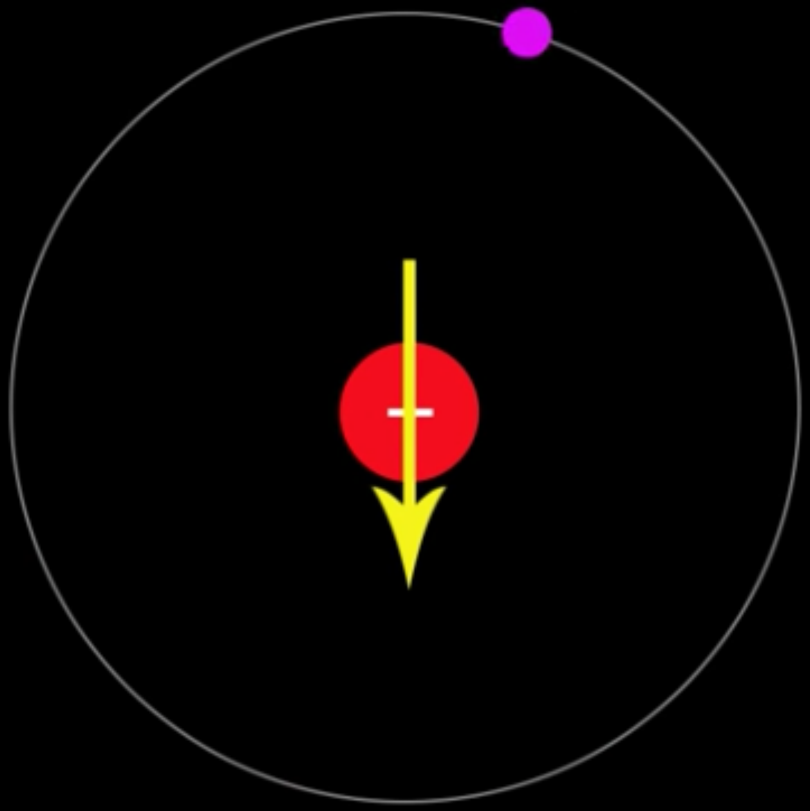
Slides (Notes) for Critical Exponents

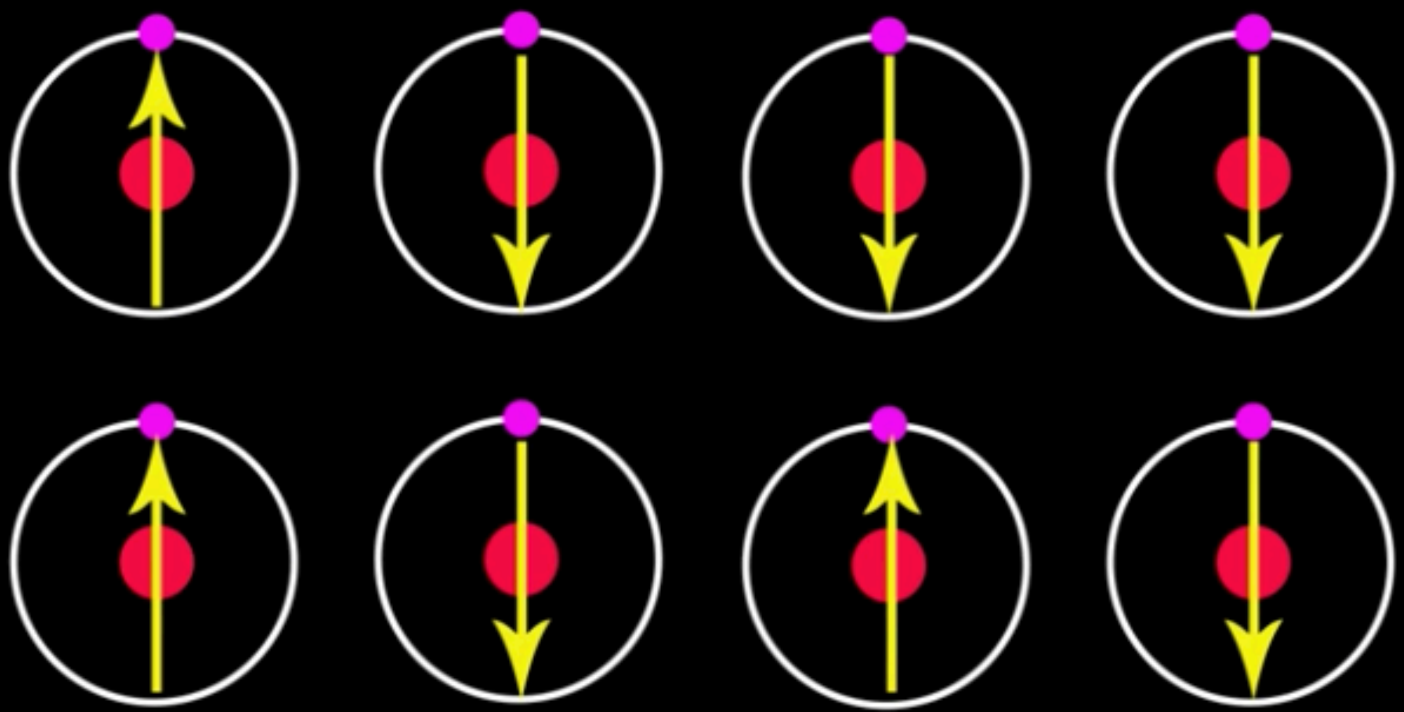
YouTube Link: https://www.youtube.com/watch?v=yAbvptzDZYc

