EXPERIMENTS WITH ALPHA COUNTING SYSTEM

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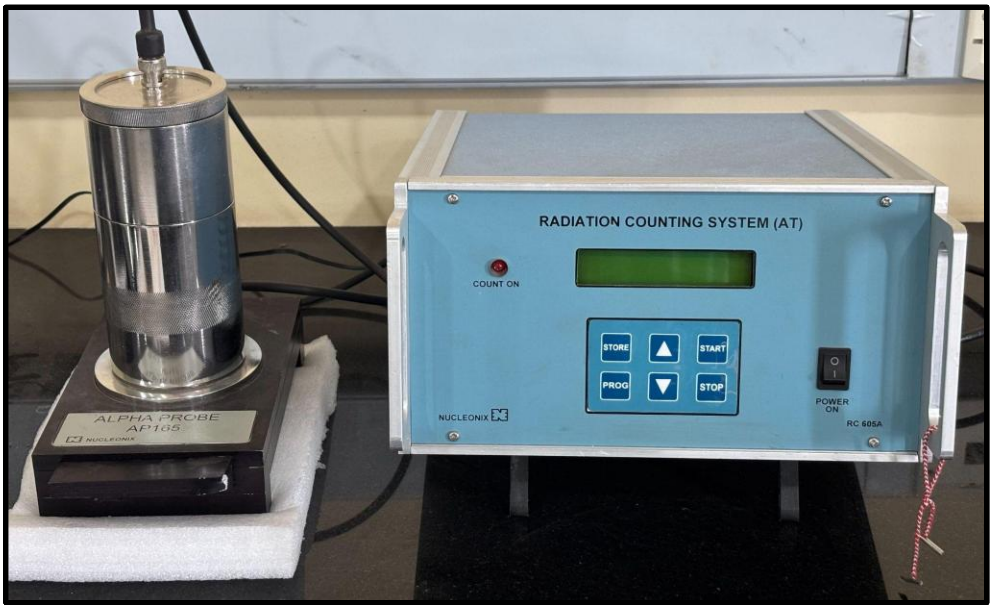
DESCRIPTION OF RADIATION COUNTING SYSTEM RC605A

The Radiation Counting system, type RC605A, manufactured by NUCLEONIX, is a versatile, state-of-the-art integral counting system designed around an eight-bit microcontroller chip for use with a variety of detector probes, such as Alpha/Beta/Gamma Scintillator detector probe, End-window G.M. detector probe, or thin-walled G.M. detector probe(s). The system is suitable for counting Alpha, Beta, and Gamma sample counting with appropriate detector probes. This counter has a processor card and other electronic circuits to generate continuously variable HV up to 1500V to be applied to scintillation detector Probes (α, β, γ) or End window G.M. detector(s), amplify the detector output, and convert them to digital pulses for counting and displaying the recorded counts for a preset time. Microcontroller design facilitates programmability for background, standard, and sample counting. The data can be downloaded to a PC or printed directly.

The system facilitates counting samples on either planchets or filter paper. This system will find applications in counting air activity, wipes, environmental, geological, and other samples for beta, gamma, and alpha activity. An activity report is generated for the unit volume of the sample.

RADIATION COUNTING SYSTEM (AT)

TYPE: RC605A



(With Alpha Probe)

ALPHA PROBE

Alpha Probe type AP165, manufactured by NUCLEONIX, is intended for use with the Radiation Counting System model RC 605A for counting alpha samples. The Radiation Counting System, along with the Alpha Probe, essentially works as an Alpha Counting System.

Alpha Probe of NUCLEONIX is essentially an integration of ZnS (Ag) scintillator screen, optically coupled to a 2" PMT & covered by a pinhole-free aluminized mylar foil to provide sealing against ambient light. Scintillations received by PMT because of Alpha particles will be converted to electrical charge and, in turn, to voltage pulses. Each of these events, after amplification in the RCS, will be counted. The required high voltage (typically 900V) is applied through RCS to the Alpha Probe.

Probe has a drawer assembly that facilitates sample placement on the sample tray for counting applications. The counting samples are usually deposited on planchets of 25mm diameter or filter paper up to 38mm diameter.

ALPHA SOURCE

The standard alpha source is Am-241, which emits alpha particles with a principal energy of 5.48 MeV (85.2% intensity) and a secondary alpha energy of 5.43 MeV (12.8% intensity). It is an electro-deposited source on an SS Planchet. Typical activity is in the range of 3000 to 5000 dpm.

FRONT PANEL CONTROLS AND INDICATIONS

1. **POWER ON SWITCH**

   This is a miniature ROCKER switch which is used to power up the unit. When the switch is set to 'ON,' the unit receives mains AC power.

