1. (a) (i) What are cathode rays? (01marks)
   (ii) State two properties of cathode rays (01mark)
   (iii) Explain two disadvantages of using the discharge tube in producing cathode rays. (02marks)
   (b) With the aid of a diagram, describe Millikan's experiment to determine the charge on an oil drop (07marks)
   (c) A beam of electrons is accelerated through a potential difference of 1.98kV and directed mid-way between two horizontal plates of length 4.8cm and separated by a distance of 2.0cm. the potential difference applied across the plates is 80.0V.
   (i) Calculate the speed of the electrons as they enter the region between the plates (03marks)
   (ii) Explain the motion of the electrons between the plates (02marks)
   (iii) Find the speed of electrons as they emerge from the region between the plates (04marks)
2. (a)(i) what is meant by thermionic emission? (01marks)
   (ii) Describe how full-wave rectification of a.c can be achieved using four semiconductor diodes. (04marks)
   (b) (i) Draw a labelled diagram to show the main parts of a cathode ray oscilloscope (C.R.O) (03marks)
   (ii) Describe how a C.R.O can be used as an a.c voltmeter. (02marks)
   (c) (i) an electron of charge –e and mass m moves in circular orbit round a central hydrogen nucleus of charge +e. Derive an expression for total energy of electron in an orbit of radius r. (05 marks)
   (ii) Why is this energy always negative (01marks)
   (d) (i) what is meant by excitation potential of an atom? (01marks)
   (ii) Some of the energy levels in mercury spectrum are shown in the figure below.

Calculate the wavelength of the radiation emitted when electron makes a transition from level A to level C. (03marks)

3. (a) What is meant by the following as applied to radioactivity?
   (i) Activity (01marks)
   (ii) Half-life of a radioactive material (01marks)

   (b) Using the radioactive decay law N = $N_0e_{-\lambda t}$, show that the half-life $T_{\frac{1}{2}} = \frac{1}{\lambda}$ (02marks)

   (c) With the aid of a labelled diagram, describe the action of an ionization chamber. (05marks)

   (d) What is meant by unified atomic unit and electron volt. (02marks)

   (e) (i) The nucleus $^{212}_{83}Bi$ decays by alpha emission as follows

   $$^{212}_{83}Bi \rightarrow {}^{208}_{81}Tl + {}^{4}_{2}He$$

   Calculate the energy released by 2g of $^{212}_{83}Bi$. (05marks)

   (ii) Explain two uses of radioactive isotopes. (04marks)

4. (a) Define the following
   (i) Binding energy (01marks)
   (ii) Unified Atomic Energy (01marks)

   (b) Explain how energy is released in a nuclear fusion process. (03marks)

   (c) Explain what is observed in a discharge tube when the pressure is gradually reduced to low values? (05marks)

   (d) With the aid of a diagram, describe the operation of Bainbridge mass spectrometer in the determination of charge to mass ratio. (07marks)

   (e) An ion of mass 2.6 x 10^{-26} kg moving at a speed of 4 x 10^4ms^{-1} enter a region of uniform magnetic field of flux density 0.05T. Calculate the radius of the circle described by the ion.

5. (a)(i) State three differences between X-rays and cathode rays. (03marks)
   (ii)Describe using a labelled diagram, the mode of operation of an X-ray tube (06marks)
   (iii) What is the difference between soft and hard X-rays (01mark)

   (b) (i) What is the main distinction between work function and ionization energy? (02marks)

   (ii) An electron of charge, e, enters at right angles into a uniform magnetic field of flux density B and rotates at frequency, f, n a circle of radius, r.

   Show that the frequency, f, is given by; f = $\frac{Be}{2\pi m}$. (03marks)

   (c) An X-ray beam is produced when electrons are accelerated through 50kV are stopped by the target of an X-ray tube. When the beam falls on a set of parallel atomic plates of a certain metal at glancing angle of 16^0, a first order diffraction maximum occurs. Calculate the atomic spacing of the planes. (05marks)

6. (a) State two differences between alpha and beta particles

(b) Describe with the aid of a diagram, the structure and mode of operation of an ionization chamber. (06marks)

(c)(i) Explain the application of carbon-14 in carbon dating. (03marks)

(ii) A sample of dad wood was found to have activity of 20units due to carbon-14 isotope whose half-life is 5600 years. If activity of wood just cut is 47.8 units, estimate the age of the sample. (03marks)

(d) The photoelectric work function of potassium is 2.25eV. Light having a wavelength of 360mm falls on a potassium metal.

(i) Calculate the stopping potential (04marks)

(ii) Calculate the speed of the most energetic electron emitted by the metal (02marks)

7. (a) What is meant by the following

(i) Radioactivity (01mark)

(ii) Isotopes (01marks)

(b) (i) Define mass defect (01mark)

(ii) State the conditions for a heavy nucleus to be unstable (01mark)

(iii) Explain your answer in (b)(ii) (02marks)

(c) A sample of $^{226}_{88}Ra$ emits both α-particles and γ-rays. A mass defect of 0.0053u occurs in the decay.

(i) Calculate the energy released in joules. (03 marks)

(ii) If the sample decays by emission of α-particle, each of energy 4.60MeV and γ-rays, find the frequency of the γ-rays emitted. (04marks)

(d) (i) Sketch a graph showing the variation of binding energy per nucleon with mass number, clearly showing the fusion and fissions. (02marks)

(ii) Use the sketch in (d)(i) to explain how energy is released in each of the process of fusion and fission. (03marks)

(e) State two

(i) applications of radioisotopes (01marks)

(ii) health hazards of radioisotopes (01mark)

8. (a) What are X-rays? (01marks)

(b) (i) With the aid of a diagram explain how X-rays are produced in an X-ray tube (05marks)

(ii) State the energy changes that take place in the production of X-rays in an X-ray tube. (02marks)

(c) In an X-ray tube, the electrons strike the target with a velocity of 3.75 x 107ms-1 after travelling a distance of 5.0cm from the cathode. If a current of 10mS flows through the tube, find the

(i) tube voltage (02marks)

(ii) number of electrons striking the target per second. (02marks)

(ii) Number of electrons within the space of 1cm length between the anode and the cathode. (05marks)

(d) Briefly explain one medical application of x-rays (03marks)

9. (a) state Bohr's postulates of an atom (03marks)

(b) Explain the occurrence of the emission and absorption line spectra. (06marks)

(c) Explain the main observations in Rutherford's α-particles scattering experiment. (06marks)

(d) A beam of alpha particles of energy 3.5MeV is incident normal to the gold foil.

