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 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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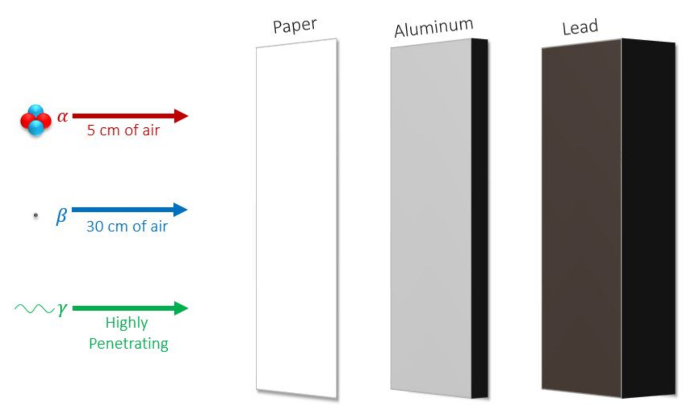
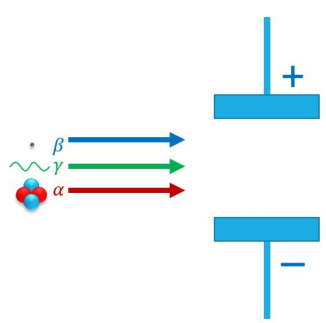
Shelving Guide

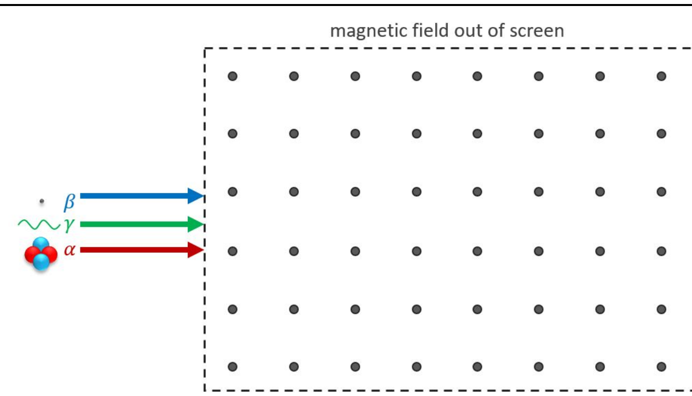
Types of Decay

$ZAX \rightarrow Z-2 + 24H$ Parent Nuclide / Daughter Nuclide / Alpha Particle	$ZA \rightarrow Z+1 + -1 + \bar{\nu}_e$ Parent Nuclide / Daughter Nuclide / Electron / Anti-neutrino	$ZA \rightarrow Z-1 + +1 + \nu_e$ Parent Nuclide / Daughter Nuclide / Positron / Neutrino

Property	Alpha (α)	Beta (β + or β -)	Gamma (γ)
Relative Charge			
Relative Mass			
Typical Speed			
Ionizing Effect			

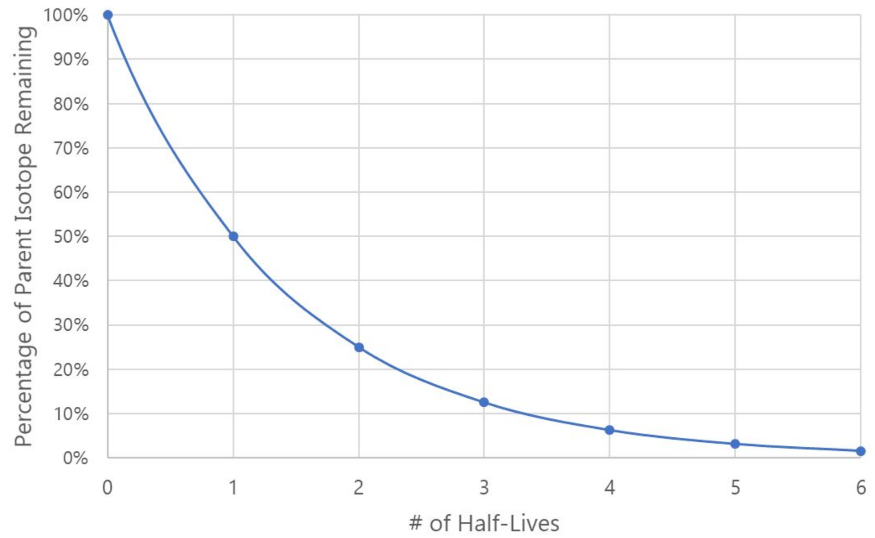






Half Life

# of Half-Lives	Fraction Remaining	Percentage Remaining
0	1	100%
1	1/2	50%
2		
3		
4		
5		
6		



Mass-Energy Equivalence

	Variable Symbol	Unit
Energy		
Mass		
Speed of Light		

Data Booklet Equation:

