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| **UNIT – 3** |
| **NUCLEAR LIQUID DROP MODEL** |
| **Unit-03/Lecture-01** |
| **NUCLEAR LIQUID DROP MODEL [Dec 2013 (7)]**  To account for the prominent aspects of nuclear properties and behaviour various nuclear models have been proposed. First of all, we shall discuss the liquid drop model. This model was proposed by Bohr. According to this model, the nucleus is similar to a small electrically charged liquid drop, i.e., the nucleus takes a spherical shape for its stability. The nucleons (protons and neutrons) move within this spherical enclosure like molecules in a liquid drop The motion of nucleons within nucleus is a measure of nuclear temperature as the molecular motion of molecules in liquid is the measure of its temperature.  The nucleons always remain a constant distant apart and share among them the total energy of the nucleus. The nucleons deep inside the nucleus are attracted from all sides by neighbouring nucleons while those on the surface are attracted from one side only The spherical surface which encloses the nucleus may be regarded as analogous to surface tension which holds a water drop to the evaporation of particles from a liquid surface The evaporation in a liquid drop takes place when Maxwellian energy distribution within the drop causes a particular molecule to have sufficient energy to overcome the intermolecular attraction and escape. Similar is the case with compound nucleus. The nucleus remains in the excited state until the nucleon or a group of nucleons happen to possess sufficiently large excitation energy escape through the potential barrier.  **Assumptions**   1. The material of the nucleus is incompressible and the density of all the nuclei is the same 2. The forces in the nucleus consist of **(a)** Coulomb forces between protons and **(b)** powerful attractive nuclear forces.   **Analogies between liquid drop and a nucleus**   1. Both are spherical in nature 2. In both the cases, the density is independent of its volume with the exceptions that the density of the nucleus is independent of the nucleus while density of the liquid depends upon its type. 3. The molecules in liquid drop interact over short ranges and so is true for nucleons in nucleus. 4. As the surface tension forces act on the surface of a drop similarly a potential barrier acts on the surface of nucleus. 5. When the temperature of the molecules in a liquid drop is increased, evaporation of molecules takes place. Similarly, when the nucleons in the nucleus are subjected to external energy, a compound nucleus is formed which emits nucleons almost immediately. The process is known as nuclear fission 6. When a small drop of liquid is allowed to oscillate, it breaks up into two smaller drops. The process of nuclear fission is similar in which the nucleus breaks up into two smaller nuclei.   **Merits :**  Following are the merits of liquid drop model :  (1) It has been successfully applied in describing nuclear reactions and explaining nuclear fission.  (2) The calculation of atomic masses and binding energies can be done with good accuracy.  However this model fails to explain other properties, in particular, the magic numbers.   |  |  |  |  | | --- | --- | --- | --- | | S.NO | RGPV QUESTIONS | Year | Marks | | Q.1 | Explain in detail liquid drop model and various terms of semi-empirical mass formula. | Dec 13,June 11 | 7, 10 | |

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| **Unit-02/Lecture-02** |
| **Semi-Empirical Mass Formula**  For most nuclei (nuclides) with A > 20 the binding energy is well reproduced by a semi empirical formula based on the idea the nucleus can be thought of as a liquid drop.  1. **Volume term**: Each nucleon has a binding energy which binds it to the nucleus. Therefore we get a term proportional to the volume i.e. proportional to A.  av A  This term reflects the short-range nature of the strong forces. If a nucleon interacted with all other nucleons we would expect an energy term of proportional to A(A − 1), but the fact that it turns out to be proportional to A indicates that a nucleon only interact with its nearest neighbours.  2. **Surface term**: The nucleons at the surface of the ‘liquid drop’ only interact with other nucleons inside the nucleus, so that their binding energy is reduced. This leads to a reduction of the binding energy proportional to the surface area of the drop, i.e. proportional to A2/3  −aS A2/3.  