Entering the Atomic Age

Entering the Atomic Age

- Atomic – association – nuclear weapons
- Focus of research – 19th century
- During this time – practice of science/relationship with society – changed
- 1815- Newtonian dominance
- Physical sciences – finetuning, applying principles
- Add new material
- New tools, information – required - new theoretical constructs

Entering the Atomic Age

- Study of energy
- Study of matter

- Two approaches – alternative views?
- Further examination – intersection
- Came together?
- Work of Einstein

Entering the Atomic Age

- Prior – transformation
- Patronage -> institutional funding
- Specialization – disciples/subdisciplines
- Example?
- Professionalization
- Research institutions

- Science to utility – speed

Mastering Electricity

- Missing from Newton?
- 1700's – research on electricity – problems – controlling/generation
- 1799 - Alessandro Volta (1745–1827) – invented electric pile/battery
- Consistency, control, quanifiable, tool
- 1820 Hans Christian Oersted (1777–1851) – electrical heating – wire – current
- Compass needle – movement
- Relationship between electricity and magnetism – 1st experimental

Mastering Electricity

- André Marie Ampère (1775–1836)
- "Mémoire sur la théorie mathématique des phénomènes électrodynamique uniquement déduite de l'expérience"
- Math and experimental – electrical/magnetic behaviour
- Georg Simon Ohm (1789–1854)
- Resistance
- Researchers – wire wrapping – iron
- Joseph Henry (1797–1878)
- Powerful magnets

Mastering Electricity

- 1831 – oscillating device – two magnetic coils – seesaw
- Telegraph
- 1830 – Dynamo – not published
- Credit?
- Michael Faraday (1791–1867)
- Began in chemistry – benzene
- 1821 – shifted to forces
- Iron ring – induction
- Experiments – electricity/magnetism – strain
- Maxwell – link- electricity, magnetism, light – field, waves in fields

Mastering Electricity

- 1879 – “Age of the Inventor”
- New technologies – social, economic, political changes
- Handmade- to mass-produced

Mastering Electricity

- North American/European society – importance
- Industrial tool
- Commercial application - Telegraph
- 1837 – Samuel Morse – version- code system – dots/dashes
- 1844 – Washington to Baltimore
- 1854 – London to Paris
- 1858 – Atlantic cable

Kinetic Theory of Gasses and Thermodynamics

- Additional area not discussed by Newton?
- Heat
- Thermodynamics

- Benjamin Thompson, Count Rumford (1753–1814)
- Observation – cannon-boring equipment
- "…observed that a dull drill bit, although spinning indefinitely, could not cut through the iron of a cannon but would continue to produce heat." (Ede and Cormack, 271)
- 1798- Experimental Inquiry Concerning the Source of Heat Excited by Friction
- Kinetic action (work) to heat

Kinetic Theory of Gasses and Thermodynamics

- James Prescott Joule (1818-1889)
- Formalized relationship
- “On the Calorific Effects of Magneto-electricity and on the Mechanical Value of Heat”
- “On the Mechanical Equivalent of Heat”
- Joule, Lord Kelvin – work – Kinetic Theory of Gasses
- Similar conclusions - Rudolf Clausius (1822–88)
- 1865 - “Entropy”
- Heat not mystery fluid – motion of atoms, molecules
- Can measure atoms, molecules

Kinetic Theory of Gasses and Thermodynamics

- Basis –existence – atoms/ molecules – importance – matter theory
- 1865 - Joseph Loschmidt (1821–95) - application
- Modern presentation- two general laws
- 1st law, energy - new fundamental concept

"… heat is a form of energy and that, in any closed system, the total amount of energy is constant. Thus, it would be impossible to create a machine in the real world that worked continually without an external source of energy, since the energy used to work the machine would be dissipated (by friction, for example) and thus become unavailable to run the machine." (Ede and Cormack, 273)

- “…in any physico-chemical process, it is impossible to convert all the energy into work. Some energy is always converted into heat and thus is not available for work. Further, in any closed system, heat will transfer only in one direction, from a warmer to a cooler region. Over time, entropy will make everything the same temperature if there is no external energy source.” Ede and Cormack, 273)

Cathode Rays and X-Rays

- 1858 Julius Plücker (1801–68)
- "…when a current was passed between electrodes inside a vacuum tube, a greenish glow appeared on the cathode (negative terminal). (Ede and Cormack, 275)
- Glow – same – no matter the metal
- William Crookes (1823–1919)
- Johann Wilhelm Hittorf (1824–1914)
- "…demonstrated that whatever was being projected through the vacuum traveled in straight lines and could cast a shadow if there was an obstacle in its path." (Ede and Cormack, 275)
- Eugene Goldstein – confirmation

Cathode Rays and X-Rays

- Heinrich Rudolf Hertz (1857–94)
- Waves
- Spark gap experiment
- Hertzian Waves – radio waves
- Notable:
- Validated Maxwell
- Extended – spectrum of electromagnetic radiation –examine experimentally

