

---

# CROSS SECTION

---

AN INTRODUCTION TO NUCLEAR AND PARTICLE PHYSICS  
SCATTERING EXPERIMENTS

Hannah Michelle Ellis

April 2, 2020



# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Scattering Experiment . . . . .	1
1.1.1	Experimental Setup . . . . .	1
1.1.2	cross section . . . . .	2
<b>A</b>	<b>Notation</b>	<b>3</b>



# List of Tables

A.1	Notation used in this book . . . . .	3
-----	--------------------------------------	---



# List of Figures

- 1.1 Typical scattering experiment setup. A target with a beam of particles incident on it. 1





# Chapter 1

## Introduction

### 1.1 Scattering Experiment

Here we will look into scattering cross sections and how they relate to scattering experiments.

#### 1.1.1 Experimental Setup

A typical experiment usually involves a beam of particles which is incident on some sort of target material as shown in figure 1.1.

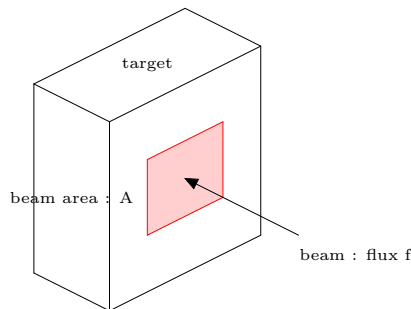


Figure 1.1: Typical scattering experiment setup. A target with a beam of particles incident on it.

#### The Target

The target material will have  $n'''$  target particles per unit volume. If the target material is of some known composition<sup>1</sup> then we can calculate the number of particles per unit mass of the target material.

$$\tilde{n} = \frac{N_A}{\tilde{m}} \quad (1.1.1)$$

where  $\tilde{m}$  is the mass of a mole of the target material and  $N_A$  is the Avogadro constant, which is the number of particles per mole<sup>2</sup>.

---

<sup>1</sup>Either elemental or some known substance

<sup>2</sup>In the notation used in this book, we should really use the symbol  $\tilde{n}$  as this is the number of particles per mole of substance. However due to this being a constant with an already agreed upon symbol, namely  $N_A$ , we shall stick to using that here.

An Example: Consider a target made of pure  $^{265}_{92}\text{U}$ . The mass per mole is just the atomic weight or  $\tilde{m} = 265 \times 10^{-3} \text{kg}$ . So to calculate the number of particles per unit mass we just divide  $N_A$  by the atomic weight. In this case  $\tilde{n} = \frac{N_A}{\tilde{m}} = \frac{6.02214076 \times 10^{23}}{265 \times 10^{-3}} \text{kg}^{-1} = 2.272505947 \times 10^{24} \text{kg}^{-1}$

This can be linked to the density of the target material by

$$\text{density} = \rho = m''' = \frac{n'''}{\tilde{n}} \quad (1.1.2)$$

Note that in equation -refeq:density we have used the standard symbol  $\rho$  for density. Included is the notation used by this text also. It is more typical to use the density of the material to calculate the number density by multiplying the density and the specific number together.

Example Continued : The density of  $^{265}_{92}\text{U}$  is  $1.91 \times 10^4 \text{kg.m}^{-3}$ , using this we can calculate the number density of our target.  $n''' = \rho \tilde{n} = 1.91 \times 10^4 \text{kg.m}^{-3} \times 2.272505947 \times 10^{24} \text{kg}^{-1} = 4.340486359 \times 10^{28} \text{m}^{-3}$

## The Beam

The beam will typically have a known flux,  $f$  or using the book notation  $\dot{n}''$  per unit area per unit time. If the area does not come into play, then the beam rate might be given instead.

### 1.1.2 cross section

The cross section for the whole target is given by

$$\text{cross section} = \frac{\text{rate}}{\text{flux}} \quad (1.1.3)$$

As you can see, it is a fairly common poke factor type equation. ie, something we can measure (here the rate of a particular interaction) is given by some poke factor times by something we can control (here the beam flux) and we poke the system with the thing we can control. So as you can see, if we double the beam flux then the rate will also double as a response.

An Example: Sticking with our Uranium target from previous examples. If we have a beam of neutrons with a flux of  $10^6 \text{m}^{-2}.\text{s}^{-1}$  incident on the target which results in  $10^2$  fission events per second, we have a cross section of  $\sigma = \frac{\text{rate}}{\text{flux}} = \frac{100 \text{s}^{-1}}{1000000 \text{m}^{-2}.\text{s}^{-1}} = 10^{-4} \text{m}^2 = 1 \text{cm}^2$

When we talk about cross section normally though, we are more concerned with the cross section per target particle  $\bar{\sigma}$ . Unless the target is a single atom thick, we have to consider the attenuation of the beam through the target material.

# Appendix A

## Notation

Due to having many material properties used in calculations, it is useful to be able to track the type of property the symbol represents. To aid in keeping track the following notation (unless stated otherwise) will be used throughout this text. In the case of space and time based

Quantity	Description	Example
Specific quantity or a quantity per unit mass	Tilde above symbol	$\tilde{n}$
Quantity per unit length	Dash following symbol	$a'$
Quantity per unit area	Double dash following symbol	$a''$
Quantity per unit volume	Triple dash following symbol	$a'''$
Quantity per particle	Bar above symbol	$\bar{a}$
Quantity per mole	Check above symbol	$\check{a}$
Quantity per unit time	Dot above the symbol	$\dot{a}$

Table A.1: Notation used in this book

symbols, you might see two used together to represent a quantity that is both spread through the material as well as through time. For example the flux of particles in a beam would be denoted as  $\dot{n}''$  as it is the number of particles per unit area per unit time.