Table 1

Material	Mean linear thickness (10^{-5} cm)	Density (g cm^{-3})	Mean density (g cm^{-3})	Tabulated bulk density (g cm^{-3})
Aluminium	8·18 ± 0·02	2·765 ± 0·028		
	10·90 ± 0·015	2·780 ± 0·022	2·77 ± 0·014	2·7
	12·06 ± 0·01	2·765 ± 0·022		
Copper	1·33 ± 0·02	8·73 ± 0·17		
	2·16 ± 0·01	9·09 ± 0·09		
	2·99 ± 0·015	8·87 ± 0·09	8·94 ± 0·07	8·93
	4·01 ± 0·02	9·15 ± 0·08		
	11·04 ± 0·04	8·84 ± 0·04		
Silver	0·97 ± 0·01	10·8 ± 0·27		
	1·48 ± 0·015	10·9 ± 0·18		
	1·89 ± 0·02	10·9 ± 0·15		
	2·80 ± 0·01	10·88 ± 0·08	10·82 ± 0·05	10·5
	3·89 ± 0·01	10·63 ± 0·06		
	4·67 ± 0·02	10·88 ± 0·06		
Gold	1·17 ± 0·02	18·8 ± 0·4		
	1·96 ± 0·025	19·3 ± 0·14		
	2·12 ± 0·01	19·0 ± 0·12		
	2·20 ± 0·02	19·7 ± 0·2	19·3 ± 0·1	19·3
	2·54 ± 0·01	19·3 ± 0·12		
	6·71 ± 0·015	19·4 ± 0·06		

ated. The density of each film was calculated from its mean thickness and the superficial density. The superficial density was determined for each film to ± 2·5 μg cm^{-2}. In most cases the accuracy of measurement of the density was limited by the weighing accuracy. The weighted mean densities of films of each metal are given in column 4 and compared with tabulated values[8] of the density of the bulk material.

Over the ranges of film thicknesses used, these materials show no significant variation of density with thickness. No variation of density was observed when gold films were heated in air at about 250° C for some hours. The mean densities obtained for copper and gold are in agreement with the tabulated densities for the bulk material. The densities of aluminium and silver films are about 2·5 per cent and 3 per cent, respectively, greater than the tabulated values.

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GENERAL

Application of the Second Law of Thermodynamics and Le Chatelier's Principle to the Developing Ecosystem

"Living organisms (biota) and their non-living (abiotic) environment are inseparably interrelated and interact on each other. Any area of nature that includes living organisms and non-living substances interacting to produce an exchange of materials between the living (biotic) and the non-living (abiotic) parts is an ecosystem" (modified after Odum[1]). The driving force which causes this exchange is the energy incident on the given area. That part of the energy which is fixed by the photosynthetic biomass is either used by the respiring biomass or is stored in chemical form as standing crop, extracellular produce, humus or peat.

The localized storage of energy within the system brings about the process of succession, which may be defined as a linked change of the biotic and abiotic components of the ecosystem. Succession passes through several stages to a complex, highly ordered, state, in which the stored (ordered) energy of the system remains at a quasi constant level. In this state in unit time an amount of energy equal to that fixed by the process of photosynthesis is used in the maintenance of the ecosystem, an equal amount of energy being lost from the system by heat transfer.

Kelvin summarized the second law of thermodynamics in his concept of the degradation of energy, "owing to the irreversible processes of nature the availability of energy to do work decreases"[2].

Consider the ecosystem and the incident energy falling on it. The incident energy is both the driving force of the ecosystem and of succession. A pioneer ecosystem has a small biomass and fixes, stores and respires (degrades) only a small proportion of the incident energy. While there is energy reaching the ecosystem which is not fixed by the process of photosynthesis, there is the possibility of an increase in the efficiency of the system to fix this energy. All the time there is energy fixed but not utilized in the process of respiration, this energy is stored by the ecosystem and succession occurs. Succession passes through a series of states in which an increasing amount of the incident energy is degraded until a state is reached in which, in unit time, an amount of energy equal to that fixed is used (degraded) in the maintenance of the ecosystem. This state can be termed "climax". The ceiling level of energy degradation will be determined by the environmental factors limiting the system, and the state of evolution of the biota, in respect to these factors.

It would therefore seem that the second law infers that succession should occur; the system should tend towards a state of maximum degradation of the energy associated with it. The more generalized statement of the second law by Clausius, "entropie strebt einem maximum zu"[3] (entropy is a measure of the non-availability of energy to do useful work), lends weight to this idea.

Classical thermodynamics can, however, only be applied to equilibrium states. Considering the seral ecosystem and the incident energy, equilibrium states only exist before development has started and again once it has reached climax. During the intervening period of development the ecosystem undergoes an irreversible change. De Groots uses generalized classical thermodynamics to consider irreversible processes. In his formulation of Le Chatelier's principle, he states that if an irreversible system is perturbed, that is, if one of its characteristic parameters is changed, then the system undergoes such a transformation as to oppose the change[4]. In the seral ecosystem the parameter in question is the degradation of incident light energy which is tending to increase. The ecosystem responds by storing energy in ordered chemical form; this stored energy brings about succession.

It may therefore be concluded that the second law infers that succession should occur and that the localized build-up of energy in the biomass is caused by the opposing force suggested by Le Chatelier.

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