(i) Calculate the least distance of approach to the nucleus of the gold atom given its atomic number is 79, (04marks)

(ii) State the significance of the value of the least distance of approach. (01mark)

10. (a) (i) Distinguish between mass defect and binding of an atomic nucleus (01mark)

(ii) Sketch a graph of nuclear binding energy per nucleon versus mass number for naturally occurring isotopes and use it to distinguish between nuclear fission and fusion. (04marks)

(b) Describe with the aid of a labelled diagram, Millikan's oil drop experiment to determine the charge on an oil drop. (07marks)

(c) (i) Explain briefly diffraction of X-rays by crystals and derive Bragg's law. (06marks)

(ii) A second order diffraction image is obtained by reflection of X-ray at atomic planes of a crystal for a glancing angle of $11^0 24'$. Calculate the atomic spacing of the planes if the wavelength of X-rays is 4.0×10^{-11}m (02marks)

11. (a) State Bohr's model of an atom. (02marks)

(b) An electron of mass m and charge –e, is considered to move in circular orbit about a proton.

(i) Write down the expression for the electric force on the electron. (02marks)

(ii) Derive an expression for total energy given that the angular momentum for the electron is equal to $\frac{nh}{2\pi}$ where n is an integer and h is Plank's constant. (06marks)

(c) With the aid of a labelled diagram, describe the operation of a diffusion type cloud chamber. (06marks)

(d) The energy levels of an atom have values

E_1 = - 21.4eV

E_2= -4.87 eV

E_3 = -2.77 eV

E4 = -0.81eV

$E_\infty = 0.00eV$

(i) Calculate the wavelength of radiation emitted when an electron makes a transition from E_3 to E_2 (03marks)

(ii) State the region of the electromagnetic spectrum where the radiation lies (01mark)

12. (a) Describe how positive rays are produced. (03marks)

(b) Describe how a Bainbridge spectrometer can be used to detect isotopes. (05marks)

(c) (i) What is time base as applied to a Cathode Ray Oscilloscope? (01mark)

(ii) Draw a sketch graph showing the variation of time base voltage with time (01mark)

(d) An alternating p.d applied to the Y-plate of an oscilloscope produces five complete waves on a 10cm length of the screen when the time base setting is $10mscm^{-1}$. Find the frequency of the alternating voltage. (03marks)

(e) (i) Explain the motion of an electron projected perpendicularly into a uniform magnetic field. (03marks)

(ii) An electron accelerated from rest by a p.d of 100V, enters perpendicularly into a uniform electric field intensity 105Vm-1. Find the magnetic field density, B, which must be applied perpendicularly to the electric field so that the electron passes undeflected through the fields. (04marks)

13. (a) (i) Define Avogadro's constant and Faraday's constant. (02marks)

(ii) Show that the charge carried by a monovalent ion is $1.6 \times 10^{-19}C$. (02marks)

(b) With the use of a labelled diagram, describe Millikan's oil drop experiment for the determination of the charge of an electron. (07marks)

(c) A beam of positive ions moving with velocity v enters a region of a uniform magnetic field density B with the velocity at right angles to the field B. By use of a diagram, describe the motion of ions. (03marks)

(d) A charged oil drop of density $880kgm^{-3}$ is held stationary between two parallel plates 6.0mm apart held at a potential difference of 103V. When the electric field is switched off, the drop is observed to fall a distance of 2.0mm in 35.7s. (Viscosity of air = $1.8 \times 10^{-5}Nsm^{-2}$, Density of air = $1.29kgm^{-3}$).

(i) Calculate the radius of the drop. (03marks)

(ii) Estimate the number of excess electrons on the drop. (03marks)

14. (a) (i) State the laws of photoelectric emission (04marks)

(ii) Explain briefly one application of photoelectric effect. (04marks)

(b) In a photoelectric set up. A point source of light of power $3.2 \times 10^{-3}W$ emits mono-energetic photons of energy 5.0eV. The source is located at a distance of 0.8m from the center of a stationary metallic sphere of work function 3.0eV and radius $8.0 \times 10^{-3}m$. The efficiency of photoelectron emission is one in every 10^6 incident photons.

Calculate

(i) Number of photoelectrons emitted per second. (04marks)

(ii) Maximum kinetic energy in joules, the photo electrons. (02marks)

(c) (i) State Bragg's law of X-ray diffraction (01marks)

(ii) Show that density, ρ, of a crystal can be given by

$$\rho = \frac{M \sin^3\theta}{125 N_A (n\lambda)^3}$$

where θ is the glancing angle, n, is the order of diffraction, λ is the X-ray wavelength and M is the molecular weight of the crystal. (05marks)

15. (a) With reference to a Geiger-Muller tube, define the following

(i) quenching agent (01mark)

(ii) back ground count rate (01mark)

(b) (i) With the aid of a labelled diagram, describe the operation of a Geiger-Muller (GM) tube (06marks)

(ii) Explain how the half-life of a short lived radioactive source can be obtained by use of a Geiger-Muller tube. (04marks)

(c) A radioactive isotope $^{32}_{15}P$ which has a half-life of 14.3days, disintegrates to form a stable product. A sample of the isotope is prepared with initial activity of 2.0 x $10^6 s^{-1}$. Calculate the

(i) the number of ^{32}P atoms present (03marks)

(ii) activity after 30days (03marks)

(iii) number of ^{32}P atoms after 30 days (02marks)

(Assume $N = N_0 e^{-\lambda t}$)

16. (a) State Rutherford's model of the atom. (02marks)

(b) Explain how Bohr's model of the atom addresses the two main failures of Rutherford's model. (07marks)

(c) With the aid of a labelled diagram, describe how cathode rays are produced. (05marks)

(d) (i) What is binding energy of a nucleus? (01mark)

(ii) Calculate the energy in MeV released by fusing four protons to form an alpha particle and two beta particles.