2. **INTELLIGENT KEYPAD**

(a) **PROG key button:** This key is an important key which facilitates the user to programme for the operation of the instrument for different modes / conditions.

(b) **START key button:** This is used for starting acquisition, once all the programme parameters have been set.

(c) **STOP key button:** This key can be used to terminate acquisition and printing in between. In the normal course, acquisition will stop automatically at the end of the preset time.

(d) **INC/DEC key button:** These keys are used while setting the programme parameters to increment and decrement a value or to change the option selected to another value available and also used for printing.

(e) **STORE key button:** This key is used for storing the readings or data values in the following way, in the manual mode of storing only. At the end of the acquisition for a preset time, if the user presses this button, the data counts will be stored.

3. **LCD DOTMATRIX DISPLAY**

   This is a 20 X 2 alphanumeric LCD dot-matrix and responds to all the commands from the keypad and displays programme parameters, current HV, data counts, preset and elapsed time, etc,

REAR PANEL CONTROLS AND INDICATIONS

1. **DC SOCKET**

   This is used to connect a 12V adaptor.

2. **SCINT PROBE**

   This is an MHV socket to which a scintillation detector probe (Alpha or Gamma (NaI) Scintillation detector) and a UHF socket to a Beta plastic scintillator-based detector from Nucleonix (or its equivalent) can be connected via an MHV-to-MHV cable.

3. **G.M. DETECTOR**

   This is an MHV socket to which an End window GM detector GM125 (End window detector probe) or a GM detector LND 72314 or its equivalent can be connected via an MHV-to-MHV cable.

4. **TO PRINTER**

   This is a 25-pin D-female connector that allows a printer (with a Centronics interface cable) to be connected for direct printing.

5. **EHT (0-1500V) MHV SOCKET:** Output socket provided for checking the HV output.

6. **MINIATURE BANANA / SOCKET TEST POINTS (for LV supplies):** These are provided on the rear panel as test points for +5V, +12V, +24V & GND.

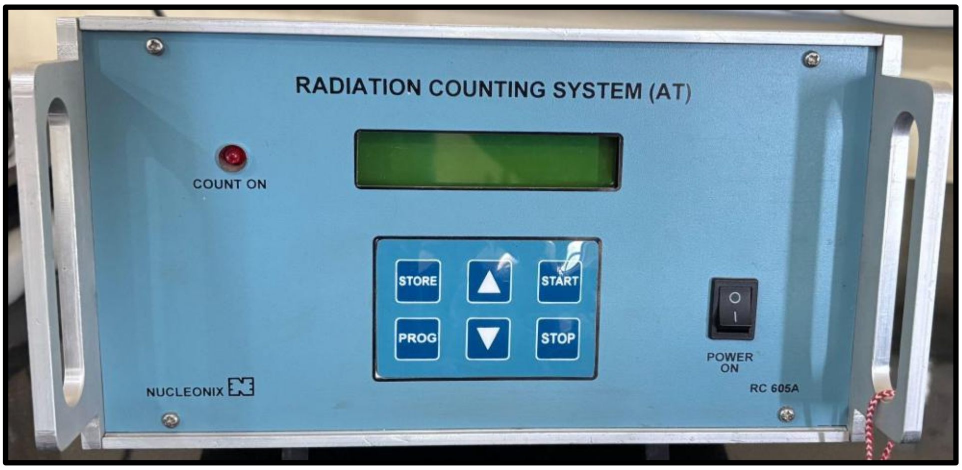


Fig. (a) Front view of Radiation Counting system (RC605A)

Fig. (b) Rear view of Radiation Counting system (RC605A)

PROCEDURE FOR ALPHA SAMPLE ACTIVITY CALCULATIONS

Nucleonix's Radiation Counting System (RC605) has embedded software that enables the user to perform the above calculations and generate reports on a connected printer or via the RS232/RS485 port on a remote PC using data communication software.

The following is the procedure for activity calculation in Bq/ml or Bq/ m^3

a. After connecting the system to the appropriate probe ($\propto$), switch ON the unit and select detector type. Apply the required operating voltage to the detector. Now allow a 5-minute warm-up.

b. Now acquire background radiation by going to 'BG' mode in the ACQ mode option. In this menu, enter the preset time based on the detector type and the expected background. Typically, one can select 60-300 sec for β detectors and 300-3600 sec for $\propto$.

c. Now, once the preset time is selected, press the START button to acquire. At the end of counting, press the STORE button to update the background CPM. (Note: Ensure to keep radiation sources away from the unit to prevent radiation interference)

d. Now the user can compute the efficiency of the detector and standardize the instrument by counting on a standard radiation source of known activity. Select 'STD' mode of ACQ mode option and subsequently enter preset time & dps of std depending upon the activity of the standard. Now acquire the standard for the selected preset time. At the end of the reset time, store the obtained efficiency data by pressing the STORE button.