3. **Coulomb term**: Although the binding energy is mainly due to the strong nuclear force, the binding energy is reduced owing to the Coulomb repulsion between the protons. We expect this to be proportional to the square of the nuclear charge, Z, (the electromagnetic force is long-range so each proton interact with all the others), and by Coulomb’s law it is expected to be inversely proportional to the nuclear radius, (the Coulomb energy of a charged sphere of radius R and charge Q is 3Q2/(20πε0R)) The Coulomb term is therefore proportional to 1/  - aC  4. **Asymmetry term**: This is a quantum effect arising from the Pauli Exclusion Principle which only allows two protons or two neutrons (with opposite spin direction) in each energy state. If a nucleus contains the same number of protons and neutrons then for each type the protons and neutrons fill to the same maximum energy level (the ‘fermi level’). If, on the other hand, we exchange one of the neutrons by a proton then that proton would be required by the exclusion principle to occupy a higher energy state, since all the ones below it are already occupied. The upshot of this is that nuclides with Z = N = (A−Z) have a higher binding energy, whereas for nuclei with different numbers of protons and neutrons (for fixed A) the binding energy decreases as the square of the number difference. The spacing between energy levels is inversely proportional to the volume of the nucleus - this can be seen by treating the nucleus as a three-dimensional potential well- and therefore inversely proportional to A. Thus we get a term  −aA  5. **Pairing term**: It is found experimentally that two protons or two neutrons bind more strongly than one proton and one neutron. In order to account for this experimentally observed phenomenon we add a term to the binding energy if number of protons and number of neutrons are both even, we subtract the same term if these are both odd, and do nothing if one is odd and the other is even. Bohr and Mottelson showed that this term was inversely proportional to the square root of the atomic mass number. We therefore have a term  The complete formula is, therefore  B(A,Z) = aV A – aS A2/3 – aC − aA +  From fitting to the measured nuclear binding energies, the values of the parameters aV , aS, aC, aA, aP are  aV = 15.56 MeV  aS= 17.23 MeV  aC = 0.697 MeV  aA = 23.285 MeV  aP = 12.0 MeV  For most nuclei with A > 20 this simple formula does a very good job of determining the binding energies - usually better than 0.5%. |

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| **Unit-02/Lecture-03** |
| **Shell Model of Nucleus**  Visualizing the densely packed nucleus in terms of orbits and shells seems much less plausible than the corresponding shell model for atomic electrons. You can easily believe that an atomic electron can complete many orbits without running into anything, but you expect protons and neutrons in a nucleus to be in a continuous process of collision with each other. But dense-gas type models of nuclei with multiple collisions between particles didn't fit the data and remarkable patterns like the "magic numbers" in the stability of nuclei suggested the seemingly improbable shell structure.  With the enormous strong force acting between them and with so many nucleons to collide with, how can nucleons possibly complete whole orbits without interacting? This has the marks of a [Pauli Exclusion Principle](http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/shellpau.html#c1) process, where two fermions cannot occupy the same quantum state. If there are no nearby, unfilled quantum states that are in reach of the available energy for an interaction, then the interaction will not occur. This is a essentially quantum idea - if there is not an available "hole" for a collision to knock a nucleon into, then the collision will not occur. There is no classical analog to this situation.  The evidence for a kind of shell structure and a limited number of allowed energy states suggests that a nucleon moves in some kind of effective potential well created by the forces of all the other nucleons. This leads to energy quantization in a manner similar to the square well and harmonic oscillator potentials. Since the details of the well determine the energies, much effort has gone into construction of potential wells for the modeling of the observed nuclear energy levels. Solving for the energies from such potentials gives a series of energy levels like that at left below. The labels on the levels are somewhat different from the corresponding symbols for atomic energy levels. The energy levels increase with orbital angular momentum quantum number l, and the s,p,d,f... symbols are used for l=0,1,2,3... Just like the atomic case. But there is really no physical analog to the principal quantum number n, so the numbers associated with the level just start at n=1 for the lowest level associated with a given orbital quantum number, giving such symbols as 1g which could not occur in the atomic labeling scheme. The quantum number for orbital angular momentum is not limited to n as in the atomic case.  **Magic numbers**  **Magic number,** in the shell models of both atomic and nuclear structure, any of a series of numbers that connote stable structure.  The magic numbers for atoms are 2, 10, 18, 36, 54, and 86, corresponding to the total number of electrons in filled electron shells. (Electrons within a shell have very similar energies and are at similar distances from the nucleus.) In the chemical elements of atomic number 17 to 19, for example, the chloride ion (Cl−), the argon atom (Ar), and the potassium ion (K+) have 18 electrons in closed-shell configurations and are chemically quite stable. The number of electrons present in the neutral atoms constituting the relatively unreactive noble gases exactly corresponds to the atomic magic numbers.  The magic numbers for nuclei are 2, 8, 20, 28, 50, 82, and 126. Thus, tin (atomic number 50), with 50 protons in its nucleus, has 10 stable isotopes, whereas indium (atomic number 49) and antimony (atomic number 51) have only 2 stable isotopes apiece. The doubly magic alpha particle, or helium-4 nucleus, composed of two protons and two neutrons, is very stable. In nuclei, this increased stability occurs when there is a large energy gap between a series of filled energy levels and the next level, which is empty. Such large gaps are said to separate shells, although these shells are not as clearly linked to the spatial structure of the nucleus as electron shells are to their orbits.  http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/imgnuc/shellmod.gif  In addition to the dependence on the details of the potential well and the orbital quantum number, there is a sizable spin-orbit interaction which splits the levels by an amount which increases with orbital quantum number. This leads to the overlapping levels as shown in the illustration. The subscript indicates the value of the total angular momentum j, and the multiplicity of the state is 2j + 1. The contribution of a proton to the energy is somewhat different from that of a neutron because of the coulomb repulsion, but it makes little difference in the appearance of the set of energy levels.  With this set of identified nuclear states and the magic numbers, we can predict the net nuclear spin of a nucleus and represent its nuclear state by based on the identification of the level of the odd nucleon in the order of states shown above. The parity of the state can also be predicted, so the single particle shell model has shown itself to be of significant benefit in characterizing nuclei.   |  |  |  |  | | --- | --- | --- | --- | | S.NO | RGPV QUESTIONS | Year | Marks | | Q.1 | What is meant by the magic numbers? Establish their existence with the help of Nuclear shell model. | June 13 | 4 | |

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| **Unit-02/Lecture-04**  **Linear Particle Accelerator**  This is a multiple accelerator developed by Sloan and Lawrence. This linear accelerator used usually for accelerating protons and other positive ions consists of a series of coaxial hollow metal cylinders usually called drift tubes 1, 2, 3... They are positioned linearly in a vacuum thick glass chamber. The alternate cylinders are connected together, the odd numbered cylinders being joined to one terminal and the even numbered ones to the second terminal of a H. F oscillator. Thus in one half cycle, if tubes and 3 are positive, 2 and 4 will be negative. After a half cycle the polarities are reversed i. e., 1 and 3 will be negative and 2 and 4 positive. It is known now that the ions are accelerated only in the gap between the tubes where they are acted upon by the electric field present in the gaps. The ions travel with constant velocity in the field force space inside the drift tubes.  C:\Users\Dishansh\Pictures\linac.jpg  Positive ions enter along the axis of the accelerator from an ion source through an aperture A. suppose a positive ion leaves A and is accelerated during the half cycle, when the drift tube 1 is negative with respect to A. Let e be the charge and m be the mass of the ions and V potential of drift tube with respect to A. Thus the velocity v1 of the ion reaching the drift tube is given by  mv12 = Ve  v1 = (1)  The length of the tube is adjusted in such a that as the positive ions come out of it, the tube has a positive potential and the next tube say 2 has a negative potential. It means that potential change sign. The positive ion is again accelerated in the space between the tubes 1 and 2. On reaching the tube 2, the velocity v2 of the positive ion is given by  mv22 = 2Ve  V2 = = v (2)  This shows that v2 is times v1. In order that this ion, on coming out of tube 2, may find tube 3 just negative and the tube 2 positive, it must take the same time to travel through the tube 2. Since v2 = X v1, the length of the tube 2 must be times the length of the tube 1. For successive accelerations in successive gaps the tubes 1, 2, 3 etc must have lengths proportional to , , etc. i.e., l1:l2:l3etc = : : etc.  