass of the carbon-12 atom.

Isotopes

Elements exist with different numbers of neutrons than the neutral atom

'Isotope' does not necessarily imply a radioactive material.

Electronic Structure of the Atom

Bohr model: electrons rotate around the nucleus in discrete energy shells that are stationary and arranged in increasing order of energy.

A maximum number of electrons allowable in each shell

K shell can hold 2 electrons, the L shell 8 electrons, the M shell 18 electrons, etc.

Orbital electrons don't actually exist in precise circular orbits, but rather in imprecisely defined regions of space around the nucleus

The electron's position is defined by probability, with decreasing probability for locations outside of the 'most likely' regions

Electron Binding Energy

Electrons have different binding energies, depending on the electron shell

In the most stable configurations, electrons occupy the innermost shells where they are most tightly bound to the nucleus.

Excitation: an electron is raised from a lower energy shell to an upper energy shell (releasing energy)

Ionisation: an electron is removed completely from an atom

Binding energy of an electron is the energy required to remove it completely from a shell

Binding energy is higher for orbitals nearer the nucleus (KB>LB>MB).

Binding energy increases with the charge (equal to the atomic number Z) of the nucleus

Removing an electron/going from an inner to an outer shell, requires energy input

An electron moving from an outer to an inner shell results in energy emission