YouTube Video Title: Critical Exponents: Why Chemistry Never Mattered



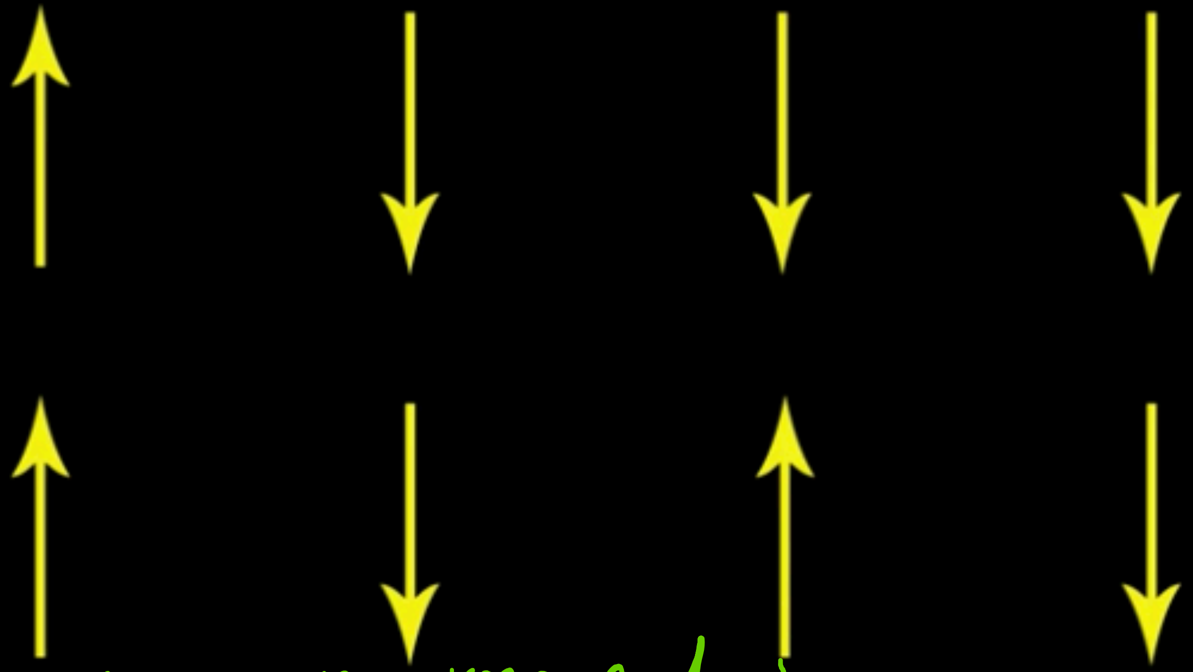
Spin States

Atomic Lattice



Spin Lattice

2-D lattice



The spins are arranged in a lattice where each spin can interact with nearest neighbour.