Mass of beta particle = 0.000549u

Mass of hydrogen atom = 1.007825u

Mass of helium atom = 4.002664u

[1u = 931MeV] (05marks)

17. (a) What is photo electric emission? (01mark)

(b)(i) Describe an experiment to demonstrate photo electric effect. (04marks)

(ii) When a clean surface of a metal in a vacuum is irradiated with light of wave length 5.5 x 10^{-7}m, electrons just emerge from the surface. However when light of wavelength 5 x 10^{-7}m is incident on the metal surface, electrons are emitted each with energy 3.62 x 10^{-20}J. Find Plank's constant. (04marks)

(c) (i) With the aid of a labelled diagram, describe an X-ray tube and how X-rays are produced. (05marks)

(ii) Describe how the intensity and quality of X-rays is controlled in an X-ray tube. (02marks)

(d) An X-ray tune operates at 1.5 x 10-3V and the current through it is 1.0 x 10-3A.

Find the

(i) number of electrons crossing the tube per second. (02marks)
(ii) kinetic energy gained by electron traversing the tube (02marks)

18. (a)(i) What is specific charge? (01mark)

(ii) State the **unit** of specific charge (01mark)

(iii) Describe with the aid of a diagram how the specific charge of positive ions can be determined using a mass spectrometer. (06marks)

(b) A beam of strongly ionized carbon atoms passes undeflected through a region of crossed magnetic and electric field of 0.10T and 1.0 x 10^4NC^{-1} respectively. When it enters a region of uniform magnetic field, it is deflected through an arc of radius 0.75m. Calculate the magnetic flux density of this magnetic field. (Mass of carbon atom = 2.0 x 10^{-26}kg) (05marks)

(c) (i) Draw a graph to illustrate the variation of ionization current and p.d across an ionization chamber and explain its features. (03marks)

(ii) Explain how ionization chamber can be used to detect ionization radiation (04marks)

19. (a) Explain briefly how positive rays are produced (03marks)

(b) An electron of charge, e, and mass, m, is emitted from a hot cathode and then accelerated by an electric field towards the anode. If the potential difference between the cathode and the anode is V, show that the speed of the electron, u, is given by

u = $\sqrt{\left(\frac{2eV}{m}\right)}$ (03marks)

(c) An electron starts from rest and moves in an electric field intensity of 2.4 x 10^3Vm^{-1}.

Find the

(i) force on the electron (02 marks)
(ii) acceleration of the electron. (02marks)
(iii) velocity acquired in moving through a p.d of 90V (02marks)

(d) A beam of electrons each of mass, m, and charge, e, is directed horizontally with speed, u, into an electric field between two horizontal metal plates separated by a distance, d.

(i) If the p.d between the plates is V, show that the deflection y of the beam is given by

$$y = \frac{1}{2m}\left(\frac{eV}{du^2}\right)x^2$$

where, x, is the horizontal distance travelled. (06marks)

(ii) Explain the path of the electron beam as it emerges out of the electric field. (02marks)

20. (a) The table below shows the energy levels of a hydrogen atom.

Principal quantum number, n	Energy, eV
6	-0.38
5	-0.54
4	-0.85
3	-1,51
2	-3.39
1	-13.60

(i) Why are the energies for the different levels negative? (01mark)
(ii) Calculate the wavelength of the line arising from a transition from the third to the second level. (03marks)
(iii) Calculate the ionization energy in joules of hydrogen atom. (02marks)

(b) Explain the physical processes in an X-ray tube that account for

(i) cut off wavelength (03marks)

(ii) characteristic lines (04marks)

(c) Calculate the maximum frequency of radiation emitted by an X-ray tube using an accelerating voltage of 33.0kV (03marks)

(d) Derive Bragg's law of X-ray diffraction in crystals. (04marks)

21. (a) A beam of α-particles is directed normally to a thin metal foil

Explain why

(i) Most of the α-particles passed straight through the foil (02marks)

(ii) Few α-particles are deflected through angles more than 900. (02marks)

(b) Calculate the least distance of approach of a 3.5MeV α-particles to the nucleus of a gold atom. (Atomic number of gold= 79) (04marks)

(c) (i) Define space charge as applied to thermionic diodes. (01mark)

(ii) Draw anode current-diode voltage curves of a thermionic diode for two different filament currents and explain their main features. (06marks)

(d) (i)What is a decay constant?

(ii) A sample from fresh wood of a certain species of tree has activity of 16.0 counts per minute per gram. However, the activity of 5g of dead wood of the same species of tree is 10 counts per minute. Calculate the age of the deadwood. (Assume half-life of 5730years) (04marks)

22. (a) (i) What are cathode rays?

(ii) With the aid of a diagram, describe an experiment to show that cathode rays travel in straight line (04mrks)

(b) A beam of electrons is accelerated through a potential difference of 500V. The beam enters midway between two similar parallel plates of length 10cm and are 3cm apart. If the potential difference across the plates is 600V, find the velocity of an electron as it leaves the region between the plates. (08marks)

(c) State the laws of photoelectric emission (04marks)

(d) Explain how line emission spectra are produced. (03marks)

23. (a) (i) what is meant by terms: radioactive decay, half-life and decay constant? (03marks)

(ii) show that the half-life, $t_{\frac{1}{2}}$ of a radioactive isotope is given by $t_{1/2} = \frac{0.693}{\lambda}$ where λ is the decay constant

(Assume the decay law $N = N_0e^{-\lambda t}$)

(b) With the aid of a labelled diagram, describe the structure and action of a cloud chamber (05marks)

(c) A radioactive isotope $^{99}_{43}X$ decays by emission of a gamma ray. The half-life of the isotope is 360minutes. What is the activity of 1mg of the isotope? (06marks)

(d) Explain the term avalanche as applied to an ionization chamber. (03marks)

24. (a) Define the terms below as applied to a triode

(i) space charge (01mark)

(ii) Amplification factor (01mark)

(iii) Mutual conductance (01mark)

(b) With the aid of a labelled diagram explain full wave rectification. (07marks)

(c) Derive an expression for the amplification factor, μ, in terms of anode resistance, R_a and mutual conductance, g_m, for a triode valve. (03marks)

(d) A triode with mutual conductance 3mAV^{-1} and anode resistance of 10kΩ is connected to a load resistance of 20kΩ, Calculate the amplitude of output signal, if the input signal is 25mV. (04marks)

(e) (i) Sketch the output characteristics of a transistor. (02marks)

(ii) Identify on the sketch in (e)(i), the region over which the transistor can be used as amplifier. (01).