Formula for the energy of the ion :  Let n be the number of gaps that the ion travels in the accelerator and vn= the final velocity acquired by the ion, then the velocity of the ion as it nicely emerges out of the nth tube is  Hence, the K.E. possessed by the ion = mvn2 = n Ve  Thus the final energy of the ions depends upon (i) the total number of gaps and (ii) the energy gained in each gap.  The demerits or limitations of the accelerator are:   1. The length of the accelerator becomes unconventionally large and it difficult to maintain vacuum in a large chamber. 2. The ion current available in the form of short interval impulses because the ions are injected at an appropriate moment. |
| **Unit-02/Lecture-05** |
| **Cyclotron**  The sub-atomic charged particles experience large forces when subjected to electric and magnetic fields due to their extremely small mass. In nuclear physics such energized particles are used to bombard nuclei causing nuclear reactions. This helps to obtain information about the nucleus.  C:\Documents and Settings\Student\Desktop\cyclotron.jpeg  A cyclotron is device by which positively charged particle can be accelerated and the desired nuclear reaction can be brought about. Principle A positively charged particle can be accelerated to high energy with the help of an oscillating electric field, by making it cross the same electric field time and again with the use of a strong magnetic field. Construction It consists of two dees or D-shaped metal chambers D1 and D2. The dees are separated by a small distance. The two dees are perpendicular to their plane. P is the position where the ion source is placed.  The dees are maintained to a potential difference whose polarity alternates with the same frequency as the circular motion of the particles. The dees are closed in a steel box placed between the poles of a strong electromagnet. The magnetic field is perpendicular to the plane of the dees. Theory and Working The positive ion P to be accelerated is placed in between the two dees. If at any instant, D1 is at negative potential and D2 is at positive potential, then the ion gets accelerated towards D1 but since its perpendicular to B, it describes a circular path of radius r and Lorentz force provides the centripetal force.    Time taken to describe a semicircle is  http://images.tutorvista.com/contentimages/physics_12/content/us/class12physics/chapter05/images/img118.gif  If this time is equal to the time during which D1 and D2 change their polarity, the ion gets accelerated when it arrives in between the gaps. The electric field accelerates the ion further. Once the ion is inside the dee D2, it now describes a greater semicircle due to the magnetic field. This process repels and the ion goes on describing a circular path of greater radius and finally acquires a high energy. The ion is further removed from a window W. The maximum energy acquired by the ion source is      The frequency of cyclotron is given by  frequency of cyclotron Limitations of Cyclotron Only when the speed of the circulating ion is less than 'c' the speed of light, we find the frequency of revolution to be independent of its speed.  At higher speeds, the mass of the ion will increase and this changes the time period of the ion revolution. This results in the ion lagging behind the electric field and it eventually loses by collisions against the walls of the dees.   * The cyclotron is suitable for accelerating heavy charged particles but not electrons. * Cyclotrons cannot accelerate in charged particles. * It is not suited for very high kinetic energy. |

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| S.NO | RGPV QUESTIONS | Year | Marks |
| Q.1 | Describe construction and working of cyclotron. What are its limitations? Show that the numbers of revolution particle takes inside the cyclotron is proportional to the square root of the radius of dees. June 13 10 | June 2013 | 10 |
| Q.2 | Describe the construction and working of a cyclotron. Discuss its limitations. | Dec 2011 | 10 |

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| **UNIT 2/LECTURE 6** |
