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PHYSICAL PROPERTIES OF NEUTRONS

Neutrons are one of the fundamental building blocks of matter, making up roughly 50% by weight of all material. Only when they are released from atomic nuclei do they constitute a hazardous form of radiation, and there are only two processes that can achieve this separation and produce ‘free’ neutrons: a nuclear reaction and spontaneous fission.

Free neutrons are unstable and have a lifetime of 886 s, decaying by emitting an electron and an antineutrino to become a proton. Neutrons have a magnetic moment, and although quite small, it has a value. Represented by the symbol $_{\mu n}$, its value is $-0.96623640 \times 10^{-26}$ J·T^{-1}, which is approximately 1/1000th of the electron magnetic moment. So, although the neutron is usually thought of as a particle without charge that interacts as though it were a billiard ball, it can be seen that neutrons are more complex entities.

The neutron has a spin of 1/2, and the mass of the neutron is 1.675×10^{-27} kg, which is slightly larger than that of the proton. Neutrons are present in every atomic nucleus with the exception of hydrogen (^{1} H). Neutrons can interact by means of the four common forces: strong nuclear, weak nuclear, electromagnetic (because of their magnetic moment) and gravitational.

Neutrons may be generated by a number of processes, including photoneutron reactions, wherein a high energy gamma ray incident on a high Z target generates neutrons; charged particle interactions, such as a proton impinging on a tritium target; or spontaneous fission in heavy elements. Generally, neutrons are produced with high energies at least above 10 keV, and potentially above 10 MeV, and these fast neutrons are slowed by collisions in matter. These collisions may be elastic, inelastic or non-elastic, and only a small amount of energy may be lost in each collision, and so it will take many collisions to reduce the neutron energy to a low value. Eventually the neutrons will slow to the point where they come to be in thermal equilibrium with the medium through which they are passing, and their distribution of velocities will have a most probable value at 20°C of 2200 m·s^{-1}, which corresponds to a neutron energy of 0.0253 eV. Generally, neutrons whose energies are below the sharp drop in the absorption cross-section in cadmium at ~0.4 eV are referred to as thermal neutrons.

When neutrons interact with matter, they undergo a number of collisions with atoms and may be considered to be acting like gas molecules that eventually come into thermal equilibrium with their surroundings. In order to evaluate the most probable distribution of neutron velocities after they have come to equilibrium, a Maxwellian distribution can be assumed.

The kinetic energy distribution of neutrons in thermal equilibrium with their surroundings at temperature T (K) may be written as

$$\frac{n(E)dE}{n} = 2/\sqrt{\pi}\sqrt{\frac{E}{kT}}\exp\left(\frac{E}{kT}\right)d\left(\frac{E}{kT}\right) \quad (1)$$

where n is the total number of neutrons in the system, n(E) is the number of neutrons of energy E per unit energy interval in the range from E to E + dE and k is the Boltzmann constant.

Thermal neutron distributions approximate to a Maxwell–Boltzmann function and can be represented in several different ways. Figure 1 shows thermal distributions in terms of neutron density, n(E), fluence rate, Φ(E), and velocity, n(v). The reference speed, v0, in this case is 2200 $m \cdot s^{-1}$, and the reference energy, kT, is 0.0253 eV.

Relationships among neutron velocity, temperature and energy can be given by

$$T = 1.159 \cdot 10^4 E \quad (2)$$

$$v = 13.83 \cdot \sqrt{E} \quad (3)$$

where E is in eV, v is in km·s–1 and T is in K [2]. Because neutron energies span such a large range, a historical precedent has been established to refer to various energy regions with descriptive terms. There is no general agreement as to the exact energies specified by the following neutron energy classification that is generally used, but the approximate values shown in Table 1 for each region can be assumed.

