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M. Sc. 2nd Semester **General Lab – 01**

STUDY THE ABSORPTION OF β-PARTICLE BY USING ALUMNIUM AND COPPER ABSORBER AND ESTIMATE THE END-POINT ENERGY OF THE GIVEN β-SOURCE.

APPARATUS REQUIRED:

1. GM tube and counter
2. Beta source
3. Aluminum plates of different thickness
4. Copper plates of different thickness

THEORY

Strontium-90 is a widely used beta-emitting isotope, commonly employed in industrial applications and as a thermal power source in radioisotope thermoelectric generators (RTGs). These generators convert heat from the radioactive decay of Strontium-90 into electricity using thermocouples. Although Strontium-90 produces less power, has a shorter half-life, and requires more shielding than Plutonium-238, it is significantly cheaper due to its abundance in nuclear waste and ease of chemical extraction. Strontium-90-based RTGs have been utilized to power remote lighthouses.

Strontium-89, another beta emitter with a shorter half-life, is used in palliative care for treating bone tumors in terminal cancer patients. Both isotopes are byproducts of nuclear fission.

In beta decay, the emitted beta particles can have energies ranging from zero up to a maximum value, known as the endpoint energy. This endpoint energy corresponds to the mass difference between the parent and daughter isotopes. On average, beta particles carry less than half the endpoint energy, with the remaining energy carried away by an anti-neutrino (in beta-minus decay) or a neutrino (in beta-plus decay).

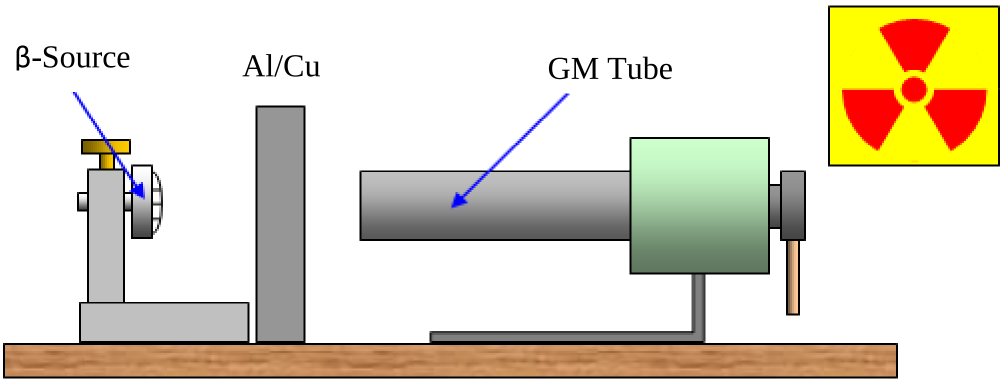

Figure 1: The experimental setup for absorption of β-particle.

The β-decay is a random process. Though it can be studied using laws of radioactivity, which is based on the laws of probability. The intensity of β-particle after passing the thickness 'x' of any absorber material having β-absorption coefficient μ is given by,

$$I = I_0 e^{-\mu x} \tag{1}$$

Here, I_0 is the intensity of β-particle at x = 0. The value of I is proportional to the number of β-particles in the beam which in turn proportional to the number of counts of β-particle per second given by GM counter. If NN_0 and N are the number of counts corresponding to I_0 and I, then,

$$N = N_0 e^{-\mu x} \tag{2}$$

Taking log, we get

$$\ln N = \ln N_0 - \mu x \tag{3}$$

If we make a plot between $\ln N$ versus distance (x), the negative slope of the line gives the absorption coefficient. The maximum range R of the β-particle is determined by extrapolation of absorption curve for zero counting (or up to the level of background). The maximum range is related to the maximum particle energy E by this empirical formula,

$$E = \frac{R + 0.133}{0.542} \tag{4}$$

Where R is measured in gm/cm^2 (thickness × density) and E is in MeV

BEST FIT CALCULATION:

Let $y = \ln N$ and x is the thickness of metal plate, then

$$y = mx + c \tag{5}$$

Represents the best fitted line, where m is the slope and c the intercept.

