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

1 – Structure of the Atom

I can describe how the historical understanding of the atom has changed over time			
I can describe the Rutherford-Geiger-Marsden experiment and how it helped discover the nucleus			
I can interpret isotope notation to determine the number of protons and neutrons			
I can describe electron energy levels and how transitions between these absorb and emit energy			
I can calculate the energy, frequency, and wavelength of light emitted by transitioning electrons			
I can identify and calculate the emission wavelengths for different elements			

2 – Radioactive Decay

I can describe the role of the strong force and explain how nuclei can become unstable			
I can predict the products of radioactive alpha, beta, and gamma decay			
I can compare and contrast the properties of alpha, beta, and gamma particles			
I can conceptually describe the meaning of half-life			
I can calculate the % of a substance remaining after a given number of half lives			
I can calculate the age of a sample when given the percentage of an isotope remaining			

3 – Energy and Mass Defect

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 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			

4 – Nuclear Power

I can describe the chain reaction that occurs to support a self-sustaining fission reactor			
I can describe the concentration of U-235 as a sample is enriched into fuel-grade uranium			
I can outline the process of enriching uranium			
I can explain how a nuclear reactor transforms the energy of a fission reaction into electricity			
I can describe the role of the moderator and control rods in a nuclear reactor			
I can discuss the challenges of disposing of nuclear waste			

Atomic Spectra

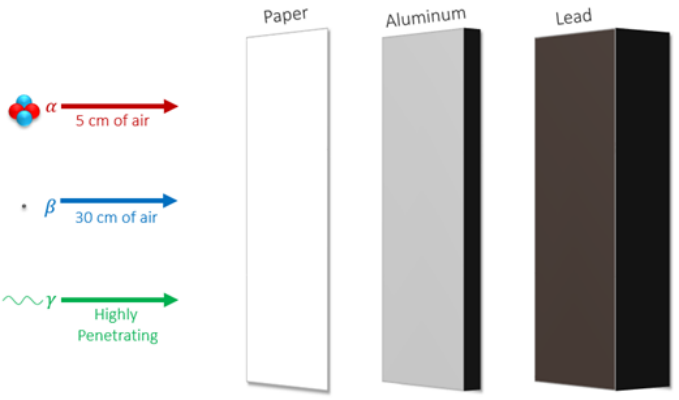
	Variable Symbol	Description	Unit
$E = hf$	E		
	h		
	f		
$h = 6.63 \times 10^{-34}$ J s $c = 3.00 \times 10^{8}$ m s^{-1}	c		
	λ		

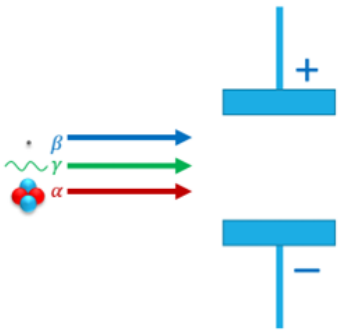
hc	J m	eV m

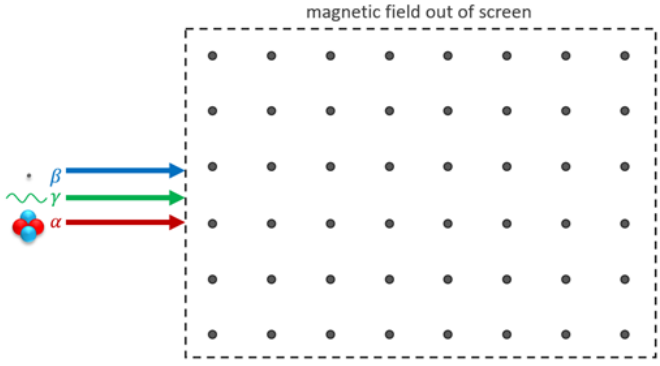
Radioactive Decay

$^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}X + {}^{4}_{2}He$	$^{A}_{Z}X \rightarrow {}^{A}_{Z+1}X + {}^{0}_{-1}e + \bar{\nu}_e$	$^{A}_{Z}X \rightarrow {}^{A}_{Z-1}X + {}^{0}_{+1}e + \nu_e$
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			

