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Chapter 1 : BBC Bitesize - KS3 Chemistry - Solids, liquids and gases - Revision 1

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But what of his other grand hypothesis? Today, the unified field theory has been modified and expanded to include scientific research unknown to Einstein, with the potential to affect our fundamental understanding of the universe and what we now know of quantum physics. We have learned a lot, but are these advances sufficient to take what we know of the macroscopic realm of gravity and merge it with the strange microscopic kingdom of quantum subatomic particles to create a Grand Unified Theory of Everything? In the whole of the known universe, just two types of elementary particles are theorized to make up everything that exists â€" fermions and bosons. In simple terms, fermions are all the particles that make up matter for example, electrons , and bosons are all the particles that carry force for example, photons. These elementary particles are then further defined by four fundamental forces that affect them: Each of these forces, or fields, exerts a particular influence on matter or energy. The Standard Model of particle physics unites the first three of these forces in a single framework. It describes the interactions of the electromagnetic, strong and weak nuclear forces and all their carrier particles, as well as detailing how these forces act on all matter particles including the recent discovery of the Higgs boson and its associated Higgs Field. In essence, the Standard Model is the logical extension of another much earlier unifying theory by James Clerk Maxwell that brought the electric and magnetic field theories together. With the exception of gravity, each of the fundamental forces has its own corresponding boson type in the Standard Model; the strong nuclear force is carried by the gluon, the electromagnetic force is carried by the photon, and the W and Z bosons are accountable for the weak nuclear force. A Feynman diagram illustrating the interaction of electromagnetic particles Credit: Fermilab This means that the electromagnetic force influences particles with an electric charge, such as photons and electrons, the strong nuclear force provides the fundamental "glue" that holds atomic particles together â€" such as gluons and hadrons â€" and the weak nuclear force is defined by its ability to assist in the radioactive decay in elements â€" it is, for example, the force that initiates the nuclear fusion reaction that powers the Sun. So, in essence, the Standard Model can be seen as the "Handbook to the Universe" for modern physics as it shows how the whole universe hangs together in every possible way. Except, that is, for gravity. On a grand scale â€" that is, at the macroscopic level â€" gravity remains the only one of the four "fields" yet to have clearly defined particles or adequately explained forces associated with it. And, though it is particularly strong around very massive bodies like planets, stars, and galaxies, gravity is the weakest of all the known forces at the microscopic level, where all the other forces exert their greatest influence. So those in science that do believe all of the fields in the universe can be united in a Grand Unified Theory of Everything are looking for ways to expand the Standard Model to encompass gravity and show its interaction with other fields and particles to substantiate their theories. Some would say that the Standard Model is not so easily changed without substantial proof, and that proof has not been observed experimentally, so gravity cannot be included. Alternatively, the Standard Model itself is may no longer considered a definitive version of all the fields in the universe because it is, they say, incompatible with the most successful theory of gravity produced to date; that of general relativity. Regardless of which side of the theoretical divide physicists may sit, the idea that there could be a universal, Grand Unified Theory of Everything remains a captivating prospect, with the result that many proposals have been expounded over the years, and many researchers have spent a great deal of their time and energy pursuing this seductive scientific siren. Even the great Albert Einstein was not immune to its beckoning call. At first glance, such a theory was a logical progression of his work and would make basic, rational sense of the things that we perceive in the universe. Such a theory would encompass a verifiable set of principles, constants, and equations that would describe the field for all of space and time and how it would behave when its parameters were altered. In effect, it would show how the whole of reality behaves in a rational, predictable manner that could be measured, tested, and verified. However, dig deeper into the events of the time, and the motivation for Einstein to produce such a hypothesis as a purely logical progression of known physics may not have been quite as rational as it seemed. At a conference for the leading physicists of the day in Brussels in , Einstein was involved in an infamous argument with the Danish physicist Niels Bohr about the newly-mooted field of quantum physics. Einstein himself had inadvertently set the wheels in motion for this new area of research when he published his paper which won him the Nobel prize in describing the law of the photoelectric effect , where light was first described as a stream of discrete particles. However, he had not â€” and would not â€” leap to the conclusions Bohr and others drew from it. Indeed, Einstein saw all the strange properties associated with quantum theory as proof of its flaws and dismissed it out of hand. For Einstein, God did not "play dice with the universe" â€” he was a strict believer in the deterministic, reliable, repeatable nature of things in his scientifically-stable world, and random effects played no part in it for him. To this end, Einstein sought to unify the forces at play in the universe from his perspective. And, indeed, from a macroscopic perspective, the forces of electromagnetism and gravity are alike in many ways and could be seen to exhibit properties that suggest they may have the same underlying forces at work. The measurable influence of both, for example, is inversely proportional to the square of the distance between two bodies, and both have a seemingly infinite distance over which that influence is capable of being seen or felt. Einstein felt that he was right in this; he was sure that the universe operated in a rational, persistent, measurable way and he saw it as a way to prove once and for all that he was correct about the elemental deterministic nature of reality, free from quantum spooky actions at a distance. During a particularly rancorous period in , he and a couple of other deterministic physicists published a paper purporting to finally prove the non-existence of quantum theory that was soundly rounded upon and howled down by many in the scientific community. Despite this, Einstein focused on little else for the rest of his life. Indeed, trying then rejecting one mathematical model after another, Einstein continued to believe that everything â€” including quantum physics â€” could be explained when the two forces of electromagnetism and gravity were proven to be two products of the same fundamental force. Einstein died on April 18, Next to his hospital bed were a dozen pages of paper covered in scores of notes and equations that had been crossed out, corrected, and re-written. To the very end, Einstein had continued to develop and explore the unification of these stubbornly disparate forces, never giving up his belief that his quest may be just one more line of mathematical code away. Much work leading on from his theories provided tantalizing glimpses at possible gravitational interactions, including the behavior of the smallest of all fermions yet discovered â€” leptons and quarks. This research led directly to the discovery of a gauge-invariant quantum field theory of the weak force, which included an electromagnetic interaction and produced the "electroweak" concept that now shows correlation between electromagnetic and weak nuclear fields , which was, in itself, a great breakthrough in particle physics research. Unfortunately, however, it did not progress to include an observable gravitational component. Nevertheless, buoyed by such revelations, theoretical physicists sought out a similar quantum field theory for the strong nuclear force, and eventually found one, dubbing it quantum chromodynamics. In this case, quarks are shown to interact through the exchange of gluons. This research has led to further postulations that the electroweak and strong nuclear forces could be united in a grand unified theory, which