$$\eta = \left(\frac{\frac{STD\ Counts}{STD\ of\ Det\ time} - \frac{BG\ CPM}{60}}{DPS\ of\ source} \right) \times 100$$

e. Once the instrument is standardized, samples can be analyzed & their activities per unit volume could be estimated. Select 'SAMPLE' mod in the ACQ mode option. Now enter parameters such as preset time, label, sample volume, and iterations before proceeding with acquisition. Press the 'START' button once the sample is loaded. At the end of the preset time, sample counts & activity are automatically computed, displayed, and stored. Activity is calculated in Bq/ml or Bq/$m^{3,}$ depending upon whether the sample is a liquid sample or an air activity sample.

$$Activity\ of\ sample\ in\ Bq/unit\ volume = \left(\frac{\frac{Sample\ \ Counts}{Sample\ Preset\ \ time} - \frac{BG\ CPM}{60} \times 100}{\eta\% \times (volume\ in\ ml)} \right)$$

I. **Field samples for study of gross Alpha activity:** The sample for study may involve

   A. environmental samples (soil/water/wastewater) or

   B. Filter paper wipe sample taken from a radiological facility, work areas of a Nuclear medicine center or Reactor building, or Radiochemical plant, etc., or

   C. Air activity deposited on a filter paper, taken from a continuous air monitor in a Nuclear facility / Radiochemical plant/waste immobilization plant

II. **Efficiency of the detector probe (Alpha probe):** When Nucleonix systems supply an Alpha probe along with RCS for an alpha sample counting application, they typically specify efficiency for the Alpha probe with a particular Alpha standard source. Taking that efficiency as the standard, one can do sample counting & from the counts obtained, interpret/calculate the activity of the sample under study.

III. **Sample preparation:**

A. Usually, samples are to be preferred in advance before they are loaded into the sample holder or sample tray for counting.
B. If it is a water or wastewater sample, approximately one liter of it can be evaporated to obtain a sample in the form of precipitate, which can be deposited on a SS pan & put in a sample tray for counting.
C. If it is a filter paper deposited air activity sample from a Nuclear facility, it can be counted straightaway.
D. If it is a soil sample, it can be ground to the required soil particle size & spread uniformly in the SS pan & put it for counting.

Experiment (1):

Aim Of the Experiment: -

To determine the intrinsic and geometric efficiency of an alpha counting system for a known alpha source.

Objectives

i. To measure counting efficiency using a calibrated alpha source (known activity).
ii. To separate intrinsic detector efficiency from geometric (solid angle) efficiency.
iii. To understand corrections due to source self-absorption and air attenuation.
iv. To estimate uncertainty and minimum detectable activity (MDA) for the setup.
v. To document procedures for routine efficiency calibration.

Apparatus Required: -

1. Radiation counting system RC605A with 12V Adaptor
2. Alpha probe with connecting cable
3. Alpha standard source (Am-241)

Procedure: -

1. Check connections of the Radiation counting system and Alpha probe.
2. Power up the Radiation counting system unit & increase the HV to the operating voltage
3. Check the background counts for a known preset time (say, five minutes.
4. Take the average value of background counts.
5. Put the standard source of known DPS and count for the same time.
6. Take the average value of source counts.
7. By subtracting the BG, we obtain net counts (CPM).
8. Calculate the efficiency using the above formula.

Measurements:

Table 1: Background counts calculation

Sr.No.	Time(sec.)	Bkg Counts	Average BKG	BKG (cps)
1		0		
2		1		
3	300	0	0.4	0.00133
4		0		
5		1		

Table 2: Efficiency Calculation

Source: Am-241 Activity: 4425Bq Date: 13/08/2025

Sr.No.	Time(sec.)	Source Counts	Average Count	Source Count(cps)
1		294917		
2		295135		
3	300	295370	295441	984.80333
4		296286		
5		295497		

Calculations:

The current activity of the source on 30 Apr 2026, is: **4420Bq**

The efficiency of the above formula

$$\eta = \left(\frac{\frac{STD\ Counts}{STD\ of\ Det\ time} - \frac{BG\ CPM}{60}}{DPS\ of\ source} \right) \times 100$$

$$\eta = \frac{(984.8033 - 0.00133)}{4420} \text{ x } 100 = 22.28\ \%$$

Geometric Efficiency

Geometric efficiency depends on the fraction of emitted particles entering the detector.

For a circular detector placed at a distance d from a point source:

$$Eg = \frac{\Omega}{4\pi}$$

where Ω is the solid angle subtended by the detector.