| **Synchrocyclotron**  Synchrocyclotron is a modified form of cyclotron. In a cyclotron the loss of resonance between the applied rf. voltage and the moving ion is caused by the relativistic increase in mass of the ion With growth of mass, the frequency of revolution of the ions in the cyclotron decreases and the ion gets out of phase with the hf. voltage of fixed frequency applied across the dees and as a result cannot be accelerated. The decrease in ion frequency may be compensated and the ion may be kept in phase with the hf. voltage in two ways. One of the ways is to keep the value of the magnetic field B constant and decreasing the frequency of hf. Generator in step with the decrease in the frequency of revolution of the ion. The frequency of the applied alternating electric field is gradually changed at such a rate that as the ion lags a little due to increase in mass, the electric field frequency also automatically decreases and the ion always enters the dee at the right moment when it experiences maximum acceleration. Accelerators based on this principle are known as synchrocyclotrons.  https://fbcdn-sphotos-h-a.akamaihd.net/hphotos-ak-xpf1/v/t34.0-12/10379230_729513960446745_430011952_n.jpg?oh=536bfc20117897fbfffe8c8375dc7439&oe=538992C8&__gda__=1401517653_be7a763d1726254fdbeef92444ab8171  A synchrocyclotron (Fig 1) consists of only one dee enclosed in a vacuum chamber. The entire unit is kept between the pole pieces of a huge electromagnet. Instead of the second dee, a metal plate (ejector) is held opposite the opening of the dee. The output of a hf. Generator is connected between the single dee and the earthed chamber. The frequency of the hf. Generator is modulated with a low frequency of 120 Hz. The high energy ions are extracted from the chamber with the help of a high positive pulse applied to the ejector plate. A synchrocyclotron is also known as a frequency modulated cyclotron 2. The following are the basic differences between a cyclotron and a synchrocyclotron A cyclotron uses two dees, whereas a synchrocyclotron uses only one dee The frequency of the hf Generator is fixed in a cyclotron operation, whereas the hf generator is modulated and hence is variable in a synchrocyclotron 3A continuous beam of high energy ions is produced in a cyclotron. In case of synchrocyclotron ions come out in a bursts of a few hundred per sec. Each burst lasts for about 100 μs. |

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| **UNIT-2/LECTURE 7**  **Betatron**  Betatron is a device to accelerate electrons to very high energies. It was constructed in 1941 by D.W. kerst .  Construction – it consists of a doughnut shaped vacuum chamber placed between the pole pieces of an electromagnet. The electromagnet is energized by an alternating current. The magnet produces a strong magnetic field in the doughnut. The electrons are produced by the electron gun and are allowed to move in a circular orbit of constant radius in the vacuum chamber (Fig. 1). The magnetic field varies very slowly compared with the frequency of revolution of the electrons in the equilibrium orbit.  C:\Users\Dishansh\Pictures\beta1.jpg  The varying magnetic field, acting parallel to the axis of the vacuum tube, produces two effects on the electron   1. The changing flux due to the electromagnet produces the induced e.m.f which is responsible for the acceleration of the electron 2. The field of the magnet serves at the same time to bend the electrons in a circular path in the chamber and confine them to the region of the changing flux.   C:\Users\Dishansh\Pictures\10372789_728397520558389_3633851098558859248_n.jpgFig 2 shows the variation of magnetic field with time. Electrons are injected into the chamber when magnetic field just begins to rise. The electrons are then accelerated by increasing magnetic flux linked with the electron orbit. During the time the magnetic field reaches its peak value, the electrons make several thousand revolutions and get accelerated. If they are allowed to revolve any more, the decreasing magnetic field would retard the electrons. Hence, the electrons are extracted this stage by using an auxiliary magnetic field to deflect them from their normal course. The high energy electron beam can be made to strike the target, generating X-rays. Alternately, the electrons can be made to emerge out of the apparatus and used for transmutation work.  