would then incorporate three of the four known forces in the universe. Again, however, an inclusion of the influence of gravity failed to be reconciled. Of loops, strings and gravitons So despite the successful conflation of the fields discussed above, physicists have been unable to formulate a complete particle-driven unified field theory for gravity since it seems to lack a force-carrier particle of its own. There is, however, one contender: A contentious theoretical particle known as a "graviton". The graviton moniker was apparently coined by the Russian physicists Dmitrii Blokhintsev and F. That is, the electromagnetic and strong and weak nuclear forces all act through a "force carrier", which is exchanged between the interacting particles. These exchange carriers are also known as field particles, or gauge bosons. Put simply, unlike the other forces, gravity can not be absorbed, transformed, or shielded against, and it only attracts and never repels. In effect, this theoretical particle appears to possess no discernible way to interact with any other particle. This fact by itself would prohibit its inclusion in the Standard Model, partly because no instrument of sufficient size or efficiency could possibly be built to detect the supposedly tiny energies associated with it, but mostly because the entire concept runs into enormous theoretical difficulties at energies close to the Planck scale , which are the smallest sizes and energies able to be probed with particle accelerators. Despite this, quantum gravity and other yet-to-be-proven quantum mechanical models such as string theory are often associated with gravitons, both of which rely on its existence. And though much hope is pinned on one of these theories eventually providing a unified description of gravity and particle physics, quantum gravity may prove the best contender. This is because string theory alone is not a physical descriptor of reality, but instead a self-contained mathematical model that describes all of the fundamental forces and the various forms of matter as models, not observed phenomena. In string theory, the basic elements of the physical world are not particles, but infinitesimally-small, one-dimensional strings that vibrate at different frequencies, which supposedly give rise to all of the various particles and forces in the universe. The vibrating strings in this hypothesis need anywhere between 10 and 26 dimensions to perform their roles, depending upon the particular branch of the discipline applied. Of all the theories posited to incorporate a fundamental explanation for all the forces so far found in the universe, loop quantum gravity is currently one of the more popular research areas. Essentially, loop quantum gravity hypothesizes that space-time actually consists of an infinite amount of small chunks. At a macroscopic level, these pieces appear to be one smooth sheet of time and space, but when you zoom in to the sub-atomic level, it actually consists of groups of dots connected by lines or loops. As such, space can be viewed as an extremely fine fabric or network woven of finite loops that provide an explanation for gravity, in that it predicts space, like matter, has an atomic structure. The lack of observational evidence to these theories, though, does not preclude the notion that quantum gravitational effects may be somewhat more noticeable near black holes and, if this is so, then quantum gravitational fluctuations could theoretically leave their mark on the emission spectrum analyzed by LIGO and other gravitational wave experiments. Given that the electromagnetic force between an electron and a proton in a hydrogen atom is times greater than the gravitational force between the same two particles, however, it will take one heck of a sensitive detector to go anywhere near differentiating such a tiny field from the background noise. Barking up the wrong apple tree? In all of these theories the inclusion of gravity in interactions with the forces and particles detailed in the the Standard Model, or some yet-to-be-proven quantum mechanical model, requires gravity to have some sort of particle or equivalent force-carrier mechanism of its own for any of these hypotheses to work at all. And, despite Einstein trying to reconcile a Newtonian-style universe with that of his own General Theory of Relativity the central tenet of his hypothesis remains the idea that gravity is an effect of mass impinging on space-time, and no particle is identified or even required to make it work. So, what if there is no particle. What is producing this "force"? To help answer this, we have to look a little deeper into the mechanisms of mass creating curves in the fabric of space time around it. To make this a little more accessible, however, we will not use any of the mathematical formula behind it. Instead, we will use some hopefully not too tortured analogies to attempt to explain what is going on. Imagine, if you will, that space is an enormous bowl of colored jello "jelly" to those of you outside the US and that each massive object in the universe is like a marble dropped into that gelatinous goo. Being solid, the marble takes up space in the jello and the jello itself is distorted around the marble. In very simple terms, this is a simple 3-dimensional interpretation of what space would look like if we could see its distortions; a gelatinous, amorphous substance that contains lumps of matter that it molds itself around, but which distort it at the same time. Now take this analogy a little further, and we see that small particles do not distort the jello of space very much, but the more of these particles you bring together into larger masses, the greater the effect they have in producing distortions. Kick this analogy up a notch, and picture this collection of marbles being able to spin themselves and move forward through this gelatinous substance. All around the marbles, the glutinous space-time material would be contorted, with slow-moving vortices creating voids of jello in their wake as they pushed through it. These distortions and voids are the very simplified equivalent to mass creating curvatures in space. In the version of space imagined by Isaac Newton, with no forces acting between objects they tend to move along the straightest possible line at a constant velocity. If these objects deviate from their path and move towards each other, Newtonian theory would have it that some force has acted one or both of these objects. That is, Newton thought that a mass exerts force directly onto nearby objects. But Einstein realized that gravity is actually a product of the curvature of space where any objects close to a large mass have their ordinary straight line motion curved, giving the appearance of being attracted to the body in question. As a result, small masses near to a massive sphere fall toward the distortion in space that the mass has created just as in our jello analogy. Using yet another analogy, imagine that you are travelling in a train on a straight track on a flat surface at night. Riding in the carriage, everything feels in equilibrium; you are moving forward horizontally, in a straight line, and with very little apparent motion. Now imagine that your train reaches a point on the line where it appears to dip into a steep, downward incline. Your train continues on its straight-line journey on its tracks, but that motion now curves downwards into the valley below. You can neither see the curve nor if the driver is not so reckless as to speed into the dip can you feel the change. But change you have. Your train is now traveling in a downward curve that appears to be in all respects to your senses a straight line, but is in fact distinctly bent. Now imagine that the train is a small mass, the train track is the apparent straight-line motion of objects through space, and the steep incline is the curvature in space-time created by a large mass. In this way, any object that appears to be traveling forward in time and space in a linear, straight-line motion as observed from your own point of view, is in fact, following the curvature of space-time created by a massive object and giving the illusion that the driver of this motion is the force of gravity. As such, gravity is not actually exerting a force, because it is not a force itself â€” it is merely an effect of the distortion of space-time being observed as something that has the apparent behavior of a force, but where objects are merely following the curve created by a mass. And this is all based on the fact that â€” and I am repeating this because it is worth doing so â€” gravity cannot be absorbed, transformed, or shielded against, and it only attracts and never repels, and so it displays no aspects at all comparable to other forces in the Standard Model.