25. (a) (i) Describe with the aid of a well labelled diagram, the structure and mode of operation of a C.R.O (06marks)

(ii) State the advantages of C.R.O over a moving coil voltmeter. (02marks)

(b) In the determination of the electron charge by Millikan's method, a potential difference of 1.5kV is applied between horizontal metal plates, 12mm apart. With the field switched off, a drop of oil of mass 1,0x 10^{-14} kg is observes to fall with constant velocity, 4 x 10^{-4}ms^{-1} between two metal plates. When a potential difference of 1.5kV is applied across the plates, the drop rises with constant velocity of 8.0 x 10^{-5}ms^{-1}.

How many electron charges are there on the drop? (Assume air resistance is proportional to the velocity of the drop and neglect air buoyancy.

(c) Explain why

(i) the apparatus in Millikan's experiment is surrounded with a constant temperature enclosure, (03marks)

(ii) low vapor-pressure oil is used. (02marks)

(d) In Millikan's experiment, the radius, r, of the drop is calculated from

$$r = \sqrt{\frac{9\eta v}{2\rho g}}$$

where η is the viscosity of air and ρ is the density of oil.

Identify the symbol v and describe briefly how it is measured. (02mark)

26. (a) (i) Explain how X-rays are produced in an X-ray tube (04 marks)

(ii) Explain the emission of X-ray characteristic spectra. (03 marks)

(iii) Derive the Bragg X-ray diffraction equation (04marks)

(iv) Under what conditions does X-ray diffraction occurs? (02marks)

(b) With the aid of a labelled diagram, describe how a Bainbridge mass spectrometer is used to measure specific charge. (07marks)

27. (a) What is meant by unified atomic mass unit? (01mark)

(b) (i) Distinguish between nuclear fusion and nuclear fission (02marks)

(ii) State the conditions necessary for each of the nuclear reaction in (b) (i) to occur. (02marks)

(c) (i) With the aid of a labelled diagram, describe the operation of an ionization chamber. (06marks)

(ii) Sketch the curve of ionization current against applied p.d and explain its main features. (04marks)

(d) A typical nuclear reaction is given by:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{95}_{42}Mo + ^{139}_{57}La + 2^{1}_{0}n + ^{0}_{-1}e$$

Calculate the total energy released by 1g of uranium. (05marks)

Mass of $^{1}_{0}n = 1.009\mu$

$^{0}_{-1}e = 0.00055\mu$

$^{95}_{42}Mo = 94.906\mu$

$^{139}_{57}La = 138.906\mu$

$^{235}_{92}U = 235.044\mu$

$1\mu = 1.66 x 10^{-27}kg$

28. (a) (i) With the aid of a labelled diagram, describe what is observed when a high tension voltage is applied across a gas tube in which pressure is gradually reduced to vary low value. (05marks)

(ii) Give two applications of discharge tubes. (01mark)

(b) Describe Thomson's experiment to determine the specific charge of an electron. (06marks)

(c) In a Millikan's experiment, a charged oil drop of radius 9.2 x 10^{-7}m and density 800kgm-3 is held stationary in an electric field of intensity 4.0 x 10^{4}Vm^{-1}.

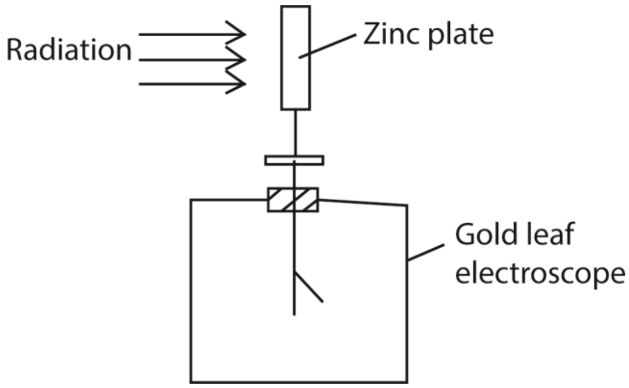
(i) How many electron charges are on the drop? (04marks)

(ii) Find the electric field intensity that can be applied vertically to move the drop with velocity 0.005ms-1 upwards.

[Density of air = 1.29kgm^{-3}, coefficient of viscosity of air = 1.8 x 10^{-5}Nsm^{-1}]

29. (a) Explain what is meant by photoelectric effect. (02marks)

(b)



Ultraviolet and infrared radiations are directed in turns on to a zinc plate which is attached to a gold leaf electroscope as shown in the figure above

Explain that happens when

(i) Ultraviolet radiation falls on the zinc plate (02marks)
(ii) Infrared falls on the zinc plate. (01mark)
(iii) The intensity of each radiation is increased. (02marks)

(c) An X-ray of wavelength 10^{-10}m is required for the study of its diffraction in a crystal. Find the least accelerating voltage to be applied on an X-ray tube in order to produce these X-rays. (04marks)

(d) Sodium has a work function of 2.0eV and is illuminated by radiation of wavelength 150nm. Calculate the maximum speed of the emitted electrons. (04marks)

(e) With the aid of a well labelled diagram, describe how stopping potential of a metal can be measured. (05marks)

30. (a) (i) What is meant by mass defect? (01marks)

(ii) Sketch a graph showing how binding energy per nucleon varies with mass number and explain its features. (03marks)

(iii) Find the binding energy per nucleon of $^{56}_{26}Fe$ given that

Mass of 1 proton = 1.007825u

Mass of 1neutron = 1.008665u

[1u = 931MeV) (03marks)

(b) With the aid of a diagram, explain how an ionization chamber works (06marks)

(c) (i) Show that an alpha particle collides head on with an atom of atomic number, Z, the closest distance of approach to the nucleus X_0 is given by

$$X_0 = \frac{ze^2}{\pi\varepsilon_0 mv^2}$$

Where

e is electronic charge

ε_0 is permittivity of fee space

m is mass of alpha particle

v is initial speed of alpha particle (04marks)

(ii) In a head on collision between an alpha particle and a gold nucleus, the minimum distance of approach is 5 x 10-14m. Calculate the energy of alpha particle (in MeV)

[atomic number of gold= 79]

31. (a) State four differences between cathode rays and positive rays (02marks)

(b) An electron having energy of 4.5 x 10^3eV moves at right angles to a uniform magnetic field of flux density 1.5 x 10^{-3}T. Find the

(i) radius of the path followed by the electron. (04marks)

(ii) period of the motion. (03marks)

(c) (i) Define the term Avogadro constant and Faraday constant (02marks)

(ii) Use the Avogadro constant and Faraday constants to calculate the charge on anion of monatomic element. (03marks)

(d) Explain the meaning of the following terms as applied to a Geiger-Muller tube.