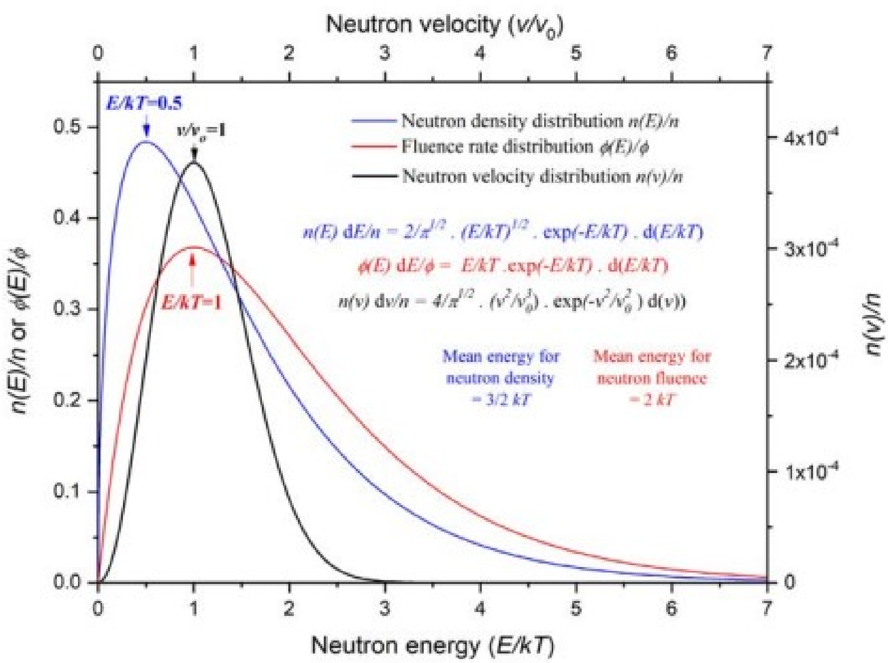

Fig. 1. The thermal Maxwell–Boltzmann distributions in energy, fluence and velocity.

Table 1

Names of neutron energy regions

Name of neutron energy region	Approximate energy range
High energy (or relativistic)	> 10 MeV
Fast	10 keV to 10 MeV
Intermediate	100 eV to 10 keV
Slow	< 1 eV
Epithermal[a]	0.025 to 1 eV
Thermal[b]	0.025 eV
Cold	5×10^{-5} eV to 0.025 eV

Courtesy of National Physical Laboratory.

[a] The epithermal region is sometimes considered to be above the cadmium cut-off energy at 0.4–0.5 eV, corresponding to the energy at which a sharp decrease in the cadmium cross-section occurs.

[b] At 20°C, the peak of the thermal neutron fluence distribution occurs at an energy of 0.0253 eV. The upper bound of the energy of thermal neutrons is sometimes given the cadmium cut-off energy.

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INFLUENCE OF HUMANITY ON NATURE

In the conditions of scientific and technological progress, the relationship between society and nature has become much more complicated. Man got the opportunity to influence the course of natural processes, conquered the forces of nature, began to master almost all available renewable and non-renewable natural resources, but at the same time pollute and destroy the environment. Human intervention in natural processes is increasing sharply and can cause a change in the regime of soil and underground water in entire regions, surface runoff, soil structure, intensification of erosion processes, activation of geochemical and chemical processes in the atmosphere, hydrosphere and lithosphere, changes in microclimate, etc.

Stages of changes in the biosphere by humanity, which culminated in environmental crises and revolutions, namely:

- the impact of humanity on the biosphere as a normal biological species;
- over-intensive hunting without ecosystem changes during the period of human development;
- changes in ecosystems as a result of processes that occur naturally: grazing, increased grass growth by burning, etc.;
- intensification of the impact on nature through soil plowing and deforestation;
- global changes of all ecological components of the biosphere as a whole.

Human influence on the biosphere can be reduced to four main forms:

- change in the structure of the earth's surface,
- a change in the composition of the biosphere, the circulation and balance of the substances that make it up,
- a change in the energy, in particular thermal, balance of individual regions of the globe and the entire planet,
- changes made to the biota as a result of the destruction of some species, the destruction of their natural habitats, the creation of new breeds of animals and varieties of plants, their relocation to new habitats, etc. [1]

According to a 2018 study in Nature, 87% of the oceans and 77% of land (excluding Antarctica) have been altered by anthropogenic activity, and 23% of the planet's landmass remains as wilderness. [2]

The concept of pollution. Classification of environmental pollution.

Environmental pollution means the entry into the biosphere of any solid, liquid, or gaseous substances or types of energy (heat, sound, radioactivity, etc.) in quantities that have a harmful effect on humans, animals, and plants, both directly and indirectly by. Directly, the objects of pollution (acceptors of polluted substances) are the main components of the ecotope (place of existence of the biotic community): - atmosphere, - water, - soil. [3]