Taking sum, then above equation takes the form:

$$\sum y = m \sum x + nc \tag{6}$$

Multiplying (5) by $\sum x$ we get,

$$\sum xy = m \sum x^2 + c \sum x \tag{7}$$

Multiplying (6) by $\sum x$ and (6) by n and solving these expressions for the slope (m), we get,

$$m = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2} \tag{8}$$

And intercept (c) is given by,

$$c = \frac{\sum y - m \sum x}{n} \tag{9}$$

OBSERVATIONS

Table 1: Background Count

SN	Counts per 60 sec	Average
1.	107	90.80
2.	50	
3.	110	
4.	98	
5.	89	

So, average count per sec = $\frac{90.80}{60} = 1.51$

a) Absorption by Aluminum

Table 2: Counts of beta particle after placing beta source and different Al plates.

SN	Thickness (x mm)	Counts per 60 seconds					Average count	Average count per second	Background subtracted (N)
1.	1.05	411	352	450	460	398	414.20	6.90	5.39
2.	1.12	364	413	395	350	325	369.40	6.16	4.64
3.	2.17	152	171	165	238	173	179.80	3.00	1.48
4.	3.82	170	156	115	149	120	142.00	2.37	0.85
5.	6.74	103	187	173	105	100	133.60	2.23	0.71
6.	8.7	150	131	153	91	130	131.00	2.18	0.67

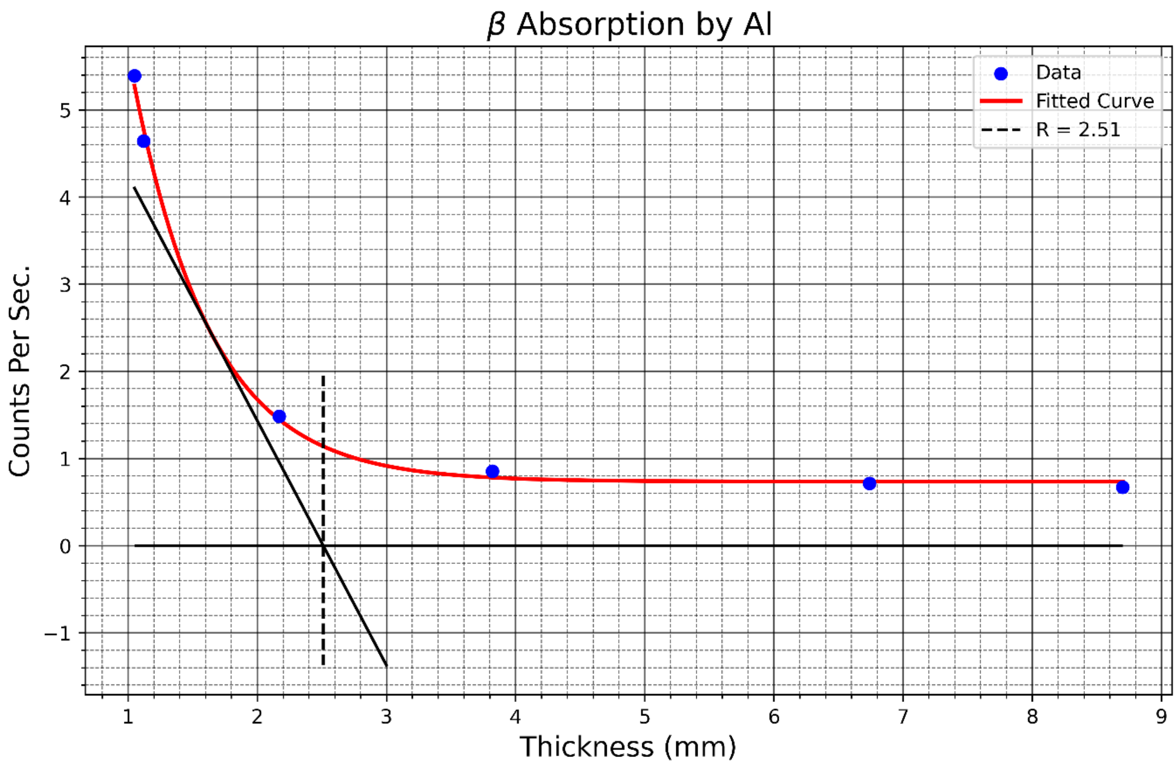

Figure 2: The count rate per sec vs thickness curve for Aluminum.

