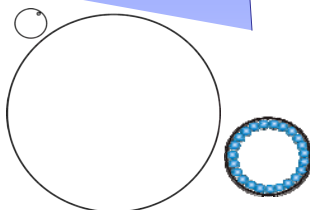


# Mean kinetic energy of liquid helium systems

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**Fig. 1:** On the right, illustration of the He atoms (blue spheres), adsorbed on the pore surface. On the left, illustration of the two pores and the He atom, to scale.

**Eq. 1:** In this model the mean kinetic energy is the sum of the contributions of the atoms close to the surface (solid-like) and the atoms in the inner part of the pore (liquid-like).

$N_l$ : number of atoms in the liquid-like layer

$N_s$ : number of atoms in the solid-like layer

$N_{tot}$ : total number of atoms

$f = N_l / N_{tot}$

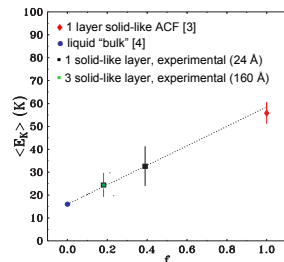
$\langle E_K \rangle_l$ : mean kinetic energy of the atoms in the liquid-like layers

$\langle E_K \rangle_s$ : mean kinetic energy of the atoms in the solid-like layers

$$\text{Eq. 1: } \langle E_K \rangle = \frac{N_l \langle E_K \rangle_l + N_s \langle E_K \rangle_s}{N_{tot}} = (1-f) \langle E_K \rangle_l + f \langle E_K \rangle_s$$

In the case of <sup>4</sup>He in porous matrices (Xerogel powders with mean pore diameters of 24 Å and 160 Å), helium atoms have a  $\langle E_K \rangle$  higher than the bulk value in the same conditions (T=2.5 K and saturated vapor pressure, Tab. I). The results are interpreted in terms of a model (Eq. 1) where <sup>4</sup>He atoms are arranged in concentric annuli along the cylindrical pore axis (Fig. 1), with the  $\langle E_K \rangle$  mainly dependent on the ratio between the atomic diameter and the pore diameter. In the case of the pore of 24 Å diameter, the experimental  $\langle E_K \rangle$  is well reproduced by assuming the first layer to be solid-like with all other inner layers in the liquid phase [1]. The  $\langle E_K \rangle$  extrapolated value of the first layer is 58.5 K. For the pore of 160 Å diameter the result is interpreted in term of three solid-like layers [2].

## <sup>4</sup>He in nanoporous systems

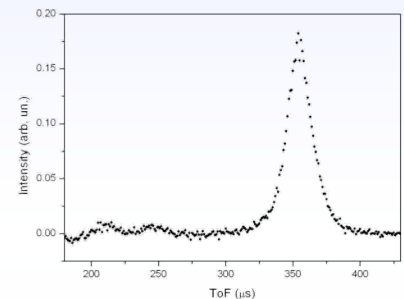


**Fig. 2:**  $\langle E_K \rangle$  dependence on the fraction  $f$ . Blue circle: bulk value; green square: exp. value for the 160 Å pore; black square: exp. value for the 24 Å pore; red diamond: slit geometry [3].

**Tab. I:**  $\langle E_K \rangle$  experimental results for the two samples with mean diameter pore of 24 Å and 160 Å, compared with the bulk liquid value [4].

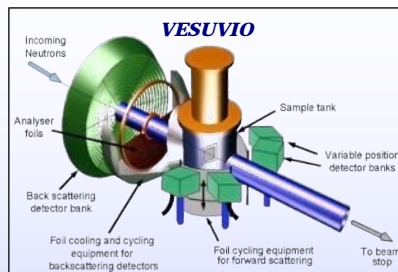
Sample	$\langle E_K \rangle$ (K)
"bulk"	16.2 ± 0.4
160 Å	24.4 ± 5.3 K
24 Å	32.6 ± 8.7 K

In this work we present the study of the single-particle dynamics of liquid helium in two systems where disorder is added: a stitistic disorder (provided by isotopic mixtures) and a spatial disorder (<sup>4</sup>He in nanometric porous systems). In both cases the microscopic dynamics is influenced by the disorder, showing a change in the mean kinetic energy value,  $\langle E_K \rangle$ , of the helium atoms.



**Fig. 4:** Example of Time of Flight spectrum obtained by means of VESUVIO spectrometer. In this case the three peaks correspond to the <sup>3</sup>He, <sup>4</sup>He and Al scattering contribution respectively (from left to right).

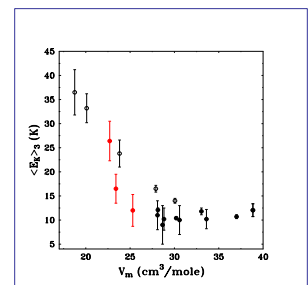
## Deep Inelastic Neutron Scattering



**Fig. 3:** Picture of the VESUVIO spectrometer (ISIS pulsed neutron source - UK), used for the studies of the liquid helium dynamics.

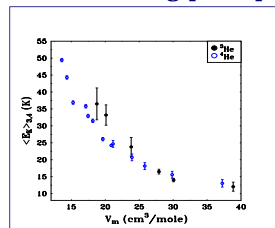
**Fig. 7:**  $\langle E_K \rangle$  as function of the molar volume for pure <sup>3</sup>He (open circles) and for <sup>3</sup>He in <sup>3</sup>He-<sup>4</sup>He mixture (full circles). The red full circles are the results of the presented work.

$V_m$ (cm <sup>3</sup> /mol)	$\langle E_K \rangle$ (K)
25.3	12 ± 3
23.4	16.5 ± 3.0
22.7	26.4 ± 4.1

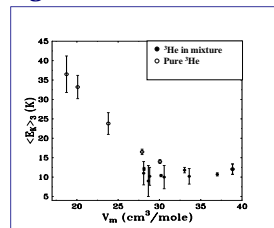


## <sup>3</sup>He-<sup>4</sup>He mixtures

Previous experiments showed that in pure fluids, the mean kinetic energy of <sup>3</sup>He and <sup>4</sup>He are remarkably dependent on the molar volume, as expected from the Heisenberg principle (Fig. 5) [5-6-7-8]. On the other hand, the  $\langle E_K \rangle$  of the <sup>3</sup>He, when in mixture, seems to be independent of the molar volume (Fig. 6), for  $V_m > 28$  cm<sup>3</sup>/mol [9-10-11-12]. Thus we have performed new measurements to extend the range of investigated molar volumes down to the melting point. The presented Deep Inelastic Neutron Scattering measurements on mixtures, performed at T=2 K and pressures ranging between 15 bar and 40 bar, reveal that the  $\langle E_K \rangle$  of <sup>3</sup>He is dependent on the total mixture density and is less than the value of the pure bulk <sup>3</sup>He, while, near the melting point, the two values are comparable (Fig. 7).



**Fig. 5:** Molar volume dependence of mean kinetic energy for pure <sup>3</sup>He (full circles) from [5-6] and pure <sup>4</sup>He (open circles) from [7-8].



**Fig. 6:**  $\langle E_K \rangle$  as function of the molar volume for pure <sup>3</sup>He (open circles) and for <sup>3</sup>He in <sup>3</sup>He-<sup>4</sup>He mixture (solid circles) [9-10-11-12].