$$E = mc^2$$

$$c = 3.00\times10^{8}\ m\ s^{-1}$$

Unified Atomic Mass Unit	u	1.661×10^{-27} kg	1.000000 u	931.5 MeV c^{-2}

Electron Rest Mass	m_e	9.110×10^{-31} kg	0.000549 u	0.511 MeV c^{-2}
Proton Rest Mass	m_p	1.673×10^{-27} kg	1.007276 u	938 MeV c^{-2}
Neutron Rest Mass	m_n	1.675×10^{-27} kg	1.008665 u	940 MeV c^{-2}

Converting between Joules and Electron-Volts

$\{Energy\ in\ eV\} = \frac{\{Energy\ in\ J\}}{1.60\times10^{-19}}$	$\{Energy\ in\ J\} = \{Energy\ in\ eV\} \times 1.60\times10^{-19}$

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	μ	τ
0	ν_e	ν_μ	ν_τ
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		

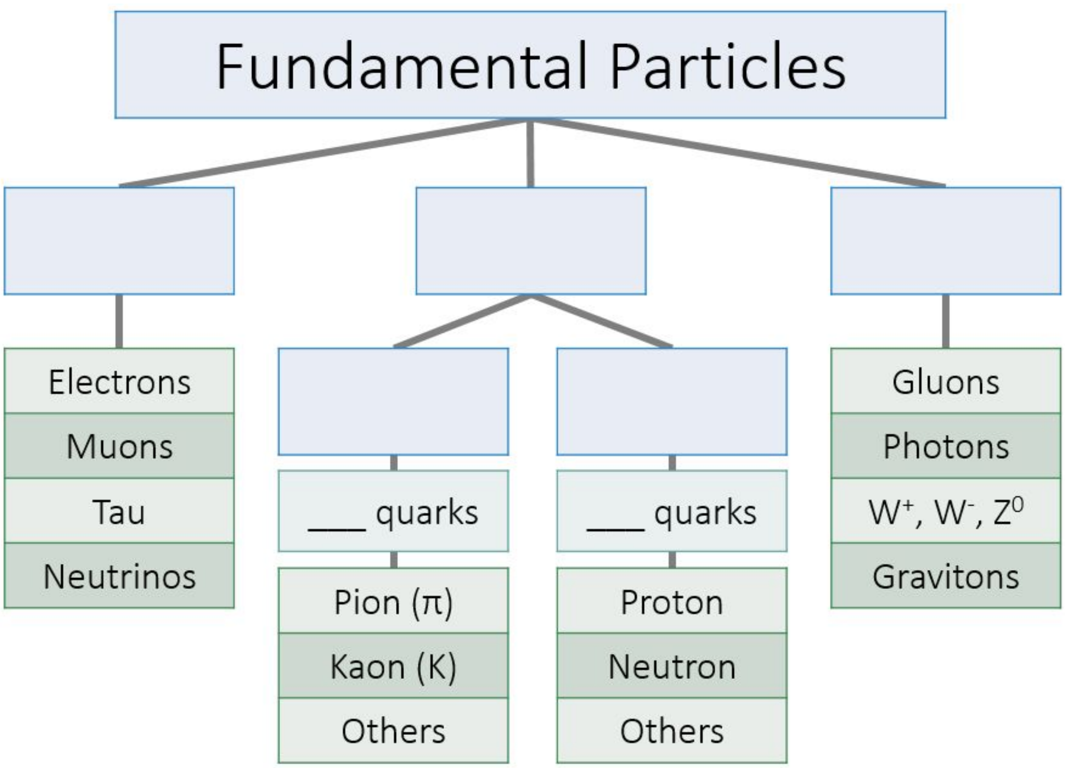
Anti-Quarks

Anti-Leptons

Symbol	Name	Charge	Baryon #
	Antiup		
	Antidown		
	Anticharm		
	Antistrange		
	Antitop		
	Antibottom		

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

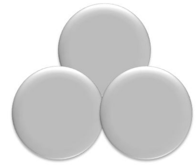
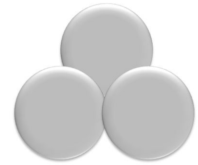
Explain the phenomenon of **Quark Confinement**:



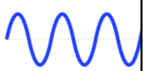
Fundamental Forces

	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 *only* 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.

Beta-Negative Decay	Beta-Positive Decay