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Chapter 2 : New, simple theory may explain mysterious dark matter | Vanderbilt News | Vanderbilt Universi

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New, simple theory may explain mysterious dark matter by David Salisbury Jun. It appears to have left behind a large clump of dark matter. Space Telescope Science Institute Most of the matter in the universe may be made out of particles that possess an unusual, donut-shaped electromagnetic field called an anapole. This proposal, which endows dark matter particles with a rare form of electromagnetism, has been strengthened by a detailed analysis performed by a pair of theoretical physicists at Vanderbilt University: An article about the research was published online last month by the journal Physics Letters B. A number of physicists have suggested that dark matter is made from Majorana particles, but Scherrer and Ho have performed detailed calculations that demonstrate that these particles are uniquely suited to possess a rare, donut-shaped type of electromagnetic field called an anapole. This field gives them properties that differ from those of particles that possess the more common fields possessing two poles north and south, positive and negative and explains why they are so difficult to detect. These predictions show that soon the existence of anapole dark matter should either be discovered or ruled out by these experiments. Their existence was predicted by Paul Dirac in Since then, physicists have been searching for Majorana fermions. The primary candidate has been the neutrino, but scientists have been unable to determine the basic nature of this elusive particle. Subsequently, astronomers have discovered that the rate that stars rotate around individual galaxies is similarly out of sync. Detailed observations have shown that stars far from the center of galaxies are moving at much higher velocities than can be explained by the amount of visible matter that the galaxies contain. Comparison of an anapole field with common electric and magnetic dipoles. The anapole field, top, is generated by a toroidal electrical current. As a result, the field is confined within the torus, instead of spreading out like the fields generated by conventional electric and magnetic dipoles. In fact, astronomical observations have basically ruled out the possibility that dark matter particles carry electrical charges. The only problem is that even these more complicated models are ruled out for Majorana particles. That is one of the reasons that Ho and Scherrer took a closer look at dark matter with an anapole magnetic moment. Since then it has been observed in the magnetic structure of the nuclei of cesium and ytterbium atoms. Particles with familiar electrical and magnetic dipoles, interact with electromagnetic fields even when they are stationary. They must be moving before they interact and the faster they move the stronger the interaction. As a result, anapole particles would have been have been much more interactive during the early days of the universe and would have become less and less interactive as the universe expanded and cooled. The anapole dark matter particles suggested by Ho and Scherrer would annihilate in the early universe just like other proposed dark matter particles, and the left-over particles from the process would form the dark matter we see today. But because dark matter is moving so much more slowly at the present day, and because the anapole interaction depends on how fast it moves, these particles would have escaped detection so far, but only just barely.

Chapter 3 : Dark matter - Wikipedia

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Exoplanets Dark Energy, Dark Matter In the early s, one thing was fairly certain about the expansion of the universe. It might have enough energy density to stop its expansion and recollapse, it might have so little energy density that it would never stop expanding, but gravity was certain to slow the expansion as time went on. Granted, the slowing had not been observed, but, theoretically, the universe had to slow. The universe is full of matter and the attractive force of gravity pulls all matter together. Then came and the Hubble Space Telescope HST observations of very distant supernovae that showed that, a long time ago, the universe was actually expanding more slowly than it is today. So the expansion of the universe has not been slowing due to gravity, as everyone thought, it has been accelerating. No one expected this, no one knew how to explain it. But something was causing it. Eventually theorists came up with three sorts of explanations. It is called dark energy. What Is Dark Energy? More is unknown than is known. Other than that, it is a complete mystery. But it is an important mystery. The more shallow the curve, the faster the rate of expansion. The curve changes noticeably about 7. Astronomers theorize that the faster expansion rate is due to a mysterious, dark force that is pulling galaxies apart. Albert Einstein was the first person to realize that empty space is not nothing. Space has amazing properties, many of which are just beginning to be understood. The first property that Einstein discovered is that it is possible for more space to come into existence. Because this energy is a property of space itself, it would not be diluted as space expands. As more space comes into existence, more of this energy-of-space would appear. As a result, this form of energy would cause the universe to expand faster and faster. Unfortunately, no one understands why the cosmological constant should even be there, much less why it would have exactly the right value to cause the observed acceleration of the universe. Dark Matter Core Defies Explanation This image shows the distribution of dark matter, galaxies, and hot gas in the core of the merging galaxy cluster Abell The result could present a challenge to basic theories of dark matter. Another explanation for how space acquires energy comes from the quantum theory of matter. In this theory, "empty space" is actually full of temporary "virtual" particles that continually form and then disappear. But when physicists tried to calculate how much energy this would give empty space, the answer came out wrong - wrong by a lot. The number came out times too big. So the mystery continues. Another explanation for dark energy is that it is a new kind of dynamical energy fluid or field, something that fills all of space but something whose effect on the expansion of the universe is the opposite of that of matter and normal energy. Some theorists have named this "quintessence," after the fifth element of the Greek philosophers. That would not only affect the expansion of the universe, but it would also affect the way that normal matter in galaxies and clusters of galaxies behaved. This fact would provide a way to decide if the solution to the dark energy problem is a new gravity theory or not: But if it does turn out that a new theory of gravity is needed, what kind of theory would it be? There are candidate theories, but none are compelling. The thing that is needed to decide between dark energy possibilities - a property of space, a new dynamic fluid, or a new theory of gravity - is more data, better data. What Is Dark Matter? What is dark matter? We are much more certain what dark matter is not than we are what it is. First, it is dark, meaning that it is not in the form of stars and planets that we see. Second, it is not in the form of dark clouds of normal matter, matter made up of particles called baryons. We know this because we would be able to detect baryonic clouds by their absorption of radiation passing through them. Third, dark matter is not antimatter, because we do not see the unique gamma rays that are produced when antimatter annihilates with matter. Finally, we can rule out large galaxy-sized black holes on the basis of how many gravitational lenses we see. The blue shows a map of the total mass concentration mostly dark matter. However, at this point, there are still a few dark matter possibilities that are viable. Baryonic matter could still make up the dark matter if it were all tied up in brown dwarfs or in small, dense chunks of heavy elements. But the most common view is that dark matter is not baryonic at all, but that it is made up of other, more exotic particles like axions or WIMPS Weakly Interacting Massive Particles. Researchers were surprised when they uncovered galaxy NGC DF2 which is missing most, if not all, of its dark matter.