Table 3: Best fit calculation

SN	Thickness (x)	Background subtracted Count (N)	$y = \ln N$	x^2	xy
1.	1.05	5.39	1.68	1.10	1.77
2.	1.12	4.64	1.53	1.25	1.72
3.	2.17	1.48	0.39	4.71	0.85
4.	3.82	0.85	-0.16	14.59	-0.62
5.	6.74	0.71	-0.34	45.43	-2.31
6.	8.70	0.67	-0.40	75.69	-3.48
	$\sum x = 23.60$		$\sum y = 2.71$	$\sum x^2 = 142.78$	$\sum xy = -2.07$

Calculations of m and c using equation (8) and (9)

We have, $n = 6$

$$\therefore m = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2} = \frac{6 \times (-2.07) - 23.60 \times 2.71}{6 \times 142.78 - (23.60)^2} = -0.25$$

$$\therefore c = \frac{\sum y - m\sum x}{n} = \frac{2.71 - (-0.25) \times 23.60}{6} = 1.45$$

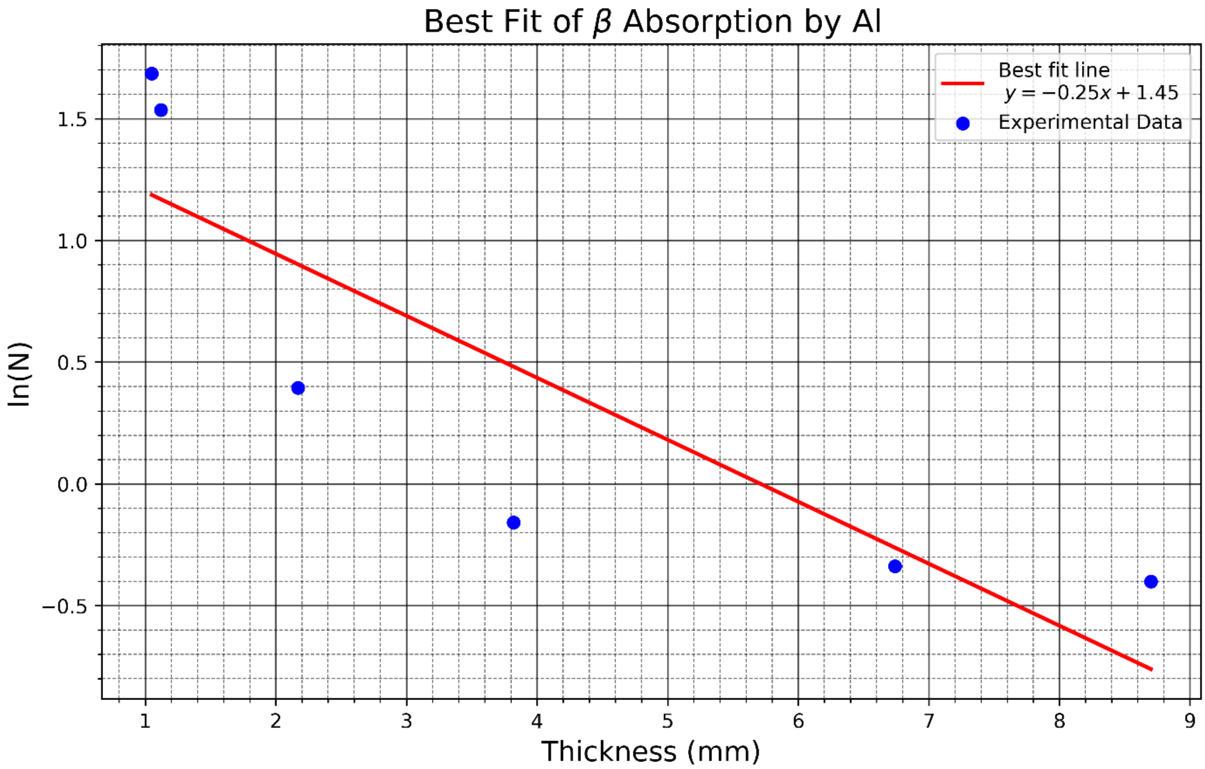

Figure 3: Best fit of ln *of count vs thickness for Aluminum.*

Comparing equation (3) and (5),

Absorption coefficient $(\mu) = -m = 0.25\ mm^{-1}$

And, End point energy $(E) = \frac{R+0.133}{0.542} = \frac{2.51\ + 0.133}{0.542} = \ 4.876\ MeV$

Error Analysis:

Table 4: Table for error analysis.