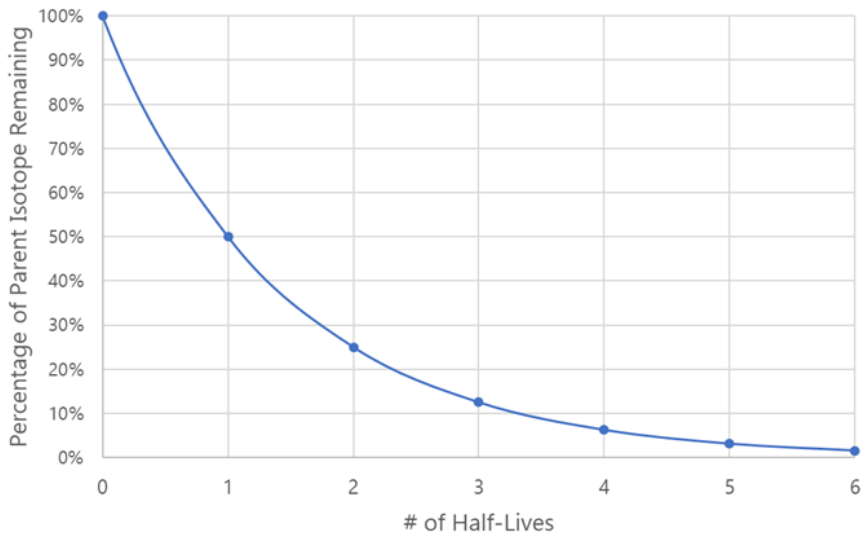






Half Life

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



Mass-Energy Equivalence

	Variable Symbol	Description	Unit
$E = mc^2$ $c = 3.00 \times 10^8\ m\ s^{-1}$	E		
	m		
	c		

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

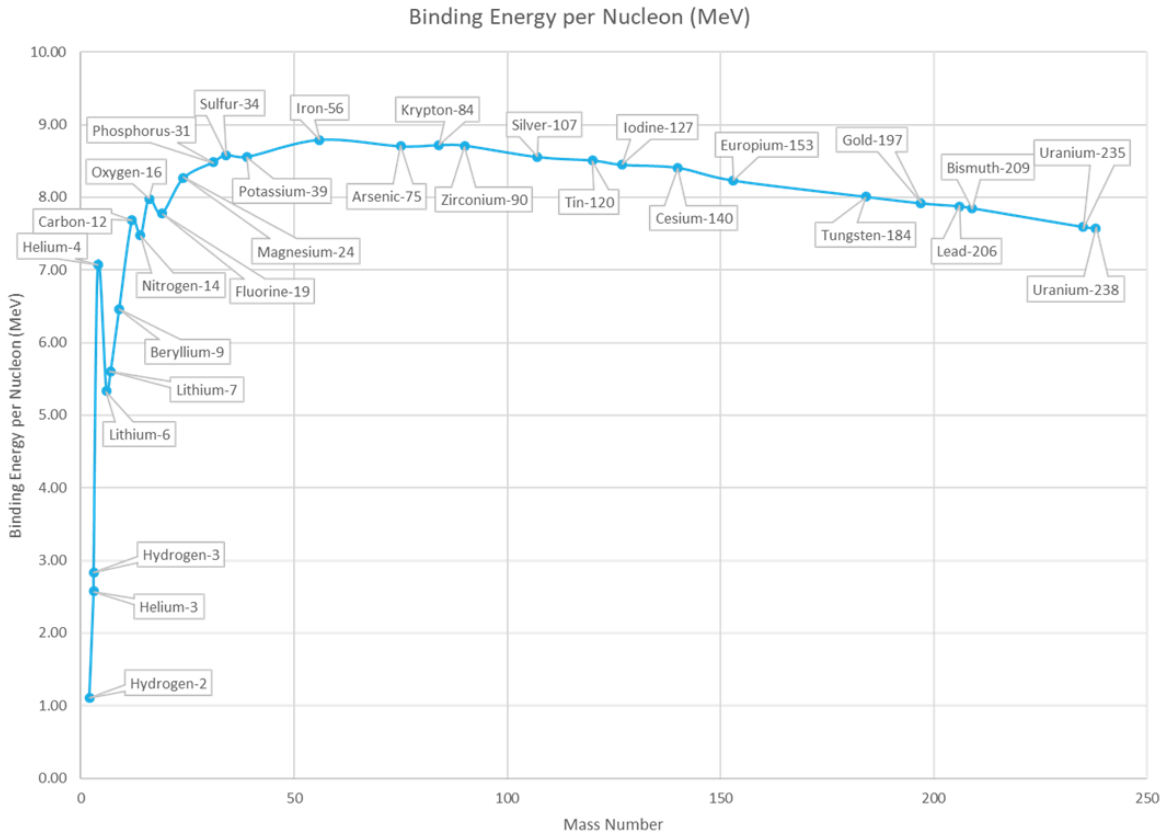
Electron Rest Mass	m_e	9.110 × 10^{-31} kg	0.000549 u	0.511 MeV c^{-2}
Proton Rest Mass	m_p	1.673 × 10^{-27} kg	1.007276 u	938 MeV c^{-2}
Neutron Rest Mass	m_n	1.675 × 10^{-27} kg	1.008665 u	940 MeV c^{-2}

Converting between Joules and Electron-Volts

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

Process for Calculating Binding Energy

Binding Energy per Nucleon



Nuclear Power

	Describe	Examples	Challenges
Fission			
Fusion			

	% of U-235
Uranium Ore	
Fuel-Grade	
Weapons-Grade	

Why is the concentration of U-235 important?
What is done with the nuclear waste?

Moderator	Control Rods