

# 11 | Atomic Physics

# IB Physics Content Guide

## Big Ideas

- Atomic nuclei decay to form more stable configurations and produce radiation in the process
- The rate of decay can be predicted for different materials and used to determine age based on isotope count
- Mass and energy are different manifestations of the same thing
- More energy efficient configurations mean that fission and fusion reactions release energy
- It is believed that all matter is made up of fundamental particles called quarks and leptons
- There is a symmetry between all matter with particles and their corresponding anti-particles
- The standard model has helped spur discovers of new particles but it may not yet be complete

## Content Objectives

### 11.1 – Radiation

 p. 287-293, 296

I can define nucleon as any subatomic particle inside the nucleus (protons and neutrons)			
I can identify isotopes of an element			
I can describe a nuclide using isotope notation			
I can interpret isotope notation to determine the number of protons and neutrons			
I can describe why the nucleus of an atom stays together despite the electrostatic repulsion			
I can describe why large nuclei have more neutrons than protons			
I can compare the radiation at different locations and list the sources of background radiation			

### 11.2 – Radioactive Decay

 p. 294-299, 303-305

I can describe the process of alpha decay			
I can describe the process of beta decay and the differences between beta-negative and positive			
I can write the notation for the decay particles (alpha particle, beta-negative/positive, gamma)			
I can predict the products of alpha and beta decay			
I can describe the impact of ionizing radiation and the ionizing effect of different types of decay			
I can predict the penetration of the radiation byproducts of nuclear decay			
I can describe the deflection of the radiation byproducts moving through a magnetic field			
I can describe the deflection of the radiation byproducts moving through an electric field			

### 11.3 – Half-Life

 p. 299-303, 305-306

I can describe the meaning of the half-life of a substance			
I can predict the percentage of an isotope remaining after a given number of half-lives			
I can predict the calculate the age of a sample when given the percentage of an isotope remaining			
I can describe the process of radiocarbon dating			
I can describe the role of medical tracers			
I can describe the danger implications of long and short half-lives for radioactive materials			

## 11.4 – Energy and Mass Defects

 p. 307-311

I can relate units of mass between kilograms (kg) and atomic mass units (u)			
I can use the mass/energy equivalence to mathematically relate mass and energy			
I can convert between joules (J) and electron-volts (eV)			
I can describe how $\text{MeV } c^{-2}$ is a valid unit for mass			
I can define mass defect and explain how it is related to energy			
I can calculate the mass defect of a nuclide			
I can calculate binding energy from mass defect			
I can interpret a chart showing binding energy per nucleon to locate stable nuclei			

## 11.5 – Fission and Fusion

 p. 311-314

I can use mass defect to calculate the energy released in a nuclear reaction			
I can compare the processes of fission and fusion			
I can predict the products of a fission reaction and the conditions requires for a chain reaction			
I can describe the conditions required for fusion to take place			
I can identify if an element will undergo fission or fusion based on its binding energy per nucleon			

## 11.6 – The Particle Adventure

 p. 315-319

I can describe the quest to discover the fundamental building blocks of matter			
I can identify the general categories of particles in the standard model			
I can interpret the IB Physics data booklet tables to identify the properties of all 24 quarks/leptons			

## 11.7 – Hadrons, Baryons, and Mesons

 p. 318-321

I can classify particle categories into an organized family tree with examples of each			
I can describe how quarks can be combined to create whole number charges			
I can identify the quarks required to form protons and neutrons			
I can calculate the charge of a given baryon or meson			

## 11.8 – The Standard Model

 p. 321-324

I can describe the phenomenon of Quark Confinement			
I can analyze a reaction based on conservation of Baryon #, Lepton #, Charge, and Strangeness			
I can describe forces in terms of exchange particles			
I can rank the fundamental forces based on strength			
I can describe the role of the Standard Model in the discovery of new particles			

## 11.9 – Feynman Diagrams and the Higgs Boson

 p. 325-328

I can describe key features of the Large Hadron Collider and its role in the Higgs Boson discovery			
I can follow the general rules for creating a Feynman Diagram			
I can describe a particle interaction using Feynman Diagram			