(i) threshold potential difference (02marks)

(ii) Dead time (02marks)

(iii) A quenching agent (02marks)

32. (a) State the laws of photoelectric effect (04marks)

(b) Describe an experiment to determine the stopping potential of a metal surface. (05 marks)

(c) A 100mW beam of light of wavelength 4.0 x 10^{-7}m falls on caesium surface of a photocell.

(i) How many photons strike the caesium surface per second? (03marks)

(ii) If 65% of the photons emit photoelectrons, find the resulting photocurrent. (03marks)

(iii) Calculate the kinetic energy of each photon if the work function of caesium is 2.20eV. (03marks)

(d) Distinguish between continuous and line spectra in an X-ray tube. (02marks)

33. (a) (i) Explain the observation made in the Rutherford α-particle scattering experiment. (06marks)

(b) Distinguish between excitation and ionization energies of an atom. (02marks)

(c) Draw a labelled diagram showing the main components of an X-ray tube (03marks)

(d) An X-ray tube is operated at 50kV and 20mA. If 1% of the total energy supplied is emitted as X-radiation, calculate the

(i) maximum frequency of emitted radiation (03marks)

(ii) rate at which heat must be removed from the target in order to keep it at a steady temperature. (03marks)

(e) A beam of X-ray of wavelength 0.2nm is incident on a crystal at glancing angle 300. If the interplanar separation is 0.20nm, find the order of diffraction. (02marks)

34. (a) What is meant by a line spectrum? (02marks)

(b) Explain how line spectrum accounts for existence of discrete energy levels in an atom. (04marks)

(c) The energy levels in mercury atom are -10.4eV, -5.5eV, -3.7eV and -1.6eV.

(i) Find the ionization energy of mercury in joules (02marks)

(ii) What is likely to happen if mercury atom in unexcited state is bombarded with an electron of energy 4.0eV, 6.7eV or 11.0eV? (03marks)

(d) Describe with the aid of a diagram, the action of an X-ray tube. (05marks)

(e) An X-ray tube is operated at 20kVwith electron current 16mA in the tube. Estimate the:

(i) the number of electrons hitting the target per second. (02marks)

(ii) rate of production of heat, assuming 99.5% of the kinetic energy of electron is converted to heat. (e = 1.6 x 10^{-19}C)

35. (a) (i) Define the term binding energy (01marks)

(ii) Sketch a graph showing the variation of binding energy per nucleon with mass number (02marks)

(iii) Use the sketch graph you have drawn in (a)(ii) to explain how energy is released during fission and fusion. (03marks)

(b) Explain why a high temperature is required during fusion of nuclides. (01mark)

(c) The isotope $^{238}_{92}U$ emits an alpha particle and forms an isotope of thorium (Th), while the isotope $^{235}_{92}U$ when bombarded by a neutron, forms $^{144}_{56}Ba$, $^{90}_{36}Kr$ and neutrons.

(i) Write the nuclear equation for the reaction of $^{238}_{92}U$ and $^{235}_{92}U$. (02marks)

(ii) How does the reaction of $^{235}_{92}U$ differ from that of $^{238}_{92}U$ (03marks)

(d) A steel piston ring contains 15g of radioactive iron, $^{54}_{26}Fe$. The activity of $^{54}_{26}Fe$ is 3.7 x 10^5 disintegration per second.

After 100 days of continuous use, the crankcase oil was found to have a total activity of 1.23 x 10^3 disintegrations per second. Find the

(i) Half-life of $^{54}_{26}Fe$ (05marks)

(ii) Average mass of iron worn off the ring per day, assuming that all the metal from the ring accumulates in the oil. (03marks)

36. (a) Describe the mechanism of thermionic emission (03marks)

(b) Explain the following terms as applied to a vacuum diode

(i) space charge limitation (03marks)

(ii) Saturation (01 mark)

(iii) Rectification (02marks)

(c) Sketch the current potential difference characteristics of a thermionic diode for two different operating temperatures and explain their main features (05marks)

(d) (i) A triode valve with an anode resistance of 3.0 x $10^3\Omega$is used as an amplifier. A sinusoidal alternating signal of amplitude 0.5Vis applied to the grid of the valve. Find the r.m.s value of the output voltage if the amplification factor is 15 and anode load is 50kΩ.

(ii) Draw an equivalent circuit of a triode as a single-stage amplifier. (01marks)

37. (a) Describe briefly the mechanism of thermionic emission (03marks)

(b) (i) Draw a labelled circuit to show a triode being used as a single-stage voltage amplifier. (03maks)

(ii) With the aid of an equivalent circuit of a triode as an amplifier, obtain an expression for voltage gain (04marks)

(iii) A triode with mutual conductance of 3.0 x 10^{-3} AV^{-1} and anode resistance of 1 x 104Ω, is used as a single-stage amplifier. If the load resistance is 3 x $10^4\Omega$, calculate the voltage gain of the amplifier. (05marks)

(c) (i) Describe the structure of a junction transistor. (02marks)

(ii) sketch and describe the collector-current against collector-emitter voltage characteristic of a junction transistor. (03marks)

38. (a) What are isotopes? (01mark)

(b) With the aid of a diagram, describe the operation of Bainbridge spectrometer in determining the specific charge of ions. (06marks)

(c) Explain the purpose of each of the following in a Geiger-Muller tube

(i) a thin mica window

(ii) Argon gas at low pressure

(iii) Halogen gas mixed with argon gas

(iv) An anode in the form of a wire (04marks)

(d) (i) What is meant by binding energy per nucleon of a nucleus? (01mark)

(ii) Sketch a graph of binding energy per nucleon against mass number for naturally occurring nuclides (01marks)

(iii) State one similarity between nuclear fusion and nuclear fission. (01mark)

(e) (i) At a certain time, an α-particle detector registers a count rate of $32s^{-1}$. Exactly 10days later, the count rate dropped to $8s^{-1}$. Find the decay constant. (04marks)

(ii) State two industrial uses and two health hazards of radioactivity. (04marks)

