PRNC024

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PUERTO RICO NUCLEAR CENTER

Simple Experiments

that can be done with a

NEUTRON SOURCE

J OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT

NO, AT (401-1839 FOR U. $. ATOMIC ENERGY COMMISSION

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Students Method for Determining

the Binding Energy of the Deuteron

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NEUTRON cptare ganna rays wore fst

observed by Lea? who appecirs to have

detocted the yuna ray prodaed by the capture

?of neutrons in hydroyen wing Re-Be newton

source and a Geiger counter ae ralintion detector

?The experiment suffered from the disadvantage

?of using a very weak teutros soured fey

insensitive radiation detecting device. However,

?more recently, Pringle? studied capture gamma

rays witha weak Ra-Be neutron source and used

?scrytal a more see

tive detector

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reactor. The reported val wan 2.23 Mey for the

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experiments in cute pyre using Pode

?euro source sd comer waite a

struments have brew develop ae putt of

sexjuenee of experianets constituting «nucle

and reactor physics laboratory. Messurig the

Dining energy of the deuteron is ome of the

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simple experiments, The procedure and mature

of the resulting data will be discussed

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stituents and Une mau of the bourd syste Ths

?the binding cengy of the deuteron fe

BON) = M0) 44,00),

where Af refers to the atomic ret masses ofthe

The Divine energy of te deuteron ean be

detcemined experinwstlly by the mesurement

of the energy of the santa rays which ane

?mitted when thermal neutrons are captured by

hydrogen. This is pouble store the

ergy approximately equals the

The validity of d

?The Q value ofthe nuckur mation it given by

Om sib ACH) ?ana) ? ay

C= Pot TAP)-Tw)?Ta, ?(s)

where 1 refers to the energy of the puticlen

Notice that the righthand! side of Fas (1) and

(2) are the sume. This cans that the binding

vengy ofthe deuteron ical tothe @ value of

the rection That,

Bu) =@, ®

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crey of the slow neutrons snd the ners of

exketes with repeet to the energy of

the emitted ganninsray photon, fellows font

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Droxintely equal 10 the energy of the photon

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EXPERIMENT AND RESULTS

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eutrons are moderated tm thermal eneryien
When the nestronsare thas therm they can
?be capture by 1 with the emission ofa yarn,
?ay photon. The yasinis ray interacts ith the
Nal scintillator ana ite energy roel by the

Figure 2 shows the tw xanma rays of 1.37
Mey anal 2.76 Mev frm Ni Ta teh athe
binding enengy of HT Tes bctween the two, Nab
sami pra it was did! to use this rad.
Sotope to calibrate the spectrometer. The Nat?
(Nas prepared at the PLRUN.C. Swimming Poot
Research Reactor

Figure 3 shows & superposition of ganm-ray
Steet from Nu® an the neutron source
water. The gin of the spectrometer wan varied
at about 2.8 Mev during the menaurement of the
Nat apcctrum. The energy ofthe deuteron peak
was found by interpolation betwoen the Net
gamma peaks. The experimental value of the
binding energy of Hse determined was, 221
Mev,

?The current beat value forthe binding energy

?of the deuteron which has evolved front s ase

pilation of mass measurements and reaction dere

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Figure 4 ilastrates the gamma spectra of the

Neutron source in ait, water and patafien The

?et en

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Dosition ofthe H* peak which is acen

?Parafinis characteristic of hydrogen

matter,

water and

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coretusions:

?This experiment has been a valuable teaching

fool nour nacksrand reactor physics laoraory

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(1) The stent can ealeua

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from the defi

e binding energy

nen verify ther eacolation caper

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acquaint the student with the theory aed oper:

ation of ganniemny spectrometer,

{@) 1c demonsirates that an intense beam of

thermal neutrons ia not meesity to. male

fairly accurate determination of he Binding energy off

?ACKNOWLEDGMENTS:

?The writer wishes to tnawk Dr.

ddovar for his cuoperation, encouragement, sod

interest uring the preparation of the experiment

and Mian Elisa Trabl for peering the earples

of Nat

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- An Inelastic Neutron ?Scattering Experiment*

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- (Received May 14, 1962)

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TERE Garcon 0900 ag, where Mf and m are the mass

RETESET fhe mn, ae a oa mas of he a

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INELASTIC NEUTRON SCATTERING

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i. 1. Neato neta seating teraction,

feneral, the intial Kinetic energy 7 of the in sing neutron is larger than Ta, the kinetic

