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 discoveries of new particles, but it may not yet be complete

Content Objectives

1 – Radiation and Decay

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 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 or electric field			
I can predict the percentage of an isotope remaining after a given number of half-lives			
I can calculate the age of a sample when given the percentage of an isotope remaining			

2 – Energy and Mass Defects

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			

3 – Atomic Spectra

I can describe the concept of emission and absorption spectra and their role in identifying elements			
I can describe what it means for light to be quantized			
I can mathematically relate energy and frequency by Planck's constant			
I can describe the process of electrons dropping energy levels and emitting photons			
I can calculate the energy and wavelength emitted from an electron as it transitions			
I can use the wavelength of light to determine the electron transition			

4 – Particles & the Standard Model

I can identify the general categories of particles in the standard model			
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			
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			

5 – Feynman Diagrams and the Higgs Boson

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			

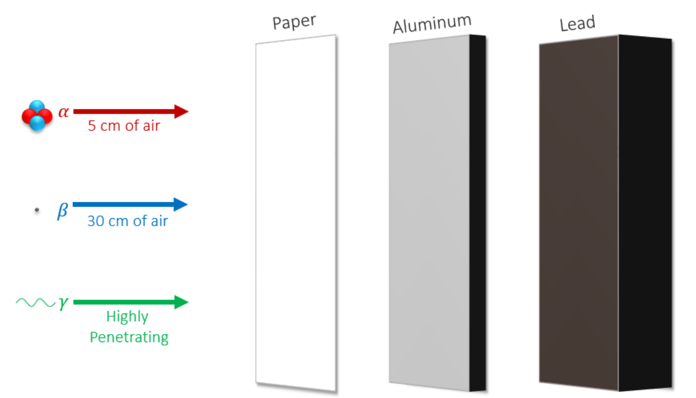
Atomic Physics

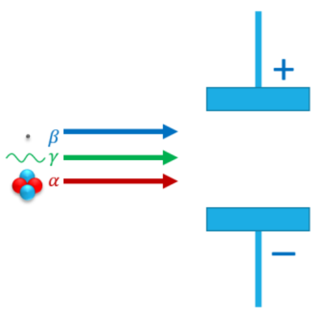