Chapter 4 : Dark Energy, Dark Matter | Science Mission Directorate

Atoms, blacksmiths, and crystals; practical and theoretical views of the structure of matter in the seventeenth and eighteenth centuries. Papers read at a Clark Library seminar, November 26, , by Cyril S. Smith [and] John G. Burke.

Play media Models of rotating disc galaxies in the present day left and ten billion years ago right. In the present-day galaxy, dark matterâ€"shown in redâ€"is more concentrated near the center and it rotates more rapidly effect exaggerated. The arms of spiral galaxies rotate around the galactic center. The luminous mass density of a spiral galaxy decreases as one goes from the center to the outskirts. If luminous mass were all the matter, then we can model the galaxy as a point mass in the centre and test masses orbiting around it, similar to the Solar System. This is not observed. In particular, there is a lot of non-luminous matter dark matter in the outskirts of the galaxy. Velocity dispersion Stars in bound systems must obey the virial theorem. The theorem, together with the measured velocity distribution, can be used to measure the mass distribution in a bound system, such as elliptical galaxies or globular clusters. With some exceptions, velocity dispersion estimates of elliptical galaxies [48] do not match the predicted velocity dispersion from the observed mass distribution, even assuming complicated distributions of stellar orbits. Galaxy clusters[edit] Galaxy clusters are particularly important for dark matter studies since their masses can be estimated in three independent ways: From the scatter in radial velocities of the galaxies within clusters From X-rays emitted by hot gas in the clusters. Gravitational lensing usually of more distant galaxies can measure cluster masses without relying on observations of dynamics e. Generally, these three methods are in reasonable agreement that dark matter outweighs visible matter by approximately 5 to 1. Dark matter map for a patch of sky based on gravitational lensing analysis of a Kilo-Degree survey. The more massive an object, the more lensing is observed. Strong lensing is the observed distortion of background galaxies into arcs when their light passes through such a gravitational lens. It has been observed around many distant clusters including Abell In the dozens of cases where this has been done, the mass-to-light ratios obtained correspond to the dynamical dark matter measurements of clusters. By analyzing the distribution of multiple image copies, scientists have been able to deduce and map the distribution of dark matter around the MACS J By examining the apparent shear deformation of the adjacent background galaxies, the mean distribution of dark matter can be characterized. The mass-to-light ratios correspond to dark matter densities predicted by other large-scale structure measurements. Light follows the curvature of spacetime, resulting in the lensing effect. Cosmic microwave background Estimated division of total energy in the universe into matter, dark matter and dark energy based on five years of WMAP data. In particular, in the early universe, ordinary matter was ionized and interacted strongly with radiation via Thomson scattering. Dark matter does not interact directly with radiation, but it does affect the CMB by its gravitational potential mainly on large scales , and by its effects on the density and velocity of ordinary matter. Ordinary and dark matter perturbations, therefore, evolve differently with time and leave different imprints on the cosmic microwave background CMB. The cosmic microwave background is very close to a perfect blackbody but contains very small temperature anisotropies of a few parts in , A sky map of anisotropies can be decomposed into an angular power spectrum, which is observed to contain a series of acoustic peaks at near-equal spacing but different heights. The series of peaks can be predicted for any assumed set of cosmological parameters by modern computer codes such as CMBFast and CAMB, and matching theory to data, therefore, constrains cosmological parameters. After the discovery of the first acoustic peak by the balloon-borne BOOMERanG experiment in , the power spectrum was precisely observed by WMAP in , and even more precisely by the Planck spacecraft in The results support the Lambda-CDM model. Structure formation 3D map of the large-scale distribution of dark matter, reconstructed from measurements of weak gravitational lensing with the Hubble Space Telescope. Prior to structure formation, the Friedmann solutions to general relativity describe a homogeneous universe. Later, small anisotropies gradually grew and condensed the homogeneous universe into stars, galaxies and larger structures. Ordinary matter is affected by radiation, which is the dominant element of the universe at very early times. As a result, its density perturbations are washed out and unable to condense into structure. Dark matter provides a solution to this problem because it is unaffected by radiation. Therefore, its density perturbations can grow first. The resulting gravitational potential acts as an attractive potential well for ordinary matter collapsing later, speeding up the structure formation process. Bullet Cluster If dark matter does not exist, then the next most likely explanation is that general relativityâ€”the prevailing theory of gravityâ€”is incorrect. The Bullet Cluster, the result of a recent collision of two galaxy clusters, provides a challenge for modified gravity theories because its apparent center of mass is far displaced from the baryonic center of mass.

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Chapter 5 : Holdings : The search for a theory of matter. - | York University Libraries

The first accessible book on a theory of physics that explains the relationship between the particles and forces that make up our universe. For decades, physicists have been fascinated with the possibility that two seemingly independent aspects of our worldâ€”matter and forceâ€”may in fact be intimately.