?nergy of the seattered neutron 7: given by

TTB, o

Ifthe suclear mass is very lange

Fe has been found that for neutron energies,

excess of 1 MeV, the inelastic seatierng

Section approaches the geometrical cross section

that is eiamoeR?, where His the raise of the

nucleus. Since the radi of atomic mice, except

for very low mass number can he eptesetel

ReLAX10- AV em, where inthe macs hun

ber of the nucleus, the inelastic scattering cose

section may be represented approximately by

640.062 A barns,

o

{follows from the above equation that inorder

?tw have a large inelastic scattering creme cecton

?nucle should have a moderate or high mass whumber,

EXPERIMENT AND RESULTS

?The experimental arrangement for the gamma ?ay measurements is one which employs a rg eomvetry an illustrated Fig. 2. The iron Seatterer which is of the form of an annulus surrounding a sodium iodide crystal, received the neutrons emitted at a small angle from the peutron source. A cone made of para with a base having ?borat? dik is ust to abl the 2ysal from direct impact by thermal neutrons ?The erystal and the photoralplier are mounted in a thin wooden container to shield them from Tight. The neutron source is placed at about $i

from the izon ring. The ring dimensions are approximately 2 in. id. and 4in, od. A aliding Window spectrometer is used to record. the gamma-ray photon energy emitted from the ?cited state of Fe which is produced during the bombardment of iron with fast neutrons, Figure 3 shows the energy distribution space ?um froma Pu-Be neutron source The fact that the source is very rch i fat neutrons made ie

use possible in the inelastic scattering experi

Figure 4 shows the respouse of the crystal

spectrometer with the iron ring peesent and with

O°

Pre2. peel stop,

i Sewict,P Re. 8, 740 (985),

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EDDIE ORTIZ

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the iron fing removed. Iron was used a the

scatterer because Fe? produces a very intense

{fama line at about 0.84 MeV. This was very

any to detect with the simple experimental

Setup ured. Both spectra show a visible peak at

bout 0 MeV due to inelastic sattering in the

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io, 4, Garuma apeciza of eo ad neutron cure in,

awe owt» woh

Fo, ow distribution of Pye euro re,

Nal erystal. The calibration ofthe spectrometer

was performed. according t0 the instruction

?manval using a C3? eource.

concunsions

?This simple expeciment has been a. valuable

teaching tool in our classes for the folowing

(1) After a bre! introduction to the element-

ary theory of inelastic scattering, the student

ble to perform aa experiment and to determine

the energy of the intense gazuma peak fom Fet*

at OB MeV.

{@) The sadent becomes acquainted with the

theory and operation ofa gammacray spectrom

(G) Te demonstrates that at least one of the

lines from the inelastic scattering spectrum of

ion can be determined fatty accurately with a

?Pu-Be neutron source.

ACKNOWLEDGMENT

?The writer wishes to express hi. sincere

appreciation to the physics major student

?Mr. Angel Hermida for his cooperation in the

preparation of the experimental setup and for

?runing the spectra.

---Page Break---

A Versatile Experiment Using # Neutron Source and @ Tank of Water

Eddie Orete

Puerto Rico Nuclear Center,® College of agriculture and Mechante Arts

Mayaguez, Puerto Rico

Purposes:

a- To determine the optinua water depth for neutron moderation.

bo To show the effect of neutron reflection in water.

ce To obtain the distribution of thermil neutrons in water.

etRopucTION

The experiment described below was worked out in the course of Te Search undertaken by two graduate students at this College for their master's thesis. 5. Pinto Vega, from Coloabia, was working on the Geteraination of the optimum thick ness of paraffin for the neutron balance between moderation and cap. ture in order to incorporate the data in the design of * high-energy neutron conversion device. Hs Plaza, from Puerto Rico, vas trying to mea sure the neutron elbedo in water. Since the results were highly inter~ esting in both cases, it vas decided to modify the experimental set-up

and prepare it for two further exper- ieents in the Nuclear and Reactor Physics Laboratory. The nev experi- ments were designed to establish the Precise water depth required for neu tron aoderation and also the body of water vhich would be equivalent to an infinite reflector. Furthermore, the

data obtained in this experiment can

also be used to show the distribution

of thermal neutrons in water.

EQUIPMENT aD PROCEDURE

?The experimental set-up ie shown

in Fig, 1, A neutron source is ce

tered at the bottom of a 43Mx43"x51"

stainless steel tanks A 1/2" dia.

and 4" active Length BF3 counter is

?established by the U. S, Atomic
Energy Connission as part of the
University of Puerto Rico.

coupled to an alustnua tube by an Lathapod plastic tube and sealed to secure wateracight fering. The ?aluctnua tube 1s supported by hort= rontal bare at the top of the tank and the detector unit can be raised or lowered along a vertical Line Bove the sources With the detector ata fixed distance d from the bot= tom of the tank, the water level 1s increased at 1" intervals and the count rate C recorded st each Level ?until the water is about 10" above the detector. The respective levels are measured by a calfbrated water manometer. If the count rate ia plotted against the water level Hy

5 curve 18 obtained for the Fixed position of the detector. after emptying the tank by means of

pomp, the procedure can be repeated

by varying d oo as to obtain « faa~

ily of curves with das a paraneter,

as shown in Fig. 2.