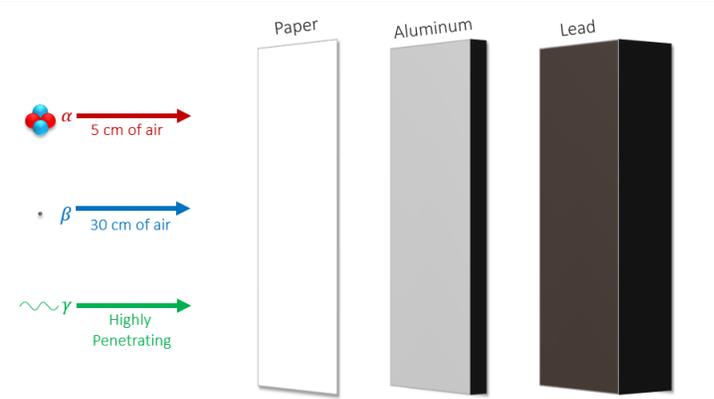
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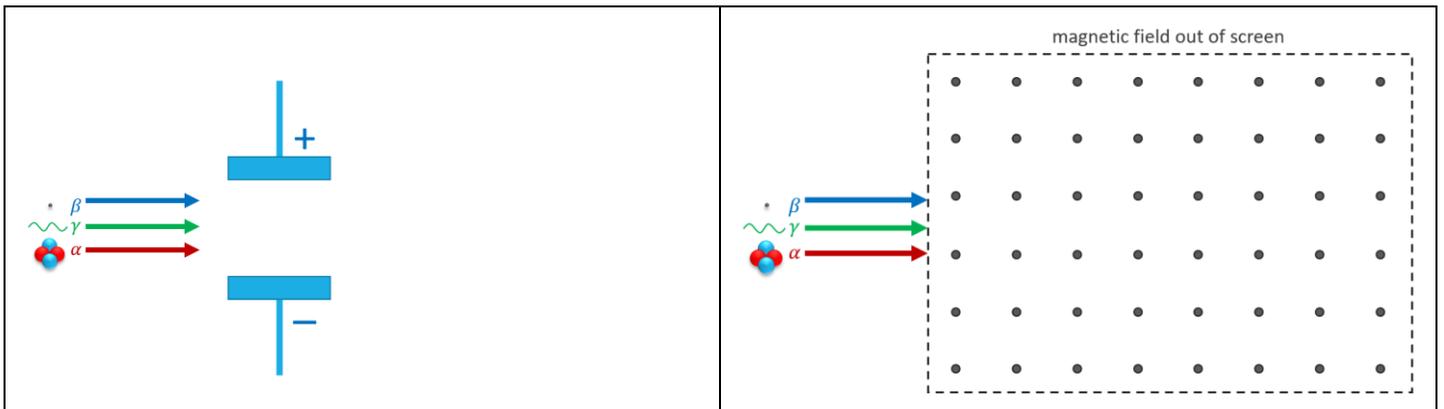
# Shelving Guide