September 25, by Glenn Roberts Jr, Lawrence Berkeley National Laboratory A visualization of a massive galaxy cluster that shows dark matter density purple filaments overlaid with the gas velocity field. Now, through a new research program supported by the U. Quantum technologies are emerging as promising alternatives to the more conventional "mousetraps" that researchers have previously used to track down elusive particles. And the DOE, through the same HEP office, is also supporting a collection of other research efforts led by Berkeley Lab scientists that tap into quantum theory, properties, and technologies in the QIS field. Unraveling the Quantum Structure of Quantum Chromodynamics in Parton Shower Monte Carlo Generators â€” This effort will develop computer programs that test the interactions between fundamental particles in extreme detail. Quantum Pattern Recognition QPR for High-Energy Physics â€”Increasingly powerful particle accelerators require vastly faster computer algorithms to monitor and sort through billions of particle events per second, and this effort will develop and study the potential of quantum-based algorithms for pattern recognition to reconstruct charged particles. Such algorithms have the potential for significant speed improvements and increased precision. Skipper-CCD, a New Single-Photon Sensor for Quantum Imaging â€" For the past six years, Berkeley Lab and Fermi National Accelerator Laboratory Fermilab have been collaborating in the development of a detector for astrophysics experiments that can detect the smallest individual unit of light, known as a photon. This Skipper-CCD detector was successfully demonstrated in the summer of with an incredibly low noise that allowed the detection of even individual electrons. As a next step, this Fermilab-led effort will seek to image pairs of photons that exist in a state of quantum entanglement, meaning their properties are inherently related â€" even over long distances â€" such that the measurement of one of the particles necessarily defines the properties of the other. Geometry and Flow of Quantum Information: From Quantum Gravity to Quantum Technology â€"This effort will develop quantum algorithms and simulations for properties, including error correction and information scrambling, that are relevant to black hole theories and to quantum computing involving highly connected arrays of superconducting qubits â€" the basic units of a quantum computer. Researchers will also compare these with more classical methods. Siddiqi is also leading a separate research program, Field Programmable Gate Array-based Quantum Control for High-Energy Physics Simulations with Qutrits, that will develop specialized tools and logic families for high-energy-physics-focused quantum computing. These projects are also part of Berkeley Quantum, a partnership that harnesses the expertise and facilities of Berkeley Lab and UC Berkeley to advance U. At Berkeley Lab, the largest HEP-funded QIS-related undertaking will include a multidisciplinary team in the development and demonstration of quantum sensors to look for very-low-mass dark matter particles â€" so-called "light dark matter" â€" by instrumenting two different detectors. One of these detectors will use liquid helium at a very low temperature where otherwise familiar phenomena such as heat and thermal conductivity display quantum behavior. The other detector will use specially fabricated crystals of gallium arsenide see a related article , also chilled to cryogenic temperatures. The ideas for how these experiments can search for very light dark matter sprang from theory work at Berkeley Lab. But LZ and similar experiments are not designed to detect dark matter particles of much lower masses. While a traditional WIMP experiment is designed to sense the recoil of an entire atomic nucleus after it is "kicked" by a dark matter particle, very-low-mass dark matter particles will bounce right off nuclei without affecting them, like a flea bouncing off an elephant. The goal of the new effort is to sense the low-mass particles via their energy transfer in the form of very feeble quantum vibrations, which go by names like "phonons" or "rotons," for example, Garcia-Sciveres said. But what if every time an invisible flea hits an elephant at one end of the herd, a visible flea is flung away from an elephant at the other end of the herd? Dan McKinsey, a Berkeley Lab faculty senior scientist and UC Berkeley physics professor who is responsible for the development of the liquid helium detector, said that the detectors will be constructed on the UC Berkeley campus. Both are designed to be sensitive to particles with a mass lighter than protons â€” the positively charged particles that reside in atomic nuclei. The superfluid helium detector will make use of a process called "quantum evaporation," in which rotons and phonons cause individual helium atoms to be evaporated from the surface of superfluid helium. Theories developed at Berkeley Lab suggest that certain exotic materials exhibit quantum states or "modes" that low-mass dark matter particles can couple with, which would make the particles detectable â€” like the "visible flea" referenced above. Versions of these sensors are already used to search for slight temperature variations in the relic microwave light that spans the universe. At the end of the three-year demonstration, researchers could perhaps turn their sights to more exotic types of detector materials in larger volumes.

Chapter 6 : New Dark Matter Theory Weighs Superheavy Particle

The kinetic energy theory of matter states that all particles of matter are in constant motion. Kinetics has to do with some kind of movement, which is why this answer is the only plausible one.

March 17, New research explores the possibility that dark matter is made up of particles that weigh about as much as a human cell. Ford Johns Hopkins University Dark matter could be made of particles that each weigh almost as much as a human cell and are nearly dense enough to become miniature black holes, new research suggests. True to its name, dark matter is invisible â€” it does not emit, reflect or even block light. As a result, dark matter can currently be studied only through its gravitational effects on normal matter. The nature of dark matter is currently one of the greatest mysteries in science. If dark matter is made of such superheavy particles, astronomers could detect evidence of them in the afterglow of the Big Bang, the authors of a new research study said. See what scientists know about dark matter in this Space. Gravitational effects attributed to dark matter include the orbital motions of galaxies: The consensus so far among scientists is that this missing mass is made up of a new species of particles that interact only very weakly with ordinary matter. These new particles would exist outside the Standard Model of particle physics, which is the best current description of the subatomic world. Some dark matter models suggest that this cosmic substance is made of weakly interacting massive particles, or WIMPs, that are thought to be about times the mass of a proton, said study co-author McCullen Sandora, a cosmologist at the University of Southern Denmark. However, despite many searches, researchers have not conclusively detected any WIMPs so far, leaving open the possibility that dark matter particles could be made of something significantly different. In this new model, known as Planckian interacting dark matter, each of the weakly interacting particles weighs about or 10 billion billion times more than a proton, or "about as heavy as a particle can be before it becomes a miniature black hole," Sandora told Space. A particle that is the mass of a proton weighs about 1 microgram. In comparison, research suggests that a typical human cell weighs about 3. In fact, so far there have been no definitive hints that there is any new physics beyond the Standard Model at any accessible energy scales, so we were driven to think of the ultimate limit to this scenario. Will dark matter and dark energy ever be actually seen? Maybe, but scientists may debate the discovery for years before it is accepted. No, there are some things in this universe humans are not meant to understand. But now the researchers have suggested that if these particles exist, signs of their existence might be detectable in the cosmic microwave background radiation, the afterglow of the Big Bang that created the universe about Currently, the prevailing view in cosmology is that moments after the Big Bang, the universe grew gigantically in size. This enormous growth spurt, called inflation, would have smoothed out the cosmos, explaining why it now looks mostly similar in every direction. After inflation ended, research suggests that the leftover energy heated the newborn universe during an epoch called "reheating. However, for this model to work, the heat during reheating would have had to be significantly higher than what is typically assumed in universal models. A hotter reheating would in turn leave a signature in the cosmic microwave background radiation that the next generation of cosmic microwave background experiments could detect. For example, if dark matter is made of these superheavy particles, that reveals "that inflation happened at a very high energy, which in turn means that it was able to produce not just fluctuations in the temperature of the early universe, but also in space-time itself, in the form of gravitational waves ," Sandora said. Choi on Twitter cqchoi. Original article on Space.