SN	x	y	$\hat{y}\ = mx + c$	$(x-\bar{x})^2$	$d_i^{\ 2} = (y-\hat{y})^2$
1.	1.05	1.68	1.19	8.3136	0.2471
2.	1.12	1.53	1.17	7.9148	0.1330
3.	2.17	0.39	0.91	3.1093	0.2657
4.	3.82	-0.16	0.50	0.0128	0.4323
5.	6.74	-0.34	-0.24	7.8774	0.0116
6.	8.70	-0.40	-0.73	22.7211	0.1053
	$\sum x = 23.60$			**D=$\sum(x-\bar{x})^2$=49.9491**	$\sum d_i^{\ 2} = 1.1950$

Mean $\bar{x}$ =3.93

The error in slope is, $\Delta m = \sqrt{\left(\frac{\sum d_i^{\ 2}}{n-2}\right) \times \frac{1}{D}} = \sqrt{\frac{1.1950}{6-2} \times \frac{1}{49.9491}} = \pm 0.077\ mm^{-1}$

Hence the error in mass absorption coefficient for β-particle is = $\pm 0.077\ mm^{-1}$

So, the mass absorption coefficient of Aluminum for β-particle is = $(0.25 \pm 0.077)\ mm^{-1}$

b) Absorption by Copper

Table 5: Counts of beta particle after placing beta source and different Cu plates.

SN	Thickness (x mm)	Counts per 60 seconds					Average count	Average count per second	Background subtracted (N)
1.	0.14	470	412	450	393	447	434.40	343.60	5.73
2.	0.4	370	390	360	367	361	369.60	278.80	4.65
3.	0.5	280	310	278	250	260	275.60	184.80	3.08
4.	1.01	170	156	150	149	120	149.00	58.20	0.97
5.	1.15	120	187	150	105	130	138.40	47.60	0.79
6.	2.5	149	105	120	98	110	116.40	25.60	0.43

