The term universe means system plus the surrounding therefore $\Delta S_{UNIVERSE} = \Delta S_{SURROUNDINGS}$.

The second law tells us that an irreversible spontaneous process occurs, the entropy of the system and the surroundings must increase i.e. $\Delta S_{universe} > o$

But when a reversible process occurs the entropy of the sysem remains constant and therefore Δ s increase =o

i.e. Δs system + Δ s surrounding = o

therefore $\Delta s_{system} = -\Delta s_{surrounding}$ for a reversible process.

Since the entire universe undergoes spontaneous change, the 2nd law is usually stated that the entropy of the system is constantly increasing.

State of the 3rd law

The entropy of a substance varies directly with temperature.

The lower the temperature the lower the entropy and vice versa

EXAMPLES

Water above 100^{o} and 1 atm exists as a gas and has high entropy (high disorder) when the system is cooled, the water vapor condenses to form a liquid and the entropy of the system decreases even though the water molecules can still move freely.

Further cooling leads to the formation of ice crystals that are highly ordered and the entropy of the system is very low.

When the solid crystal is cooled further the vibration of the molecules held on the crystal lattice gets slow and they have very little freedom of movement (very little disorder) and hence very small entropy.

At absolute zero, all molecular vibrations seize and the water molecules are said to be perfectly ordered and the entropy of the system is zero and this leads to the statement of 3rd law of thermodynamics which states that **at absolute zero the entropy of a pure crystal is also zero i.e. s=o at T=ok**

By numerical definition of entropy was first introduces by scientist called **Clausius (1850)**

According to him the entropy of a system, not undergoing any chemical or physical changes is a constant quantity when there is no communication of heat.

But when heat flows into the system the entropy increases by a quantity.

$$\frac{q}{T}$$

Heat flowing out of the system produces a corresponding decrease of - $\frac{q}{T}$