## Types of Decay

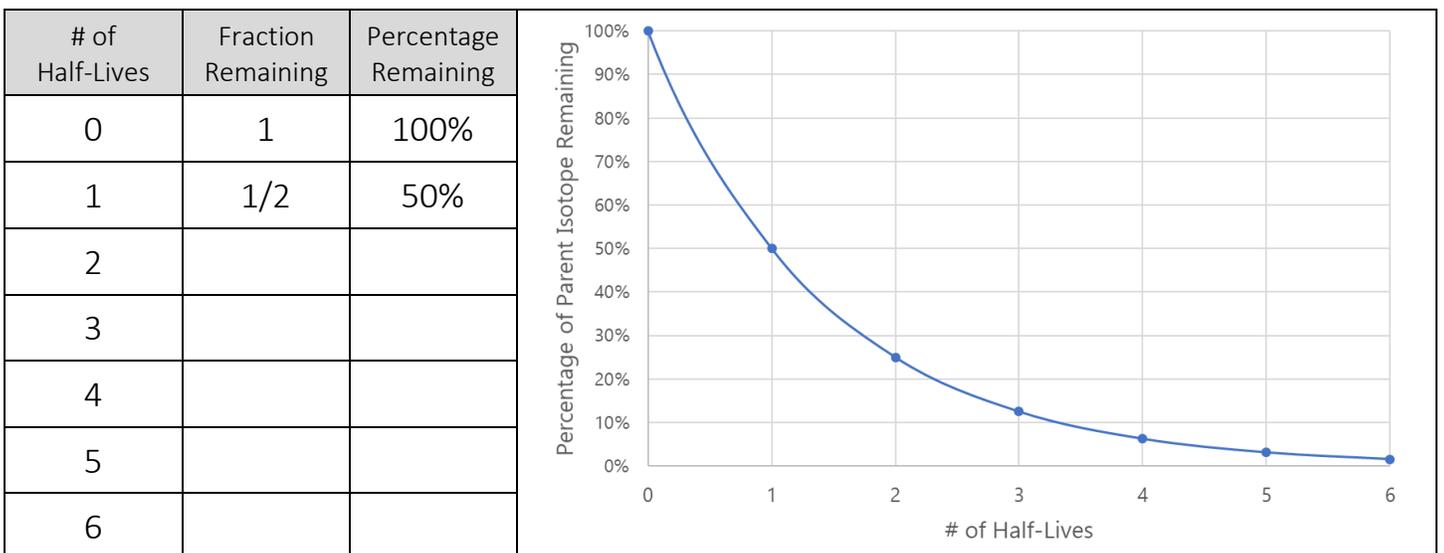
${}^A_Z X \rightarrow {}^{A-4}_{Z-2} X + {}^4_2 \text{He}$			${}^A_Z X \rightarrow {}^A_{Z+1} X + {}^0_{-1} e + \bar{\nu}_e$				${}^A_Z X \rightarrow {}^A_{Z-1} X + {}^0_{+1} e + \nu_e$			
Parent Nuclide	Daughter Nuclide	Alpha Particle	Parent Nuclide	Daughter Nuclide	Electron	Anti-neutrino	Parent Nuclide	Daughter Nuclide	Positron	Neutrino

Property	Alpha ( $\alpha$ )	Beta ( $\beta^+$ or $\beta^-$ )	Gamma ( $\gamma$ )
Relative Charge			
Relative Mass			
Typical Speed			
Ionizing Effect			





## Half Life



## Mass-Energy Equivalence

	Variable Symbol	Unit
Energy		
Mass		
Speed of Light		

*Data Booklet Equation:*

$$E = mc^2$$

$$c = 3.00 \times 10^8 \text{ m s}^{-1}$$

Unified Atomic Mass Unit	$u$	$1.661 \times 10^{-27} \text{ kg}$	1.000000 u	931.5 MeV $c^{-2}$
Electron Rest Mass	$m_e$	$9.110 \times 10^{-31} \text{ kg}$	0.000549 u	0.511 MeV $c^{-2}$
Proton Rest Mass	$m_p$	$1.673 \times 10^{-27} \text{ kg}$	1.007276 u	938 MeV $c^{-2}$
Neutron Rest Mass	$m_n$	$1.675 \times 10^{-27} \text{ kg}$	1.008665 u	940 MeV $c^{-2}$

*Converting between Joules and Electron-Volts*

$\{\text{Energy in eV}\} = \frac{\{\text{Energy in J}\}}{1.60 \times 10^{-19}}$	$\{\text{Energy in J}\} = \{\text{Energy in eV}\} \times 1.60 \times 10^{-19}$
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## Process for Calculating Binding Energy

	Describe	Examples	Challenges
Fission			
Fusion			

# Fundamental Particles

The following two tables are provided in the IB Physics Data Booklet

Charge	Quarks			Baryon Number
$\frac{2}{3}$	u	c	t	$\frac{1}{3}$
$-\frac{1}{3}$	d	s	b	$\frac{1}{3}$
All quarks have a strangeness number of 0 except the strange quark that has a strangeness number of -1				