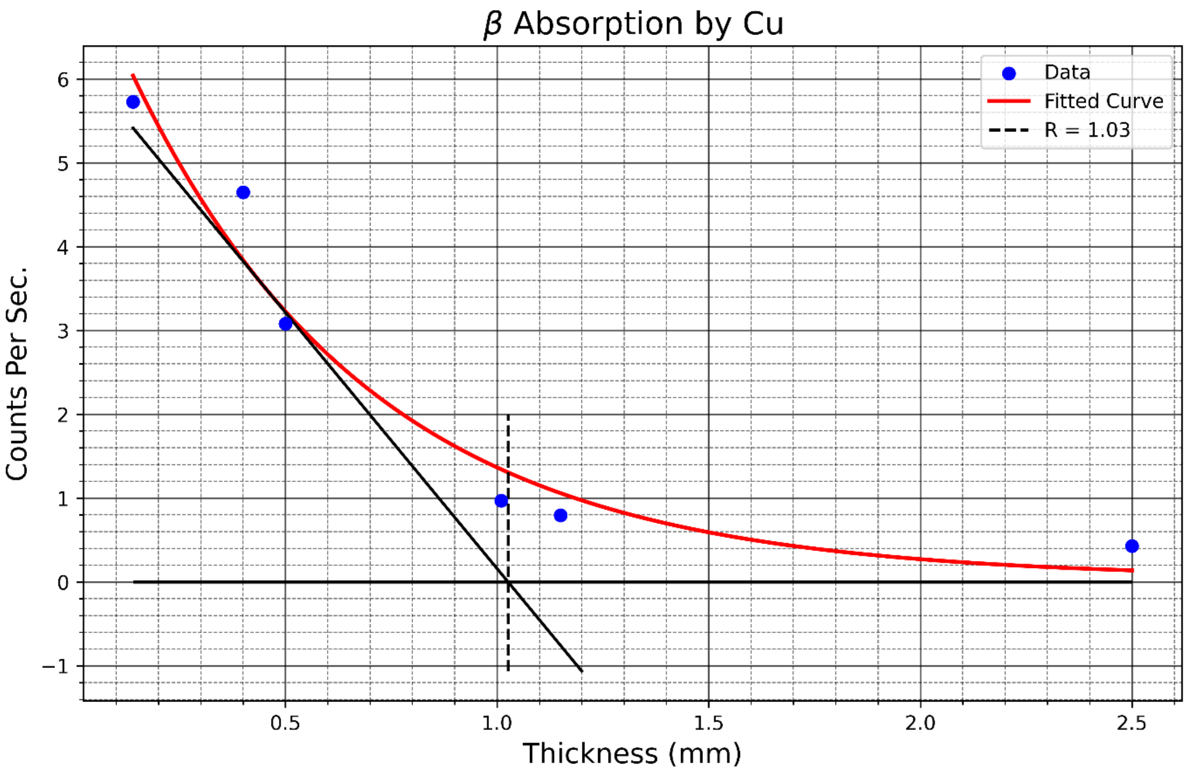

Figure 4: The count rate per sec vs thickness curve for Copper.

Table 6: Best fit calculation

SN	Thickness (x)	Background subtracted Count (N)	$y = \ln N$	x^2	xy
7.	0.14	5.73	1.75	0.02	0.24
8.	0.40	4.65	1.54	0.16	0.61
9.	0.50	3.08	1.12	0.25	0.56
10.	1.01	0.97	-0.03	1.02	-0.03
11.	1.15	0.79	-0.23	1.32	-0.27
12.	2.50	0.43	-0.85	6.25	-2.13
	$\sum x = 5.70$		$\sum y = 3.29$	$\sum x^2 = 9.02$	$\sum xy = -1.01$

Calculations of m and c using equation (8) and (9)

We have, $n = 6$

$$\therefore m = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2} = \frac{6 \times (-1.01) - 5.70 \times 3.29}{6 \times 9.02 - (5.70)^2} = -1.146$$

$$\therefore c = \frac{\sum y - m\sum x}{n} = \frac{3.29 - (-1.146) \times 5.70}{6} = 1.637$$