Shelving Guide

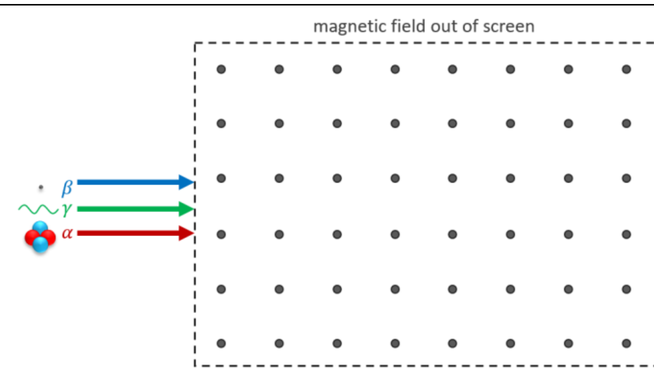
Types of Decay

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

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

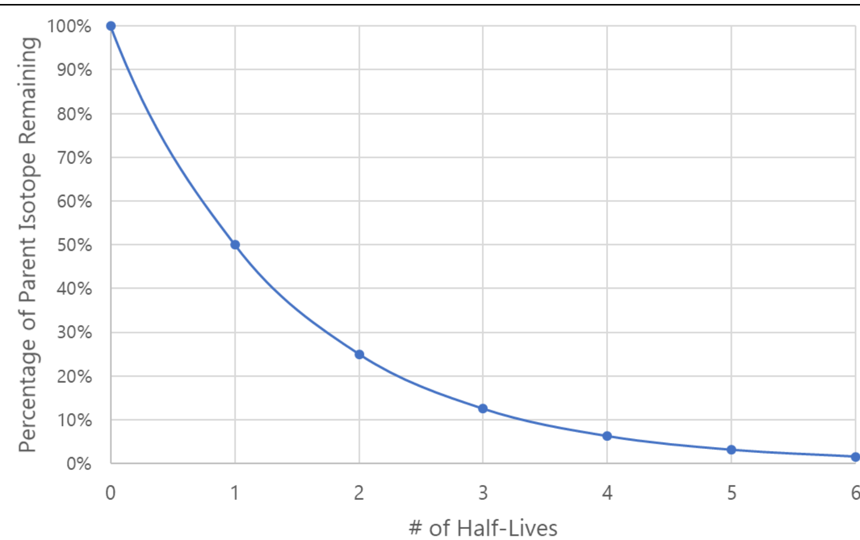






Half Life

# 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:

$$E = mc^2$$

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

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

$\{Energy\ in\ eV\} = \dfrac{\{Energy\ in\ J\}}{1.60 \times 10^{-19}}$	$\{Energy\ in\ J\} = \{Energy\ in\ eV\} \times 1.60 \times 10^{-19}$

Process for Calculating Binding Energy

Atomic Spectra

	Variable Symbol	Unit
Energy		
Planck's Constant		
Frequency		
Speed of Light		
Wavelength		

Data Booklet Equations:

$$E = hf$$

$$\lambda = \frac{hc}{E}$$

$$h = 6.63 \times 10^{-34}\ \mathrm{J\ s}$$

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

hc	J m	eV m

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			

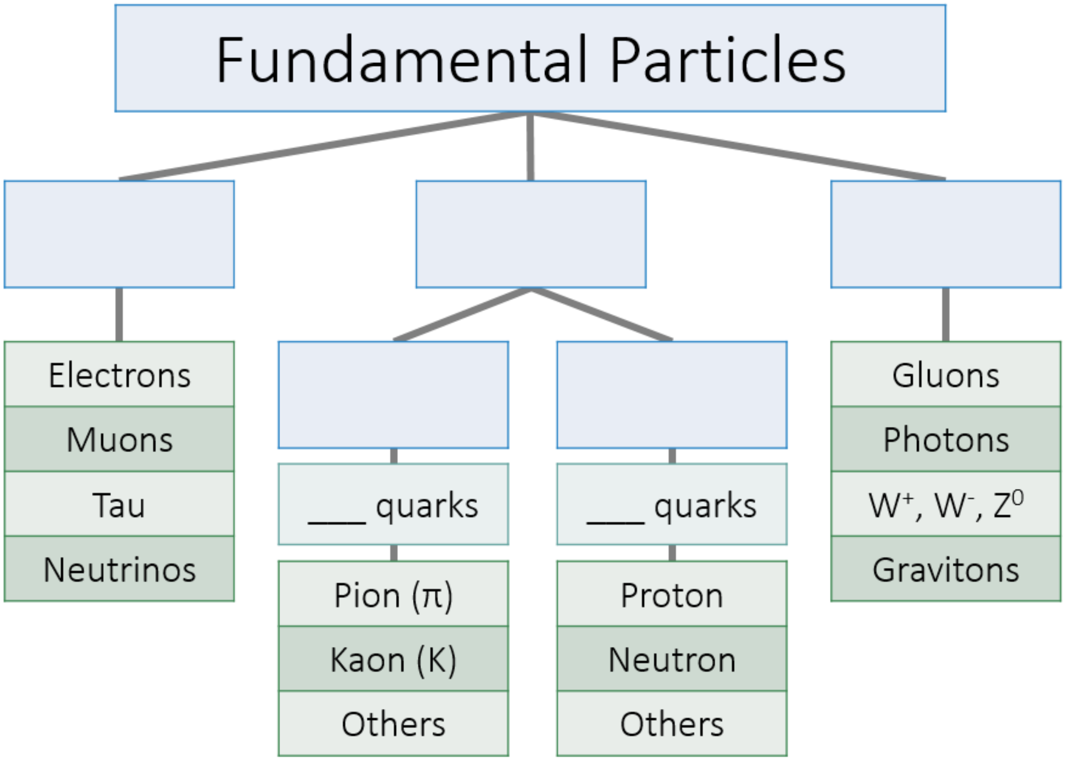
Quarks			
Symbol	Name	Charge	Baryon #
	Up		
	Down		
	Charm		
	Strange		
	Top		
	Bottom		

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

Anti-Quarks			
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		

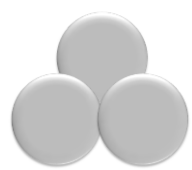
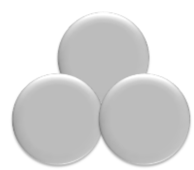
Explain the phenomenon of **Quark Confinement**:



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 *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