Charge	Leptons		
-1	e	$\mu$	$\tau$
0	$\nu_e$	$\nu_\mu$	$\nu_\tau$
All leptons have a lepton number of 1 and antileptons have a lepton number of -1			

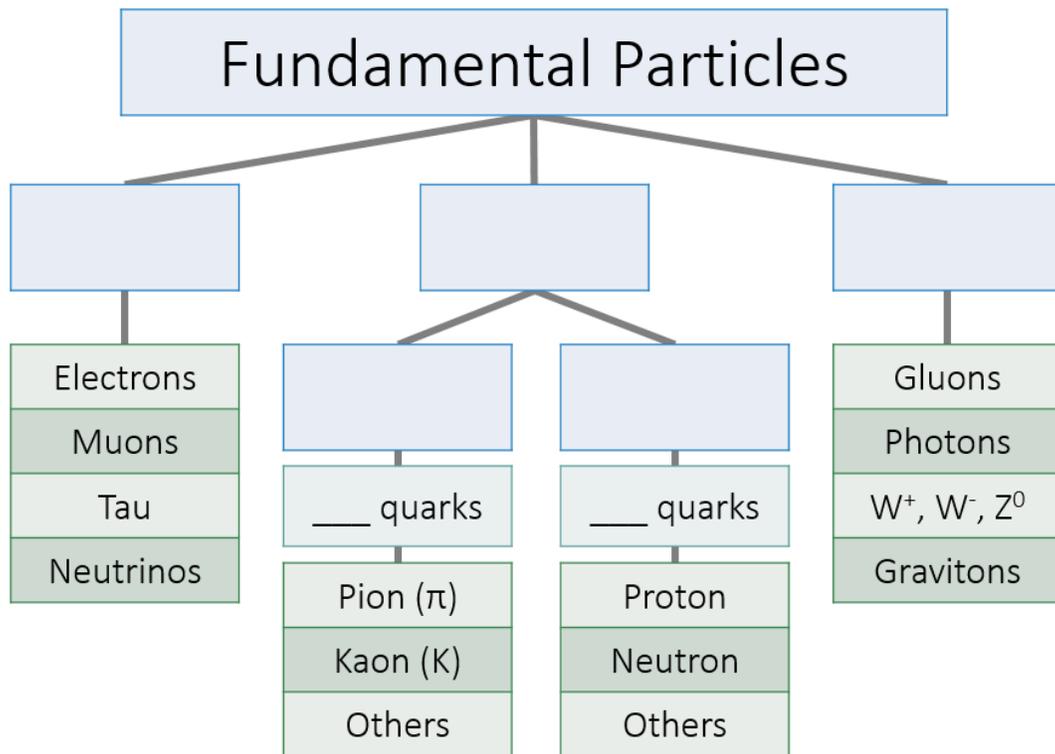
Quarks			
Symbol	Name	Charge	Baryon #
	Up		
	Down		
	Charm		
	Strange		
	Top		
	Bottom		

Leptons			
Symbol	Name	Charge	Lepton #
	Electron		
	Muon		
	Tau		
	Electron Neutrino		
	Muon Neutrino		
	Tau Neutrino		

Anti-Quarks			
Symbol	Name	Charge	Baryon #
	Antiup		
	Antidown		
	Anticharm		
	Antistrange		
	Antitop		
	Antibottom		

Anti-Leptons			
Symbol	Name	Charge	Lepton #
	Antielectron (positron)		
	Antimuon		
	Antitau		
	Electron Antineutrino		
	Muon Antineutrino		
	Tau Antineutrino		

Explain the phenomenon of **Quark Confinement**:



## Fundamental Forces

	Strength	Distance
Gravitational		
Weak		
Electromagnetic		
Strong		

## Particle Configurations

Proton		Neutron	
Total Charge		Total Charge	

## Feynman Diagrams

You can only draw two kinds of lines 	You can <i>only</i> connect these lines if you have two lines with arrows meeting a single wiggly line	The x-axis represents time and is read from left to right. Everything left of the vertex is the "before" condition.
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Beta-Negative Decay	Beta-Positive Decay