39. (a) (i) Describe, with aid of a diagram, the production of cathode rays

(ii) state and justify two properties of cathode rays (02marks)y

(b) Explain each of the following terms as applied to photoelectric emission:

(i) stopping potential (01marks)

(ii) threshold frequency (01mark)

(c) Explain X- ray diffraction by crystals and derive Bragg's law (06marks)

(d) The potential difference between the cathode and anode of an X-ray tube is 5.0×10^{-4}V. If only 0.4% of the kinetic energy of the electrons is converted into X-rays and the rest is dissipated as heat in the target at a rate of 600W, find the

(i) current that flows (03marks)

(ii) speed of the electrons striking the target. (03marks)

40. (a) (i) What is a photon? (01mark)

(ii) Explain, using quantum theory, the experimental observation on the photoelectric effect. (06marks)

(iii) when light of wavelength 150nm falls on a certain metal, electrons of maximum kinetic energy 0.76eV are emitted. Find the threshold frequency for the metal. (04marks)

(b) Explain, using suitable sketch graph, how X-ray spectrum in an X-ray tube are formed. (06marks)

(c) A beam of X-rays of wavelength 8.42×10^{-11}m is incident on a sodium chloride crystal of interplanar separation 2.82×10^{-10}m. Calculate the first order of diffraction angle. (03marks)

41. (a) (i) A beam of electrons, having a common velocity, enters a uniform magnetic field in a direction normal to the field. Describe and explain the subsequent path of the electrons (04marks)

(ii) Explain whether a similar path would be followed if a uniform electric field were substituted for magnetic field (01mark)

(b) Describe an experiment to measure the ratio of the charge to mass of an electron (07marks)

(c) Electrodes are mounted at opposite ends of low pressure discharge tube and a potential difference of 1.20kV applied between them. Assuming the electrons are accelerated from rest, calculate the maximum velocity which they could acquire. [Specific electron charge =-1.76 x 10^{11} Ckg^{-1}) (02marks)

(d) (i) Give an account of the stages observed when an electric discharge passes through a gas at pressure varying from atmospheric to about 0.01mmHg as air is pumped out when the p.d across the tube is maintained at extra high tension. (05marks)

(ii) State two disadvantages of discharge tubes when used to study cathode rays. (01mark)

42. (a) (i) What is meant by half-life of a radioactive material? (01mark)

(ii) Given the radioactive law, $N_t = N_0e^{-\lambda t}$, obtain the relationship between λ and half-life $T_{\frac{1}{2}}$ (02marks)

(iii) What are radioisotopes? (01mark)

(iv) The radioisotope $^{90}_{38}Sr$ decays by emission of β-particles. The half-life of the radioisotope is 28.8years. Determine the activity of 1g of the isotope (05marks)

(b) (i) With aid of a diagram describe the structure and action of Geiger-Muller tube. (06marks)

(ii) Sketch the current –voltage characteristic of the Geiger- Muller tube and explain its main features. (03marks)

(iii) Identify, giving reasons, the suitable range in (b) (ii) of operation of the tube (02marks)

43. (a)(i) Draw a labelled diagram of an X-ray tube. (02marks)
(ii) Use the diagram in (a)(i) to describe how X-rays are produced. (03marks)
(iii) State one industrial and one biological use of X-rays. (01marks)
(b)(i) Sketch a graph of intensity versus wavelength of X-rays from an X-ray tube and describe its main features. (04marks)
(ii) Calculate the maximum frequency of X-rays emitted by an X-ray tube operating on voltage of 34.0kV. (03marks)
(c) In the measurement of electron charge by Millikan's apparatus, a potential difference of 1.6kV is applied between two horizontal plates 14mm apart. With the potential difference switched off, an oil drop is observed to fall with constant velocity 4.0 x $10^{-4}ms^{-1}$. When the potential difference is switched on, the drop rises with constant velocity 8.0 x $10^{-5}ms^{-1}$.
If the mass of the oil drop is 1.0 x 10^{-14}kg, find the number of electron charges on the drop. [assume air resistance is proportional to velocity of the oil drop and neglect the up thrust due to air] (07marks]
44. (a) (i) State the laws of photo-electric emission. (04marks)
(ii) Write down Einstein's equation for photo electric emission. (02marks)
(iii) Ultra –violet light of wavelength 3.3 x 10-8m is incident on a metal. Given the work function of the metal is 3.5eV, calculate the maximum velocity of the liberated electron. (03marks)
(b) Describe, with aid of a diagram, the structure and mode of operation of a cathode ray oscilloscope (C.R.O) (06marks)

A C.R.O has its y-sensitivity set to $10Vm^{-1}$. A sinusoidal input voltage is suitably applied to give a steady trace with time base switched on so that the electron beam takes 0.01s to traverse the screen. If the trace seen has a peak-to-peak height of 4.0cm and contains two complete cycles, find the

(i) r.m.s value of the input voltage. (03marks)

(ii) frequency of the input signal. (02marks)

45. (a) define binding energy of nuclide (01mark)

(b) (i) Sketch a graph showing how binding energy per nucleon varies with mas number (01mark)

(ii) Describe the main features of the graph in (b)(i). (03marks)

(c) Distinguish between nuclear fission and nuclear fusion and account for the energy released. (03mark)

(d) (i) with the aid of a labelled diagram describe the working of the Geiger-Muller tube. (05marks)

(ii) How would you use a Geiger-Muller tube to determine the half-life of a radioactive sample? (04marks)

(e) A radioactive source produces alpha particles each of energy 60eV. If 20% of the alpha particles enter an ionization chamber a current of 0.2μA flows. Find the activity of the alpha source, if the energy needed to make an ion pair in the chamber is 32MeV. (03marks)

46. (a) (i) Describe with the aid of a labelled diagram the main features of a cathode ray oscilloscope (C.R.O) (08marks)

(ii) State two uses of C.R.O (01mark)

(iii) The gain control of a C.R.O is set on $0.5Vcm^{-1}$ and an alternating voltage produces a vertical trace of 2.0cm long with the time base off. Find the root mean value of the applied voltage. (02marks)

(b) a beam of electrons is accelerated through a potential difference of 2000V and is directed mid-way between two horizontal plates of length 5.0cm and separation of 2.0cm. The potential difference across the plates is 80V.