Theory-  Consider the electron moving in an orbit of radius r. let φ be flux linked the orbit. The flux increases at the rate and the induced e.m.f in the orbit is given by  E = - (1)  The work done on an electron of charge e in one revolution is Ee = - e  W = Ee = - e (2)  Let F be the tangential force acting on the orbiting electron. The path travelled in one revolution is 2πr. Hence the work done on the electron in one revolution is  F Χ 2πr = - e  F = - (3)  When the velocity of the electron increases due to the above force, it will try to move into an orbit of larger radius, it will try to move into an orbit of larger radius. Because of the presence of the magnetic flux perpendicular to the plane of the electron orbit, the electron will experience a radical force inward given by  Bev =  Hence the momentum of the electron  P = mv = Ber  According to Newton’s second law  (mv) = er = F (4)  To have constant radius for the orbit, the value of F given by equation (3) must be equal to equation (4)  i.e., = er  dø = 2πr2 dB  ʃ dø = 2πr2 ʃ dB  ø = 2πr2B (5)  If the uniform magnetic field B acts over an area A=πr2, the magnetic flux ø=πr2B. This means the flux through the orbit is twice the flux enclosed by the orbit, if the magnetic field were to be uniform over the area. Eqn. (5) gives the condition under which a betatron works and is called betatron condition. This distribution of the magnetic flux is obtained by the special pole-pieces where the magnetic field is greater at the centre of the orbit than at its circumference. | | | |
| S.NO | RGPV QUESTION | YEAR | MARKS |
| Q.1 | Describe the construction and working of a Betatron. Explain Betatron condition. | June 2012 | 10 |

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| **UNIT 2/LECTURE 8** |
| **Motion of charged particle in crossed electric and magnetic fields**  C:\Users\Dishansh\Documents\New Doc 36_1_1.jpg  C:\Users\Dishansh\Documents\New Doc 37_1.jpg  C:\Users\Dishansh\Documents\New Doc 38_1.jpg |

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| **UNIT 2/LECTURE 9** |
| **Bainbridge Mass spectrometer**  In 1919 Aston developed the first really good mass spectrograph, an instrument for measuring the masses of isotopes. His apparatus gave accuracies of one part in 1000. A simpler form of the mass spectrograph than Aston's is that due to Bainbridge (1933) and a plan view of this is shown in Figure 1.  C:\Users\Dishansh\Desktop\1.png  Ions are formed at D and pass through the cathode C and then through a slit S1. They then travel between two plates A and B, between which a potential (V) is applied. A magnetic field (strength B) is applied at right angles to the electrostatic field and so the electrostatic and electromagnetic forces act in opposite directions to each other.   A particle with a charge q and velocity v will only pass through the next slit S2 if the resultant force on it is zero that is it is traveling in a straight line. That is if:  Electromagnetic force (Bqv) = Electrostatic force (qE)  Therefore, for the particle to pass through S2:  Velocity of particle (v) = E/B  But this is a constant, and so only particles with a certain velocity enter the deflection chamber F. For this reason the combination of slits and deflecting plates is called a **velocity selector**. In the deflection chamber the ions are affected by the magnetic fields alone and so move in circular paths, the lighter ions having the larger path radius. If the mass of an ion is M, its charge q and its velocity v then:  Bqv=Mv2/r  where r is the radius of the path. Therefore r = Mv/(Bq)    and so:  Mass of ion (M) = rB2q/E  The radius of the path in the deflection chamber is directly proportional to the mass of the ion. The detection is by either a photographic plate or a collector that produces a small current when the ions fall on it. The magnetic field may be varied, so changing the radii of the particles' paths so that ions of different masses fall on a fixed collector.  This method of analysis is very accurate and can detect differences in the masses of two ions as small as one part in 109.   |  |  |  |  | | --- | --- | --- | --- | | S.NO | RGPV QUESTION | YEAR | MARKS | | Q.1 | Explain construction and working of Bainbridge mass spectrograph. | June 2011 | 10 | |

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| **UNIT-2/ LECTURE 10**  **ASTON’S MASS SPECTROGRAPH**  [Aston’s mass spectrograph is an apparatus of high accuracy designed by Aston of Cambridge University, which enables the measurement of the mass of single ions and is useful for the investigation of isotopes. This method is an improvement on J.J. Thompson’s method](https://www.rgpvonline.com/)  **Principle**  The positive rays emerging from perforated cathode are made into a fine pencil by using slits. They are then subjected to an electrostatic field in a direction perpendicular to the direction of rays with the help of electrically charged plates P1 and P2. The beam is not only deflected but also dispersed because the particles are having different velocities. The dispersed beam is then subjected to a magnetic field whose direction but in the same plane. If a photographic plate is held in the direction of deflected beam, line images are obtained. Each line corresponds to particular value of q’/m’. The number of lines correspond to the number of isotopes present in the element.  **Theory**  Here AO is the direction of positives rays before entering the electrostatic field, S1 and S2 are slits which provides a fine pencil of positives rays. The electrostatic field is maintained by plates P1 and P2 in a direction perpendicular to the beam. As all the positives ions have same specific charge (q’/m’), they are deflected towards the negative plate P2. Let, θ and dθ be the angles of deviation and dispersion (due to different velocities). Using a diaphram D some of the rays are selected and are allowed to pass between the poles if an electromagnet. The magnetic field being perpendicular to the plane of the paper and inward. According to the Fleming’s left hand rule, the beam will be deflected upwards. This magnetic field annuls the dispersion produced by electric field and recombines the particles which are brought to focus in the form of sharp lines on a photographic plate CD. The lines are similar to those spectral lines.  https://fbcdn-sphotos-h-a.akamaihd.net/hphotos-ak-prn2/v/t34.0-12/1969410_729096637155144_25351298786772762_n.jpg?oh=b9d18e2395fb5cb41fb9af85b7dc73ba&oe=5385890D&__gda__=1401251236_1df8140d68f97f97d285aa66bc0a3cee  Let, q’ = charge on positives ray particle,  m’ = mass of each particle,  E = electrostatic field,  B = magnetic field strength,  v = velocity of each particle,  φ = angle of deviation produced by magnetic field,  dφ = angle of dispersion produced by magnetic field,  Considering that the deflection in electrostatic field is small, the curve near the vertex may be considered as circular of radius r, we have  Eq’ =  Or =  Hence, the deflection θ, which proportional to 1/r is given by  θ = C = C1  where C1 = C E  ∴ Dispersion = - 2C1 = - 2 …(1)  If r’ be the radius of curvature in magnetic field, then  B q’ v =  Or =  ∴ Φ = C’ = C2  Therefore  Again dispersion = - C2 = - …(2)  From equation (1) and (2), we have  = 2 …(3)  Thus for given deflection, the dispersion due to the electric field is twice that due to magnetic field. The small changes  Thus, for a given deflection, the dispersion due to the electric field is twice that due to magnetic field. The small changes d and dΦ refer to the particles with identical mass and charge but possessing velocities differing by dv.  In the absence of magnetic field, the dispersion produced in the beam for a distance (a + b) is given by  = (a+b) dθ …(4)  where a = distance 0 0' and b = distance O'F  The magnetic field acts in a direction perpendicular to the electric field and produces the same dispersion in a distance b but in the opposite direction.  Dispersion produced by the magnetic field = b dΦ …(5)  As all the ions are focused to the same position  (a + b) dθ = b dΦ  and = …(6)  from equation (3) =  =  bφ = ( a + b ) 2θ  b(φ - 2θ) = 2 a θ  or (b/a) = { 2θ/ (φ - 2θ) } …(7)  This is the condition of focusing.   |  |  |  |  | | --- | --- | --- | --- | | S.NO | RGPV QUESTION | YEAR | MARKS | | Q.1 | What is mass spectrograph? Describe the construction of Aston’s mass spectrograph with necessary theory. Show that it can be used in detection of isotopes. | June 2013 | 10 | |

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| **UNIT 3/LECTURE 11** |
| **Geiger-Muller counter**  The Geiger-Muller counter consists of a fine wire (Usually tungsten) laced along the axis of a hollow metal-cylinder electrode (cathode) enclosed in a thin glass tube. The tube contains a mixture of 90% argon at 10 cm pressure and 10% ethyl alcohol vapour at 1 cm pressure. Different mixtures of gases at different designs. At one end of the tube, a window covered with thin mica sheet () is provided through which the ionizing particles or radiations may enter the tube. A d.c. potential of about 1200 volts is applied between the cathode and the wire which acts as an anode. The value of the voltage is adjusted to be somewhat below the breakdown voltage of the gaseous mixture. A high resistance R is connected in series with battery.  C:\Users\Dishansh\Pictures\gm1.jpg  When a charged particle passes through the counter, it ionizes the gas molecules. The central wire attracts the electrons while the cylindrical electrode attracts the positive ion. This causes an ionization current which depends upon the applied voltage. At sufficiently high voltages, the electrons gain high kinetic energy and cause further ionization of argon atoms Thus, the larger number of secondary electron are produced. The number of secondary electrons is independent of the number of primary ions produced by incoming particle due to the following reasons:   1. The production of secondary electrons is not confined to the region near the primary electrons but it takes place all along the length of the wire as their number is extremely large (=108 ). 