Chapter 7 : A quantum leap toward expanding the search for dark matter

The kinetic molecular theory of matter states that all particles of matter are in constant battering motion. It is mostly applied to gaseous particles. This is because they have room for movement in that their distance between each particle is great.

Atomism The idea that matter is made up of discrete units is a very old idea, appearing in many ancient cultures such as Greece and India. The word "atom" Greek: The first was the law of conservation of mass , closely associated with the work of Antoine Lavoisier , which states that the total mass in a chemical reaction remains constant that is, the reactants have the same mass as the products. First established by the French chemist Joseph Louis Proust in , [7] this law states that if a compound is broken down into its constituent chemical elements, then the masses of the constituents will always have the same proportions by weight, regardless of the quantity or source of the original substance. John Dalton studied and expanded upon this previous work and defended a new idea, later known as the law of multiple proportions: For example, Proust had studied tin oxides and found that there is one type of tin oxide that is Dalton noted from these percentages that g of tin will combine either with Dalton found several examples of such instances of integral multiple combining proportions, and asserted that the pattern was a general one. Indeed, carbon dioxide molecules CO_2 are heavier and larger than nitrogen molecules N_2. Dalton proposed that each chemical element is composed of atoms of a single, unique type, and though they cannot be altered or destroyed by chemical means, they can combine to form more complex structures chemical compounds. This marked the first truly scientific theory of the atom, since Dalton reached his conclusions by experimentation and examination of the results in an empirical fashion. In Dalton orally presented his first list of relative atomic weights for a number of substances. This paper was published in , but he did not discuss there exactly how he obtained these figures. Dalton estimated the atomic weights according to the mass ratios in which they combined, with the hydrogen atom taken as unity. However, Dalton did not conceive that with some elements atoms exist in moleculesâ€”e. He also mistakenly believed that the simplest compound between any two elements is always one atom of each so he thought water was HO, not H_2O. For instance, in he believed that oxygen atoms were 5. Adopting better data, in he concluded that the atomic weight of oxygen must actually be 7 rather than 5. Thus, Avogadro was able to offer more accurate estimates of the atomic mass of oxygen and various other elements, and made a clear distinction between molecules and atoms. Brownian Motion In , the British botanist Robert Brown observed that dust particles inside pollen grains floating in water constantly jiggled about for no apparent reason. In , Albert Einstein theorized that this Brownian motion was caused by the water molecules continuously knocking the grains about, and developed a hypothetical mathematical model to describe it. Discovery of subatomic particles Main articles: Electron and Plum pudding model The cathode rays blue were emitted from the cathode, sharpened to a beam by the slits, then deflected as they passed between the two electrified plates. Atoms were thought to be the smallest possible division of matter until when J. Thomson discovered the electron through his work on cathode rays. When a voltage is applied across the electrodes, cathode rays are generated, creating a glowing patch where they strike the glass at the opposite end of the tube. Through experimentation, Thomson discovered that the rays could be deflected by an electric field in addition to magnetic fields , which was already known. He concluded that these rays, rather than being a form of light, were composed of very light negatively charged particles he called " corpuscles " they would later be renamed electrons by other scientists. He measured the mass-to-charge ratio and discovered it was times smaller than that of hydrogen, the smallest atom. These corpuscles were a particle unlike any other previously known. Thomson suggested that atoms were divisible, and that the corpuscles were their building blocks. Discovery of the nucleus Main article: Rutherford model The Geiger-Marsden experiment Left: In the Geigerâ€”Marsden experiment , Hans Geiger and Ernest Marsden colleagues of Rutherford working at his behest shot alpha particles at thin sheets of metal and measured their deflection through the use of a fluorescent screen. To their astonishment, a small fraction of the alpha particles experienced heavy deflection. Rutherford concluded that the positive charge of the atom must be concentrated in a very tiny volume to produce an electric field sufficiently intense to deflect the alpha particles so strongly. This led Rutherford to propose a planetary model in which a cloud of electrons surrounded a small, compact nucleus of positive charge. Only such a concentration of charge could produce the electric field strong enough to cause the heavy deflection. Bohr model The planetary model of the atom had two significant shortcomings. The first is that, unlike planets orbiting a sun, electrons are charged particles. An accelerating electric charge is known to emit electromagnetic waves according to the Larmor formula in classical electromagnetism. An orbiting charge should steadily lose energy and spiral toward the nucleus, colliding with it in a small fraction of a second. The second problem was that the planetary model could not explain the highly peaked emission and absorption spectra of atoms that were observed. The Bohr model of the atom Quantum theory revolutionized physics at the beginning of the 20th century, when Max Planck and Albert Einstein postulated that light energy is emitted or absorbed in discrete amounts known as quanta singular, quantum. In , Niels Bohr incorporated this idea into his Bohr model of the atom, in which an electron could only orbit the nucleus in particular circular orbits with fixed angular momentum and energy, its distance from the nucleus i. Discovery of isotopes Main article: Isotope While experimenting with the products of radioactive decay , in radiochemist Frederick Soddy discovered that there appeared to be more than one element at each position on the periodic table. That same year, J. Thomson conducted an experiment in which he channeled a stream of neon ions through magnetic and electric fields, striking a photographic plate at the other end. He observed two glowing patches on the plate, which suggested two different deflection trajectories. Thomson concluded this was because some of the neon ions had a different mass. Discovery of nuclear particles Main articles: Atomic nucleus and Discovery of the neutron In Rutherford bombarded nitrogen gas with alpha particles and observed hydrogen nuclei being emitted from the gas Rutherford recognized these, because he had previously obtained them bombarding hydrogen with alpha particles, and observing hydrogen nuclei in the products. Rutherford concluded that the hydrogen nuclei emerged from the nuclei of the nitrogen atoms themselves in effect, he had split a nitrogen. This, coupled with the atomic mass of many elements being roughly equivalent to an integer number of hydrogen atoms - then assumed to be the lightest particles - led him to conclude that hydrogen nuclei were singular particles and a basic constituent of all atomic nuclei. He named such particles protons. Further experimentation by Rutherford found that the nuclear mass of most atoms exceeded that of the protons it possessed; he speculated that this surplus mass was composed of previously-unknown neutrally charged particles, which were tentatively dubbed " neutrons ". In , Walter Bothe observed that beryllium emitted a highly penetrating, electrically neutral radiation when bombarded with alpha particles. It was later discovered that this radiation could knock hydrogen atoms out of paraffin wax. Initially it was thought to be high-energy gamma radiation , since gamma radiation had a similar effect on electrons in metals, but James Chadwick found that the ionization effect was too strong for it to be due to electromagnetic radiation, so long as energy and momentum were conserved in the interaction. In , Chadwick exposed various elements, such as hydrogen and nitrogen, to the mysterious "beryllium radiation", and by measuring the energies of the recoiling charged particles, he deduced that the radiation was actually composed of electrically neutral particles which could not be massless like the gamma ray, but instead were required to have a mass similar to that of a proton. Quantum physical models of the atom Main article: Atomic orbital The five filled atomic orbitals of a neon atom separated and arranged in order of increasing energy from left to right, with the last three orbitals being equal in energy. Each orbital holds up to two electrons, which most probably exist in the zones represented by the colored bubbles. Each electron is equally present in both orbital zones, shown here by color only to highlight the different wave phase. In , Louis de Broglie proposed that all moving particlesâ€”particularly subatomic particles such as electronsâ€”exhibit a degree of wave-like behavior. Although this concept was mathematically convenient, it was difficult to visualize, and faced opposition. This theory stated that the electron may exhibit the properties of both a wave and a particle. For example, it can be refracted like a wave, and has mass like a particle. This became known as the Heisenberg uncertainty principle after the theoretical physicist Werner Heisenberg , who first described it and published it in The modern model of the atom describes the positions of electrons in an atom in terms of probabilities. An electron can potentially be found at any distance from the nucleus, but, depending on its energy level, exists more frequently in certain regions around the nucleus than others; this pattern is referred to as its atomic orbital. The orbitals come in a variety of shapes- sphere , dumbbell , torus , etc.