(i) Calculate the speed of the electron as they enter the region between the plates. (03marks)

(ii) Explain the motion of the electrons between the plates. (02marks)

(iii) find the speed of electrons as they emerge from the region between the plates. (04marks)

47. (a) Explain the term stopping potential as applied to photo electric effect. (02marks)

(b) Explain how intensity and penetrating power of X-rays from X-ray tube would be affected by changing:

(i) the filament current (02marks)

(ii) the high tension potential difference across the tube (02marks)

(c) When a p.d of 60kV is applied across an X-ray tube, a current of 30mA flows. If 99% of the power supplied is converted into heat at the anode, calculate the rate at which the temperature of the water rises. {Specific heat capacity of water = $4.2 \times 10^3 Jkg^{-1}K^{-1}$] (05marks)

(d) (i) Derive Bragg's law of X-ray diffraction. (05marks)

(ii) Calculate the atomic spacing of sodium chloride if the relative atomic mass of sodium is 23.0 and that of chlorine is 35.5.

[Density of sodium chloride = $2.18 \times 10^3 kgm^{-3}$] (04marks)

48. (a) (i) Explain briefly the mechanism of thermionic emission. (02marks)

(ii) Draw a labelled diagram of the circuit used to determine the anode current and anode voltage characteristics of a thermionic diode. (02marks)

(iii) Sketch the characteristic expected in (a) (ii) at constant filament current, and account for its special features. (04marks)

(b) Describe, with the aid of a labelled diagram, the structure and action of a diffraction cloud chamber (06marks)

(c) (i) Define radioactivity and half-life of a radioactive substance (02marks)

(ii) A radioactive isotope of strontium of mass 5.0μg has a half-life of 28years. Find the mass of the isotope left after 14 years.

[Assume the decay law $N = N_0e^{-\lambda t}$]

49. (a) (i) State Rutherford's model of the atom. (02marks)

(ii) Explain two main features of Rutherford's model of the atom. (03marks)

(b) (i) Explain how Millikan's experiment for measuring the charge of an electron proves that charge is quantized. (04marks)

(ii) Oil droplets are introduced into the space between two flat horizontal plates, set 5.0mm apart. The plate voltage is then adjusted to exactly 780V so that one of the droplets is held stationary. Then the plate voltage is switched off and the selected droplet is observed to fall a measured distance of 1.5mm in 11.2s. Given the density of oil used is $900kgm^{-3}$ and the viscosity of air is $1.8 \times 10^{-5}Nsm^{-2}$, calculate the charge on the droplet. (06marks)

(c) A beam of positive ions is accelerated through a potential difference of 1 x 103V into a region of uniform magnetic field of flux density 0.2T. While in magnetic field it moves in a circle of radius 2.3cm. Derive an expression for the charge to mass ration of the ions, and calculate the value. (05marks)

50. (a) (i) What is meant by thermionic emission? (01mark)

(ii) Sketch the current-potential difference characteristics of a thermionic diode for two different operating temperature and explain their main features. (05marks)

(iii) Describe one application of a diode. (02marks)

(b) (i) What features of an x-ray tube make it suitable for continuous production of X-rays. (03marks)

(ii) Sketch a graph of intensity versus frequency of a radiation produced in an X-ray tube and explain its main feature. (05marks)

(iii) A mono chromatic X-ray beam of wavelength 1.0×10^{-10}cm is incident on a set of planes in a crystal of spacing 2.8×10^{-10}m.What is the maximum order possible with these X-rays? (04marks)

51. (a) What is meant by the following terms:

(i) nuclear number (01mark)

(ii) binding energy (01marks)

(b) Calculate the energy released during the decay of $^{220}_{86}Rn$ nucleus into $^{216}_{84}P_0$ and α-particle

Mass of $^{220}_{86}Rn$ = 219.964176u

Mass of $^{216}_{84}Po$ = 215.955794u

Mass of $^{4}_{2}He$ = 4.001566u

(1u = 931eV) (04marks)

(c) Describe the Bainbridge mass spectrometer and explain how it can be used to distinguish between isotopes (07marks)

(d) (i) Explain how you would use a decay curve for a radioactive material to determine its half-life. (02marks)

(ii) A radioactive source contain 1.0μg of plutonium of mass number 239. If the source emits 2300 α-particles per second, calculate the half-life of plutonium.

[Assume the decay law $N + N_0e^{-\lambda t}$] (05mark)

52. (a) What is meant by

(i) Bohr atom (01mark)

(ii) binding energy of a nucleus (02marks)

(b) The total energy, E, of an electron n an atom may be expressed as

$$E = \frac{-mq^4}{8\varepsilon_0^2 n^2 h^2}$$

(i) Identify the quantities, m, q, n and h in this expression (02marks)

(ii) Explain the physical implication of the fact that E is always negative (02marks)

(iii) Draw an energy level diagram for hydrogen to indicate emission of ultraviolet, visible and infrared spectral lines. (03marks)

(c)(i) Explain briefly the sources and absorption of infrared radiation. (04 marks)

(ii) Describe briefly, the method of detecting infrared radiation (03marks)

(d) The atomic nucleus may be considered to be a sphere of positive charge with a diameter very much less than that of an atom. Discuss the experimental evidence which supports this view. (03marks)

53. (a) (i) What are cathode rays? (01mark)

(ii) An electron gun operating at 3 x 10^3V is used to project electrons into the space between two oppositely charged parallel plates of length 10cm and separation 5cm.

Calculate the deflection of the electrons as they emerge from the region between the charged plates when the potential difference is 1 x 10^3V. (03marks)

(b) (i) Describe a simple experiment to demonstrate photoelectric emission. (04marks)

(ii) Explain why the wave theory of light fails to account for the photoelectric effect. (06marks)

(iii) Describe an experiment to verify Einstein's equation for the photoelectric effect and explain how Plank's constant may be obtained from the experiment. (06marks)

54. (a) What is meant by

(i) half-life of radioactive element (01mark)

(ii) nuclear fission (01mark)

(iii) Nuclear fusion

(b) An atom of ^{222}Ra emits an α-particle of energy 5.3eV. Given that the half-life of ^{222}Ra is 3.8days. Use the decay law, $N= N_0e^{-\lambda t}$ to calculate the:

(i) decay constant (03marks)

(ii) amount of energy released by 3.0 x 10^{-9}kg of ^{222}Ra after 3.8days (05marks)