Cathode Rays and X-Rays

- Wilhelm Konrad Röntgen (1845–1923)
- X-rays
- Further expansion of radiation spectrum
- Months later- medical use

- What made it possible?
- Photography
- Nicéphore Niépce (1765–1833)
- 1825 – “first permanent photograph”

Cathode Rays and X-Rays

- George Eastman (1854–1932)
- 1884 – film photography
- Modern standard until digital

- Best example – commercial tech, into lab

- Rontegen – Nobel prize in physics (1st awarding)

Cathode Rays and X-Rays

- Alfred Bernhard Nobel (1833–96)
- Self-taught scientist
- Chemistry – explosives
- Fortune?
- 1867 – dynamite
- Other explosive materials
- Industrial explosives – demand – engineering projects – canals, railways, mining
- Dangerous – stable, increased predictability
- Military demand – European colonialism

Cathode Rays and X-Rays

- Fortune left – prizes – science, peace, literature
- Speculation – prize created due to criticism
- Annually – committee selection
- Physics,
- Chemistry
- Physiology or medicine
- Peace
- Literature

Resolving the Wave/Particle Dilemma

- X-rays – news
- Understand particles in cathode tube – Hertz
- "…by constructing a cathode tube that sent a beam of rays between two electrically charged metal plates, that cathode rays were not deflected from their course when they passed through an electric field." (Ede and Cormack, 279)
- J.J. Thomson (1856–1940) – Hertz – wrong
- Were deflected
- Significant implications: technical foundation –modern consumer electronics

Resolving the Wave/Particle Dilemma

- Two lines of work – unravelling Newtonian system
- 1.) Discovery of radioactivity
- 2.) Logical conundrum – Newtons mechanics – wave theory

Resolving the Wave/Particle Dilemma

- Antoine Henri Becquerel (1852–1908)
- Marie Sklodowska Curie (1867–1934)
- Radioactivity
- New radioactive element – polonium
- 1898 – radium
- Curies, Becquerel, Nobel Prize in Physics
- First female winner, professor
- 1911 - Académie des Sciences – rejected – misogyny, antisemitism, nationalism, conservative/liberal

Resolving the Wave/Particle Dilemma

- Two Nobel prizes
- Important – radioactivity, new elements
- Structure of matter

- Becquerel
- Ionizing radiation – not single type
- Some penetrate thin, others deep
- Some – deflected by electric field

Resolving the Wave/Particle Dilemma

- Differences?
- Types of rays:
- 1900- alpha, beta
- 1903 – gamma

The Atom Deciphered

- Hot topics – xrays, radiation
- Another area – colloids – physical reality – atoms and matter
- Why overshadowed?
- Associated with mundane
- Associated with organic/biological studies vs. nature of matter

- Easier to study?
- 1903 - invention of the ultramicroscope
- Quantitative evaluation

The Atom Deciphered

- Additional development - Theodor (“The”) Svedberg (1884–1971)
- Ultracentrifuge
- Study – organic colloids – hemoglobin
- Discovery – particles – same size
- Uniformity in chemical components of cells
- Results – not readily accepted
- Hermann Staudinger (1881–1965)

The Atom Deciphered

- 1895 Jean-Baptiste Perrin (1870–1942)
- Study of colloids – cathode rays – not waves - > charged particles

- 1909 – publication
- Confirmation – Einstein – physical existence of atoms and molecules (1905)

The Atom Deciphered

- 1903 Ernest Rutherford (1871–1937) and Frederick Soddy (1877–1956)
- Atoms not permanent structures – transformations
- Significant?
- Undermined corpuscular theory of Greeks, Newtonian corpuscularism

- Hans Geiger (1882–1945) – detector –single particle
- Student - Ernest Marsden (1889–1970) - experiment
- Beam of alpha particles – strip of gold
- Most – passed through, few – deflected – tiny – bounced back

The Atom Deciphered

- Deduction?
- Alpha particles – solid core – atom
- Remainder of atom? Empty space
- Solid core – “nucleus” almost all mass
- Atom – nucleus surrounded by electrons

- Niels Bohr (1885–1962)
- Nuclear model - not – classical rules of physics
- Link – atomic structure – thermodynamics

Niels Bohr (1885–1962)

- Important for Bohr’s work?
- Max Planck (1858–1947)
- Quantum theory
- First introduced – impact?
- Growth of importance –once applied – i.e. Bohr’s -atomic structure

- Important application?
- Einstein – photoelectric effect – light – kind of particle
- Atom of light – photon
- Significance – 100+ plus – ideas pertaining to waves of light

Activity: Nobel Prize

- Go to: https://www.nobelprize.org/frequently-asked-questions/
- Answer the following questions:
- 1.) Who selects the Nobel prize laureates?
- 2.) When was the first Nobel prize awarded?
- 3.) Why are they called Nobel Prize laureates?
- 4.) What is Nobel Day?