2. The production of secondary electrons at one point affects the production at other points.   The incoming particle serves the purpose of triggering the release of an avalanche of secondary electrons. The electrons quickly reach the anode and cause ionization current. The positive ions move more slowly away from anode and they form a sheath around the anode for a short while. They reduce the potential difference between the electrodes to a very low value because ion sheath depresses electric field near anode the current therefore, stops. In this way a brief pulse of current flows through resistance R. This current creates a potential differences across R. The pulse is amplified and fed to counter circuit. As each incoming particle produces a pulse, hence, the number of incoming particles can be counted.  The successful operation of GM Counter depends upon the proper voltage to the electrodes Fig (2) represents the counts per minute as a function of voltage. It is obvious from the figure that if the voltage is less than 1000 volt, there is no discharge, i.e., no secondary ionization. When the voltage is increased, secondary ionization takes place. Now the number of impulses increases almost linearly with applied voltage. As already discussed, this region is most suitable for proportional counters. As the applied voltage is further increased to about 1200 volts, the number of impulses remains constant over a certain region known as plateau. In this region, the magnitude of impulses becomes independent of the amount of original ionization and is a function of potential, nature of gas, resistance R and geometrical condition of apparatus. This region is most suitable of G. M. Counter. If the voltage is increased above this region, a continuous discharge will take place. This is undesirable and hence, avoided.  C:\Users\Dishansh\Pictures\gm2.jpg  **Quenching**  When the positive ions reach the cathode, they detach secondary electrons from the cathode because they have acquired large kinetic energies. These electrons travel to the anode and produce fresh avalanches, i.e., unwanted pulse. The counter is now kept in the state of continuous avalanching. If in this state, measurements are made, the counter will confuse the two pulses, one due to continuous avalanching and the other due to fresh event. The process of preventing the continuous avalanching is known as quenching. The self-quenching is obtained by adding a quenching agent like alcohol in the tube. Alcohol has low ionization potential (11.3 eV). The argon ions (having ionization potential 15.7 eV) on their journey to the cathode are practically all neutralized by acquiring an electron from the alcohol molecules. Now only alcohol ions reach the cathode. They acquire electrons from cathode and becomes neutral alcohol molecules. Though the alcohol molecules still possess kinetic energy yet this is used for dissociation into alcohol atoms and not for the production of secondary electrons by colliding with cathode. Thus, the possibility of continuous avalanching is removed Counting rate The GM Counter can count about 500 particles per second. The counting rate depends upon (i) dead time, (ii) recovery time and (iii) paralysis time. The slowly moving positive ions take about 100 microseconds to reach the cathode. This time is known as dead time. If a second particle enters the tube during this time, it will not be recorded as the potential difference across the electrodes is very low. After dead time, the tube takes nearly 100 microseconds before it regains its original working conditions. This time interval is known as recovery time. The sum of dead time and recovery time is known as paralysis time which, of course, is 200 microseconds. The tube can respond fully to the second incoming particle after 200 microsecond. Thus, the tube can count nearly 5000 particles per second.  **Efficiency**  The efficiency of count is defined as the rate of the observed counts/sec to the number of ionizing particles entering the counter per second. The counting efficiency is defined as the ability of its counting, if atleast an ion-pair is produced in it.  Counting efficiency η = 1 – exp (s p l)  where s = specific ionization at one atmosphere  p = pressure in atmosphere  l = length of the ionization particle in the counter  The GM Counter is very useful for counting β-particles. It can also be used for measuring γ-rays intensities. It cannot be used for counting α-particles due to their low energy as the window cannot be made thin enough to pass them.   |  |  |  |  | | --- | --- | --- | --- | | S.NO | RGPV QUESTION | YEAR | MARKS | | Q.1 | Briefly discuss Geiger-Muller counter. | June 2011 | 4 | |