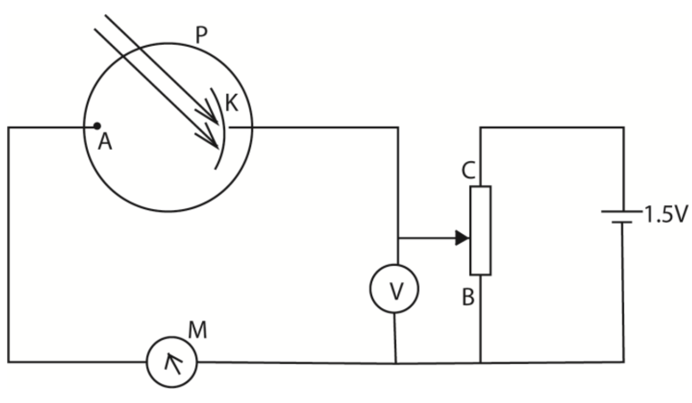
(c) Describe a simple form of a mass spectrometer and explain how it is used to distinguish between isotopes (07marks)

(d) the nucleus of $^{37}_{17}Cl$ emits an α-particle followed by two β-particles. Show that the final nucleus is an isotope of chlorine (02mark)

55. (a) (i) Write down the Einstein photo-electric equation (01mark)

(ii) Explain how the equation in (a)(i) above accounts for the emission of electrons from metal surfaces illuminated by radiation. (04marks)

(b)



P is a vacuum photocell with anode, A, and cathode, K, made from the same metal of work function 2.0eV. The cathode is illuminated by monochromatic light of constant intensity and wavelength 4.4 x 10^{-7}m

(i) Describe and explain how the current shown by the micro ammeter, M will vary as the slider of potential divider is moved from B to C. (03marks)

(ii) What will the reading of the high-resistance voltmeter, V, be when photo-electric emission just ceases? (03marks)

(c) With the slider set mid-way between B and C, describe and explain how the reading of M would change if

(i) the intensity of the light was increased, (03marks)

(ii) the wavelength of the light was changed to 5.5×10^{-7}m

56. (a) What is meant by the following

(i) an alpha particle, (01mark)

(ii) radioactivity (01mark)

(b) Show that when an alpha particle collides head –on with an atom of atomic number Z, the closest distance of approach to the nucleus b_o, is given by

$$b_o = \frac{Ze^2}{\pi\varepsilon_0 mv^2}$$

where e is the electronic charge, ε0 is the permittivity of free space, m, mass of the alpha particle and v is the initial velocity of the particle. (06marks)

(c) Describe the structure and action of a cloud chamber. (06marks)

(d) State four uses of radioactive isotopes (02marks)

(e) one kilogram of wood from a ship wreck has activity of 1.2×10^2 counts per second due to ^{14}C, whereas the same amount of wood had an activity of 2.0×10^2counts per second. Find the age of the ship wreck. [Half-life of 14C = 5.7×10^3years] (04 marks)

57. (a) what is meant by emission line spectra?

E_∞ ………………………………………………………… 0eV
E_4………………………………………………………… -0.81eV
E_3………………………………………………………… -2.77eV
E_2………………………………………………………… -4.87eV
E_1………………………………………………………… -27.47eV

(ii) The figure above shows some energy levels of neon. Determine the wavelength of the radiation emitted in an electron transition from E_4 to E_3. In what region of the electromagnetic spectrum does the radiation lie? (04marks)

(b) Outline the principles of generation of continuous line spectra of X-rays in X-ray tube. (05marks)

(c) State Bragg's law of X-ray diffraction. (01mark)

(d) A beam of X-rays of wavelength 1.0 x 10-10m is incident on a set of cubic planes in a sodium chloride crystals. The first order diffraction m is obtained for a grazing angle of 10.2^0.

Find

(i) The spacing between consecutive planes (03marks)

(ii) The density of the sodium chloride (04marks)

58. (a) state the laws of pho electric emission. (04marks)

(b) (i) Describe an experiment Plank's constant. (05marks)

(ii) Violet light wavelength 0.4µm is incident on a metal surface of threshold wavelength 0.65µm. Find the maximum speed of emitted electrons

(iii) Explain why light whose frequency is less than the threshold frequency cannot cause photo emission. (02marks)

(c) (i) What are X-rays? (01marks)

(ii) Explain how the intensity and penetrating power of X-rays produced by an X-ray tune can be varied. (04marks)

59. (a)(i) Define the terms half-life and decay constant as applied to radioactivity. (02marks)

(ii) State relationship between half-life and decay constant. (01mark)

(b) The radioisotope ^{60}Co decays by emission of a β-particle and γ-rays. Its half-life is 5.3years.

(i) find the activity of a source containing 0.10g of ^{60}Co. (04marks)

(ii) In which ways do γ-rays differ from β-particles (03marks)

(c) (i) What is meant by mass defect in nuclear physics? (01mark)

(ii) Calculate the mass defect for $^{59}_{26}Fe$, given the following information

Mass of $^{59}_{26}Fe$ nucleus = 58.93488u

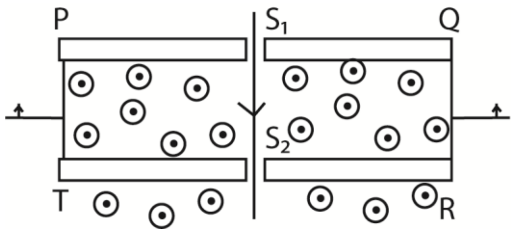
Mass of a proton = 1.00728u

Mass of neutron = 1.00867u (04marks)

(d) Describe the structure and action of ionization chamber. (05marks)

60. (a) what is meant by specific charge of an ion? (01mark)

(b)



Positive ions of the same charge are directed through slit S_1 into a region PQRT as shown in the figure above. There is a uniform electric field of intensity $300NC^{-1}$ between the plate PT and QR. A uniform magnetic field of flux density 0.6T is directed perpendicularly out of the paper as shown above.

(i) Calculate the velocity of the ions which go through slit S_2. (03marks)

(ii) Describe the motion of ions in the region TR. (3marks)

(c) When fast moving electrons strike a metal target in X-ray tube, two type of X-ray spectra are produced

(i) Draw a sketch graph of intensity against wavelength of the X-rays (02marks)

(ii) Account for the occurrence of the two types of spectra (05marks)

(d) Outline the experimental evidences for the quantum theory of matter. (06marks)