Chapter 8 : Early Ideas about Matter | Chemistry | Visionlearning

The corpuscular theory of matter,. [J J Thomson] Search. Search for Library Items Search for Lists Search for Contacts Search for a Library. Create lists.

Then they gave these things the names, such as "fur," "stone," or "rabbit. Empedocles , a Greek philosopher and scientist who lived on the south coast of Sicily between BCE and BCE, proposed one of the first theories that attempted to describe the things around us. Empedocles argued that all matter was composed of four elements: The ratio of these four elements affected the properties of the matter. Stone was thought to contain a high amount of earth, while a rabbit was thought to have a higher ratio of both water and fire, thus making it soft and giving it life. For example, regardless of how many times you break a stone in half, the pieces never resemble any of the core elements of fire, air, water, or earth. Democritus knew that if you took a stone and cut it in half, each half had the same properties as the original stone. He reasoned that if you continued to cut the stone into smaller and smaller pieces, at some point you would reach a piece so tiny that it could no longer be divided. He suggested that atomos were eternal and could not be destroyed. Democritus theorized that atomos were specific to the material that they made up, meaning that the atomos of stone were unique to stone and different from the atomos of other materials, such as fur. This was a remarkable theory that attempted to explain the whole physical world in terms of a small number of ideas. Ultimately, though, Aristotle and Plato, two of the best-known philosophers of Ancient Greece, rejected the theories of Democritus. Aristotle accepted the theory of Empedocles , adding his own incorrect idea that the four core elements could be transformed into one another. In the 17th and 18th centuries CE , several key events helped revive the theory that matter was made of small, indivisible particles. In , Evangelista Torricelli , an Italian mathematician and pupil of Galileo, showed that air had weight and was capable of pushing down on a column of liquid mercury thus inventing the barometer. This was a startling finding. If air â€” this substance that we could not see, feel, or smell â€" had weight, it must be made of something physical. But how could something have a physical presence, yet not respond to human touch or sight? Daniel Bernoulli , a Swiss mathematician, proposed an answer. He developed a theory that air and other gases consist of tiny particles that are too small to be seen, and are loosely packed in an empty volume of space. The particles could not be felt because unlike a solid stone wall that does not move, the tiny particles move aside when a human hand or body moves through them. Bernoulli reasoned that if these particles were not in constant motion, they would settle to the ground like dust particles; therefore, he pictured air and other gases as loose collections of tiny billiard-ball-like particles that are continuously moving around and bouncing off one another. Law of Conservation of Mass Mercury calx Many scientists were busy studying the natural world at this time. Shortly after Bernoulli proposed his theory , the Englishman Joseph Priestley began to experiment with red mercury calx in Mercury calx, a red solid stone, had been known and coveted for thousands of years because when it is heated, it appears to turn into mercury, a silver liquid metal. Priestley had observed that it does not just turn into mercury; it actually breaks down into two substances when it is heated, liquid mercury and a strange gas. Priestley carefully collected this gas in glass jars and studied it. After many long days and nights in the laboratory, Priestley said of the strange gas, "What surprised me more than I can well express was that a candle burned in this air with a remarkably vigorous flame. For example, a colorless, odorless gas could combine with mercury, a silver metal, to form mercury calx, a red mineral. Priestley called the gas he discovered dephlogisticated air, but this name would not stick. In , Antoine Lavoisier , a French scientist, conducted many experiments with dephlogisticated air and theorized that the gas made some substances acidic. Lavoisier knew from other scientists before him that acids react with some metals to release another strange and highly flammable gas called phlogiston. Lavoisier mixed the two gases, phlogiston and the newly renamed oxygen, in a closed glass container and inserted a match. He saw that phlogiston immediately burned in the presence of oxygen, and afterwards he observed droplets of water on the glass container. Lavoisier also burned other substances such as phosphorus and sulfur in air, and showed that they combined with air to make new materials. These new materials weighed more than the original substances, and Lavoisier showed that the weight gained by the new materials was lost from the air in which the substances were burned. From these observations , Lavoisier established the Law of Conservation of Mass , which says that mass is not lost or gained during a chemical reaction. Comprehension Checkpoint Elements are used up when they fuel chemical reactions, so resulting substances have less mass. Their experiments showed that some substances could combine with others to form new materials, other substances could be broken apart to form simpler ones, and a few key "elements" could not be broken down any further. But what could explain this complex set of observations? John Dalton , an exceptional British teacher and scientist, put together the pieces and developed the first modern atomic theory in Through his observations of morning fog and other weather patterns, Dalton