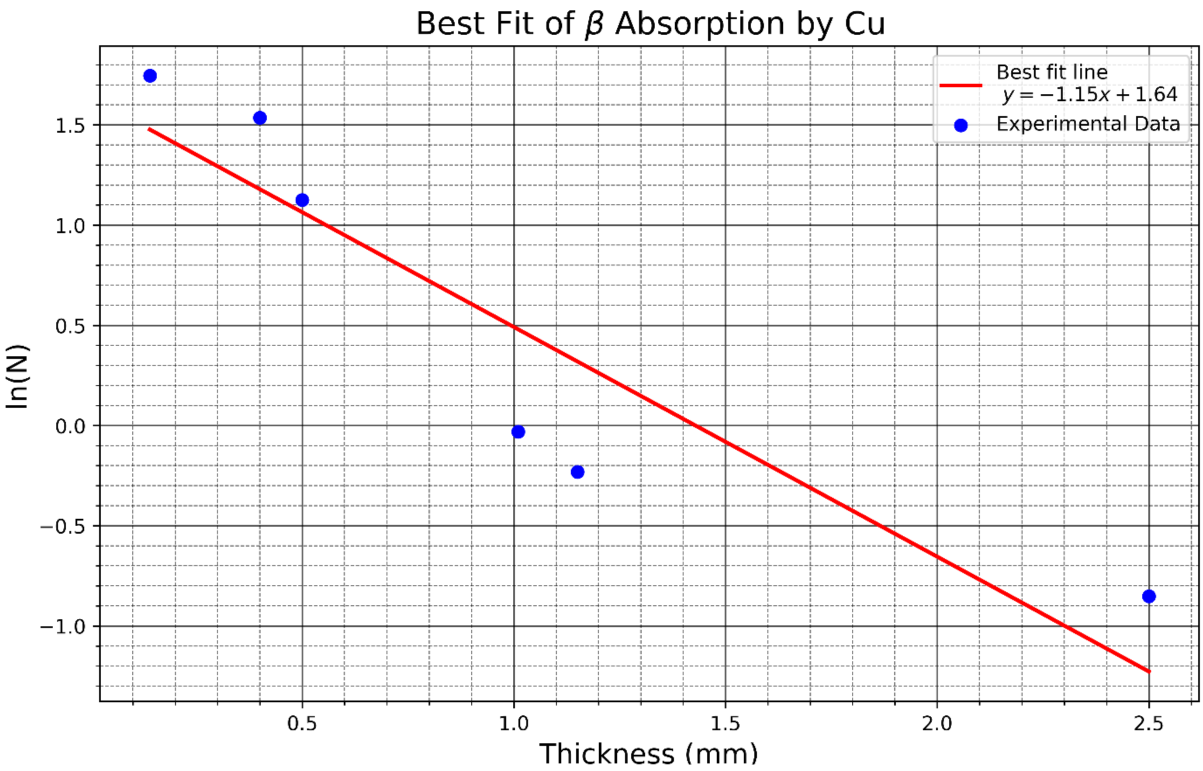

Figure 5: Best fit of ln *of count vs thickness for Copper*.

Comparing equation (3) and (5),

Absorption coefficient $(\mu) = -m = 1.146\ mm^{-1}$

And, End point energy $(E) = \frac{R+0.133}{0.542} = \frac{1.03 \ \ + 0.133}{0.542} = \ 2.146\ MeV$

Error Analysis:

Table 7: Table for error analysis.

SN	x	y	$\hat{y}\ = mx + c$	$(x - \bar{x})^2$	${d_i}^2 = (y - \hat{y})^2$
1.	0.14	1.75	1.48	0.6561	0.0720
2.	0.40	1.54	1.18	0.3025	0.1276
3.	0.50	1.12	1.06	0.2025	0.0037
4.	1.01	-0.03	0.48	0.0036	0.2606
5.	1.15	-0.23	0.32	0.0400	0.3037
6.	2.50	-0.85	-1.23	2.4025	0.1410
	$\sum x = 5.70$			**D**=$\sum(x - \bar{x})^2$=**3.6072**	$\sum {d_i}^2 = 0.9085$

Mean $\bar{x}$ =3.93

The error in slope is, $\Delta m = \sqrt{\left(\frac{\sum {d_i}^2}{n-2}\right) \times \frac{1}{D}} = \sqrt{\frac{0.9085}{6-2} \times \frac{1}{3.6072}} = \pm 0.25\ mm^{-1}$

Hence the error in mass absorption coefficient for β-particle is = $\pm 0.25\ mm^{-1}$

So, the mass absorption coefficient of Copper for β-particle is = $(1.146 \pm 0.25)\ mm^{-1}$.

RESULT

1. It is found that the absorption coefficient for beta -particles emitted from the given source in the **Aluminum** absorber is $(\mathbf{0.25} \pm \mathbf{0.077})\ \boldsymbol{mm^{-1}}$. And the end point energy of beta-particle is found to be **4.876 MeV**.
2. It is found that the absorption coefficient for beta -particles emitted from the given source in the **Copper** absorber of is $(\mathbf{1.146} \pm \mathbf{0.25})\ \boldsymbol{mm^{-1}}$. And the end point energy of b-particle is found to be **2.146 MeV**.

INTEPRETATION OF RESULT

1. This value indicates how quickly the intensity of β-particles is reduced as they pass through aluminum. A lower absorption coefficient suggests that aluminum provides moderate resistance to β-particle penetration.
2. The absorption coefficient of cupper is significantly higher than in aluminum, showing that copper is a more effective material for stopping or attenuating β -particles due to its higher density and atomic number. These factors increase the likelihood of interactions between β -particles and the absorber material.

PRECAUTION

1. **Use Proper Shielding:** Ensure appropriate shielding materials (e.g., lead blocks) are used to minimize radiation exposure.
2. **Wear Protective Gear:** Use radiation badges, gloves, and lab coats to monitor and reduce exposure risks.
3. **Calibrate the Detector:** Calibrate the radiation detector before starting the experiment for accurate measurements.
4. **Handle Source Safely:** Use tools like tongs to handle the radioactive source and store it securely in a lead container when not in use.
5. **Repeat Measurements:** Perform multiple trials to account for random errors and ensure reliable results.

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