For small detector approximation:

$$\Omega \approx \frac{Area}{d^2}$$

where d is the distance between source and detector.

For a detector of radius r :

$$\varepsilon_g = \frac{1}{2}\left(1 - \frac{d}{\sqrt{d^2+r^2}}\right) = \frac{1}{2}\left(1 - \frac{4}{\sqrt{16\blacksquare+645.16}}\right) = 0.422 = 42.2\%$$

Intrinsic Efficiency:

It represents the probability that an alpha particle incident on the detector produces a count.

Intrinsic efficiency of the detector is :

$$\varepsilon_i = \frac{\varepsilon_{total}}{\varepsilon_g} = \frac{0.223}{0.422} = 0.528 = 52.8\%$$

Air Attenuation Correction

Alpha particles lose energy rapidly in air. For the Am-241 source (Energy = 5.486 MeV), the typical range of alpha particles in air is 3.8 to 4.2 cm.

Taking air range: ~4 cm and source to detector distance = 0.3 cm, the alpha particles travel only about 7.5% of their range before reaching the detector, and air attenuation losses are generally small.

Self-Absorption Correction

If the source layer is thick, some alpha particles are absorbed within the source material.

Corrected activity:

$$A_{eff} = A \times f_s$$

where f_s is the self-absorption correction factor.

For Sealed Am-241 Calibration Sources supplied by a manufacturer, self-absorption has already been accounted for during source calibration, and no additional correction is required.

The self-absorption correction factor f_s~1

Uncertainty in set-up

Efficiency calculation $E = \frac{N-B}{60A} X100$

where N=Standard count rate

B= Background count rate

A= Source activity (DPS)

By uncertainty propagation, the relative combined uncertainty

$$(\frac{u_E}{E})^2 = (\frac{u_{N-B}}{N-B})^2 + (\frac{u_A}{A})^2$$

where uncertainty in N-B, $u_{N-B} = \sqrt{{u_N}^2 + {u_B}^2}$, $u_N = \frac{\sqrt{n_s}}{t_s}$ & $u_B = \frac{\sqrt{n_b}}{t_b}$

Minimum Detectable Activity (MDA)

Using Currie's equation:

$$MDA = \frac{2.71+4.65\sqrt{B}}{\varepsilon \times t}$$

where B=background counts, ε =total efficiency and t=counting time

Here B=0.4 for 300 sec, efficiency=0.22

$MDA = \frac{2.71+4.65\sqrt{0.4}}{0.22\times300}$ =0.085 Bq

Experiment (2):

Aim of the Experiment: -

Calculation of unknown sample gross alpha activity by knowing the efficiency of the Alpha probe with Radiation Counting System.

Apparatus Required: -

(i) Radiation counting system RC605A with 12V Adaptor
(ii) Alpha probe with known efficiency
(iii) Sample (prepared) deposited on a SS planchat or SS pan of unknown activity

Procedure:-

(i) Check connections of the Radiation counting system and Alpha probe.

(ii) Power up the Radiation counting system unit & increase the HV to Alpha probe operating voltage (850V).

(iii) Check the background counts for known preset time (say) 3600 Sec.

(iv) Take the average value of background counts.

(v) Measure 100ml water in a beaker and evaporate it in the oven on 100^{0}C.

(vi) When it remains up to 10ml, transfer the sample in SS planchet by 2ml each time.

(vii) When it dried fully, keep the planchet in the furnace on 400^{0}C for one hour.

(v) Now place the unknown sample whose activity is to be found in the sample holder & acquire counts for the same preset time of 3600 Sec.

(vi) Take the average value of source counts.

(vii) By subtracting the BG, we obtain net counts (CPH).

(viii) Calculate the activity of the sample using known efficiency of the alpha counting system.

Measurements:

Table1: Background counts calculation

Sr.No.	Time(sec.)	Bkg Counts	Average BKG	BKG(cps)
1	3600	14	12	0.0033
2		11		
3		13		
4		10		
5		12		

Table2: Activity Calculation

Source: Unknown sample (Bisleri Water) Activity: Unknown Date: 07/2026

Sr.No.	Time(sec.)	Source Counts	Average Count	Net Counts (Avg Counts-Bkg Counts)	Net Counts/Sec
1	3600	25	22.8	10.8	0.003
2		22			
3		21			
4		24			
5		22			

Activity of the sample = $\frac{Net\ counts/Sec}{Efficiency\ of\ the\ system} = \frac{0.003}{0.2228} = 0.013\ DPS$ (Becquerel)

Result:

The calculated value of the unknown gross alpha activity of the sample is 0.013 Bq.