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| **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

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| 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 | |  |  |  |

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| 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 | |  |  |  |

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| 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 | | |  |  |  |

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| 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 | |  |  |  |

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| **Atomic Physics** | Shelving Guide |

## Types of Decay

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Alpha | | | | |  | Beta-Negative | | | | | | |  | Beta-Positive | | | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Parent  Nuclide |  | Daughter Nuclide |  | Alpha Particle |  | Parent  Nuclide |  | Daughter Nuclide |  | Electron |  | Anti-neutrino |  | Parent  Nuclide |  | Daughter Nuclide |  | Positron |  | Neutrino |

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| --- | --- | --- | --- | --- |
| Property | Alpha  (α) | Beta  (β+ or β-) | Gamma  (γ) |  |
| Relative Charge | +2 | +1 or -1 | 0 |
| Relative Mass | 4 | 0.0005 | 0 |
| Typical Speed | 107  m s-1 | 2.5 × 108  m s-1 | 3.0 × 108 m s-1 |
| Ionizing Effect | Strong | Weak | Very Weak |

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## Half Life

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| --- | --- | --- | --- |
| # of  Half-Lives | Fraction  Remaining | Percentage Remaining |  |
| 0 | 1 | 100% |
| 1 | 1/2 | 50% |
| 2 | 1/4 | 25% |
| 3 | 1/8 | 12.5% |
| 4 | 1/16 | 6.25% |
| 5 | 1/32 | 3.125% |
| 6 | 1/64 | 1.5625% |

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| --- | --- | --- | --- | --- |
| Mass-Energy Equivalence | Variable Symbol | Unit |  | *Data Booklet Equation:* |
| Energy | E | J |  |  |
| Mass | m | kg |  |
| Speed of Light | c | m s-1 |  |  |

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| --- | --- | --- | --- | --- |
| Unified Atomic Mass Unit |  | 1.661 × 10-27 kg | 1.000000 u | 931.5 MeV c-2 |
|  |  |  |  |  |
| Electron Rest Mass |  | 9.110 × 10-31 kg | 0.000549 u | 0.511 MeV c-2 |
| Proton Rest Mass |  | 1.673 × 10-27 kg | 1.007276 u | 938 MeV c-2 |
| Neutron Rest Mass |  | 1.675 × 10-27 kg | 1.008665 u | 940 MeV c-2 |

#### Converting between Joules and Electron-Volts

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## Process for Calculating Binding Energy

1. Add up the “before and after” masses
2. Find the mass defect by taking the difference
3. Convert atomic mass units (u) into MeV c-2 by using the conversion factor 1 u = 931.5 MeV c-2
4. The c-2 cancels out when converting to energy using E = mc2 so this is your binding energy

# Atomic Spectra

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| --- | --- | --- | --- | --- |
|  | Variable Symbol | Unit |  | *Data Booklet Equations:* |
| Energy | E | J or eV |  |  |
| Planck’s Constant | h | J s |  |  |
| Frequency | *f* | Hz |  |
| Speed of Light | c | m s-1 |  |  |
| Wavelength | λ | m |  |  |

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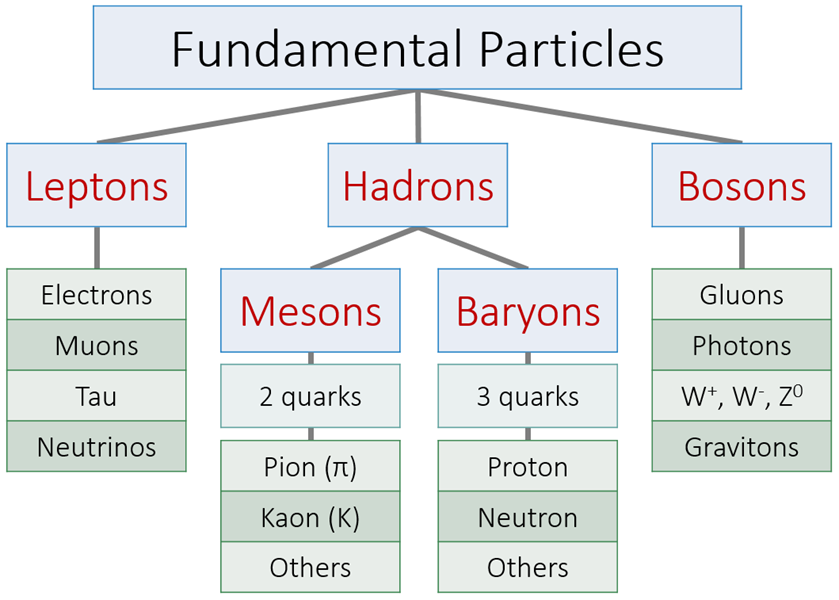
# Fundamental Particles

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

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| Charge | Quarks | | | Baryon Number |  | Charge | Leptons | | |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
| All quarks have a strangeness number of 0 except the strange quark that has a strangeness number of –1 | | | | |  | All leptons have a lepton number of 1 and antileptons have a lepton number of –1 | | | |

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| Quarks | | | |  | Leptons | | | |
| Symbol | Name | Charge | Baryon # |  | Symbol | Name | Charge | Lepton # |
|  | Up |  |  |  |  | Electron |  |  |
|  | Down |  |  |  |  | Muon |  |  |
|  | Charm |  |  |  |  | Tau |  |  |
|  | Strange |  |  |  |  | Electron Neutrino |  |  |
|  | Top |  |  |  |  | Muon Neutrino |  |  |
|  | Bottom |  |  |  |  | Tau Neutrino |  |  |
|  |  |  |  |  |  |  |  |  |
| Anti-Quarks | | | |  | Anti-Leptons | | | |
| Symbol | Name | Charge | Baryon # |  | Symbol | Name | Charge | Lepton # |
|  | Antiup |  |  |  |  | Antielectron (positron) |  |  |
|  | Antidown |  |  |  |  | Antimuon |  |  |
|  | Anticharm |  |  |  |  | Antitau |  |  |
|  | Antistrange |  |  |  |  | Electron Antineutrino |  |  |
|  | Antitop |  |  |  |  | Muon Antineutrino |  |  |
|  | Antibottom |  |  |  |  | Tau Antineutrino |  |  |

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| Explain the phenomenon of **Quark Confinement**:  Quarks have never been observed on their own. The amount of energy required to overcome the strong nuclear force holding the quarks together gets converted into mass and forms a new quark pair. |



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| Fundamental Forces  |  |  |  | | --- | --- | --- | |  | Strength | Distance | | Gravitational | Weakest | Long Range | | Weak | Weak | Short Range | | Electromagnetic | Strong | Very Long Range | | Strong | Strongest | Very Short Range | | Particle Configurations  |  |  |  |  | | --- | --- | --- | --- | | Proton | | Neutron | | |  | |  | | | Total Charge | +1 | Total Charge | 0 | |

# Feynman Diagrams

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| You can only draw two kinds of lines  propagator2types | 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. |

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| Beta-Negative Decay | Beta-Positive Decay |
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