DNTERPRETATION OP RESULTS

The nature of the experimental

curves my be explained qualitative

ly by taking a particular curve, dtviding {t Into three regions, and

considering its course. Fig. 3 shows the three regions: (1) Slowing-down, (2) Absorption and (3) Reflection.

Regions (1) and (2) are sintlar to those obtained ia a tranenteston experiment when the thickness of the aaterial between detector and source is varied, In order to explain re~

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gion (1) the following factors must

be taken into consideration: The

Puche neutron source omite fast neu

Exons; the count race of the FF; de=

Lector 1s cnergy-dapentent becarse

BIO is @ L/v absorber; neutron energy

is degraded by elastic collision and

Beonetrical effects may be neglect:

As the water Level rists, the en

exgy spectrum of the neutrons escape

ing toward che detector will vary,

depending on the number of collie

Sions with TI nuclei, and the neutrons

within the energy threshold of the

detector will be counted. hith fare

ther rises in the water level, the

neutrons escaping townsd the detect

or becone practically thermal and

consequently the count rate will in=

crease. When 2 water Level 1

Feached at which the neutrons are

thermalized, however, the curve

starts bending toward a masinum due

to absorption. At point B, where

there is = state of balance between

moderation and capture, the saxiaum

couNE Fate fs obtained: Curve Ab is

called the slowing~down curves

Since at My thermilization ts at

its opcimun, Faising the water level

Deyond ehis?potne vill increase neue

Exon absorption with * consequent

decrease in the number of thermal

neutrons escaping toward the detects

or. Curve BC is a typical attenuae

fon curve due to neutron absorptions

At water Level fic, backeseatter of

neutrons to the detector will beginy

while some neutrons will escape at be

absorbed. Consequent rises tn the

water level will increase the neutron

count, due. to collision and reflection

until a steady rate is obtained.

Gurve ODE represents the reflection

or backeseatter region.

At this stage of the caperinent,

Purposes (a) and (b) have been sceome

plished, vize:

= The optiqua water depth for

neutron thermalization {s about

5, independently of the position

of the detuctor.

be AE a Level higher than 4" a=

dove the detector, the count rate

Yenains constant; accordingly,

this level can be considered equiv

alent to an infinite amount of wi

ter stove the detector-

Im order to accomplish purpose (c)

of the experinent, the date from Fig. 2 can be replotted to show the relax tionship between G and d, H being kept constane. IE this is done for zd #4, the relationship between he count "rate and the distance of the detector from the botton for « Filled tank of infinite size 1s ob- tained. ?If r te the distance from the source to the detector, ve find that Fe d?2 since the source is 2? bighs If a soml-log plot of Gr? a= gainst r 1s aade, results similar co those shown in Fig. 4 are obtained, Here the curve represents the distri bution of thermal neutrons in water. Since if x tg large the curve fo a straight Line, this relationship can be expressed by the function

OL (az)

where A is che attenuation Length. From the eafolding value of the count vate, an attenuation Lengeh of 4.4" ie obtained, ow ~ r/Q

coxcuustos

?The above experiment {3 of grest

practical value for the following

after an introductton to the

theory of the neutron sloving-

own and reflection properties

of aoderating media, the stu

dent should perform the experi

ment $0 as to determine that the

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?optimum depth of water for neu
tron thermalization ig about 5",
and that 4M of water are equiva
Lent to an infinite body of water
above the detector, Also, the
student will de mde to realize
that the reason why the critical
ass of a reactor can be reduced
by surrounding the reactor core
with 2 roflector ts the con
Sequent decrease in the proba
bility of neutron leakage.

From the themaal distribution of
neutrons in water, the student
WGLL establish thie starting at
6" from the source, the attenua~
tion length is 4.4, This aspect
of the experiment 1s very impor
tant in connection with thermal
neutron shielding design.

The simplicity and relatively low

cost of the equipment needed makes

the experinent feasible in any

laboratory possessing 2 neutron

source and nestron counting

accessories, that {s to say, it

can be carried out in practically

any modern physics laboratory at

College oF University level.

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FIG.

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2 3

~ wd

FIG.4

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