realized that water could exist as a gas that mixed with air and occupied the same space as air. Solids could not occupy the same space as each other; for example, ice could not mix with air. So what could allow water to sometimes behave as a solid and sometimes as a gas? Dalton realized that all matter must be composed of tiny particles. In the gas state, those particles floated freely around and could mix with other gases, as Bernoulli had proposed. But Dalton extended this idea to apply to all matter â€” gases, solids, and liquids. Dalton first proposed part of his atomic theory in and later refined these concepts in his classic paper A New System of Chemical Philosophy which you can access through a link under the Resources tab. All matter is composed of indivisible particles called atoms. Bernoulli, Dalton, and others pictured atoms as tiny billiard-ball-like particles in various states of motion. While this concept is useful to help us understand atoms, it is not correct as we will see in later modules on atomic theory linked to at the bottom of this module. All atoms of a given element are identical; atoms of different elements have different properties. Dalton characterized elements according to their atomic weight ; however, when isotopes of elements were discovered in the late s, this concept changed. Chemical reactions involve the combination of atoms, not the destruction of atoms. Atoms are indestructible and unchangeable, so compounds , such as water and mercury calx, are formed when one atom chemically combines with other atoms. When elements react to form compounds, they react in defined, whole-number ratios. The experiments that Dalton and others performed showed that reactions are not random events; they proceed according to precise and well-defined formulas. This important concept in chemistry is discussed in more detail below. Comprehension Checkpoint An element is made up of a. As early as , Robert Boyle recognized that the Greek definition of element earth, fire, air, and water was not correct. Boyle proposed a new definition of an element as a fundamental substance, and we now define elements as fundamental substances that cannot be broken down further by chemical means. Elements are the building blocks of the universe. They are pure substances that form the basis of all of the materials around us. Some elements can be seen in pure form, such as mercury in a thermometer; some we see mainly in chemical combination with others, such as oxygen and hydrogen in water. We now know of approximately different elements. Each of the elements is given a name and a one- or two-letter abbreviation. Often this abbreviation is simply the first letter of the element; for example, hydrogen is abbreviated as H, and oxygen as O. Sometimes an element is given a two-letter abbreviation; for example, helium is He. When writing the abbreviation for an element, the first letter is always capitalized and the second letter if there is one is always lowercase. A single unit of an element is called an atom. The atom is the most basic unit of matter , which makes up everything in the world around us. Each atom retains all of the chemical and physical properties of its parent element. At the end of the nineteenth century, scientists would show that atoms were actually made up of smaller, "subatomic" pieces, which smashed the billiard-ball concept of the atom see our Atomic Theory I: The Early Days module. Most of the materials we come into contact with are compounds, substances formed by the chemical combination of two or more atoms of the elements. A single "particle" of a compound is called a molecule. Dalton incorrectly imagined that atoms "hooked" together to form molecules. However, Dalton correctly realized that compounds have precise formulas. Water, for example, is always made up of two parts hydrogen and one part oxygen. The chemical formula of a compound is written by listing the symbols of the elements together, without any spaces between them. If a molecule contains more than one atom of an element, a number is subscripted after the symbol to show the number of atoms of that element in the molecule. Proust performed a number of experiments and observed that no matter how he caused different elements to react with oxygen, they always reacted in defined proportions. For example, two parts of hydrogen always reacts with one part oxygen when forming water; one part mercury always reacts with one part oxygen when forming mercury calx. The law also applies to multiples of the fundamental proportion, for example: In both of these examples, the ratio of hydrogen to oxygen to water is 2 to 1 to 1. When reactants are present in excess of the fundamental proportions, some reactants will remain unchanged after the chemical reaction has occurred. The story of the development of modern atomic theory is one in which scientists built upon the work of others to produce a more accurate explanation of the world around them. This process is common in science, and even incorrect theories can contribute to important scientific discoveries. Dalton, Priestley, and others laid the foundation of atomic theory, and many of their hypotheses are still useful. However, in the decades after their work, other scientists would show that atoms are not solid billiard balls, but complex systems of particles. Summary Tracking the development of our understanding of the atomic structure of matter, this module begins with the contributions of ancient Greeks, who proposed that matter is made up of small particles.

Chapter 9 : Atomic theory - Wikipedia

Figuring out how to extend the search for dark matter particles - dark matter describes the stuff that makes up an estimated 85 percent of the total mass of the universe yet so far has only been.