Ising Model

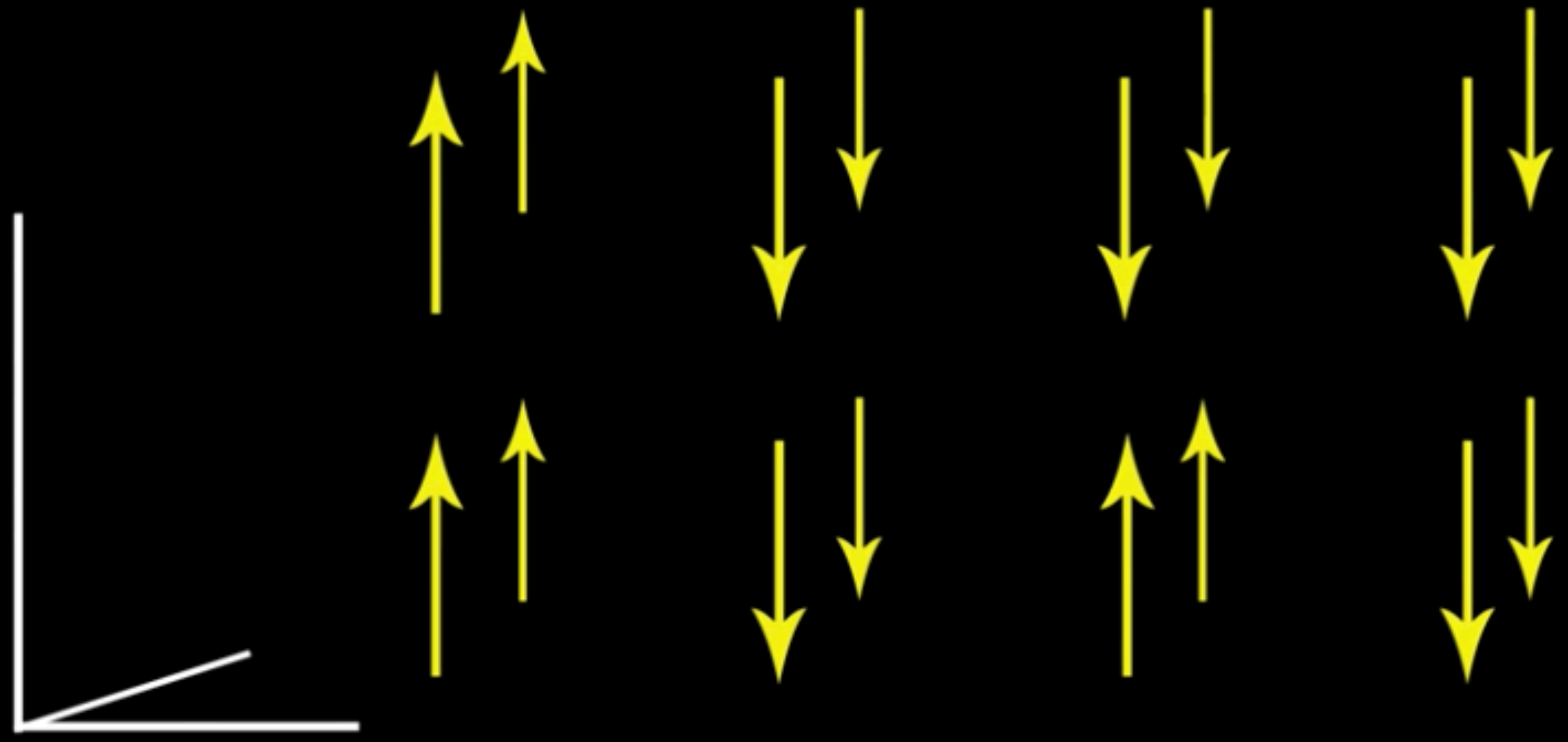
(Ernst Ising)

We could forget about the physical items (Atoms) themselves and just consider the lattice of spins $\longrightarrow$ Ising Model

3-D $\rightarrow$ Spin Lattice

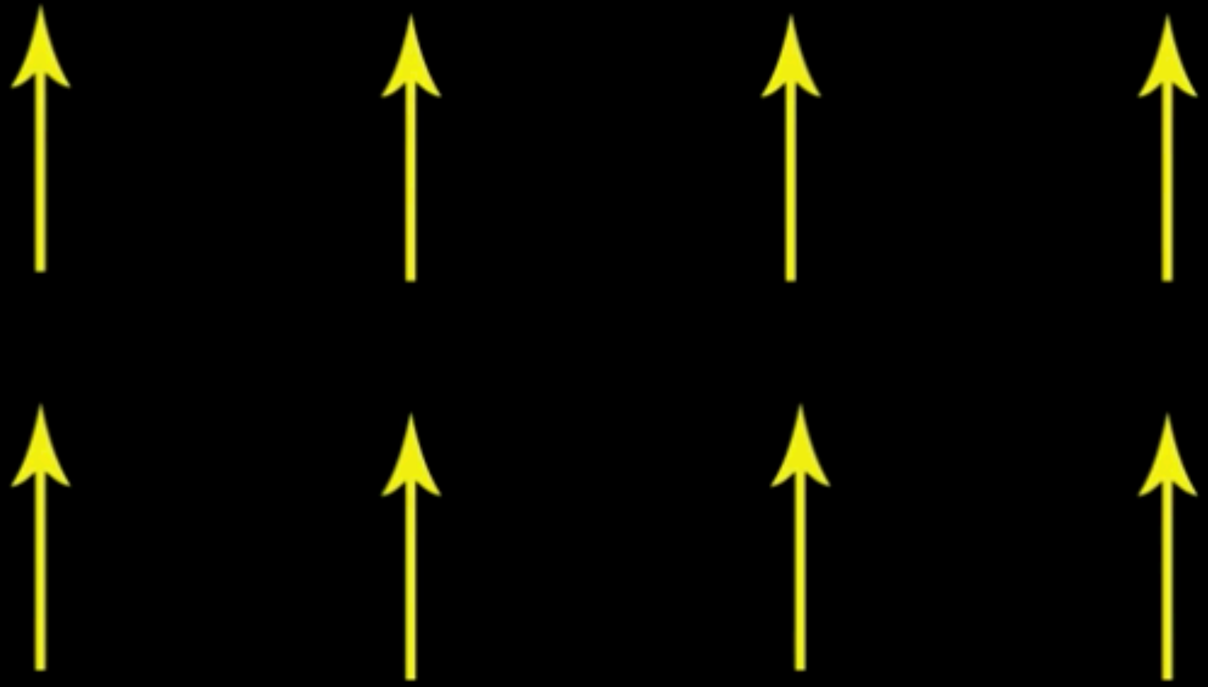
Ising Model

(Ernst Ising)

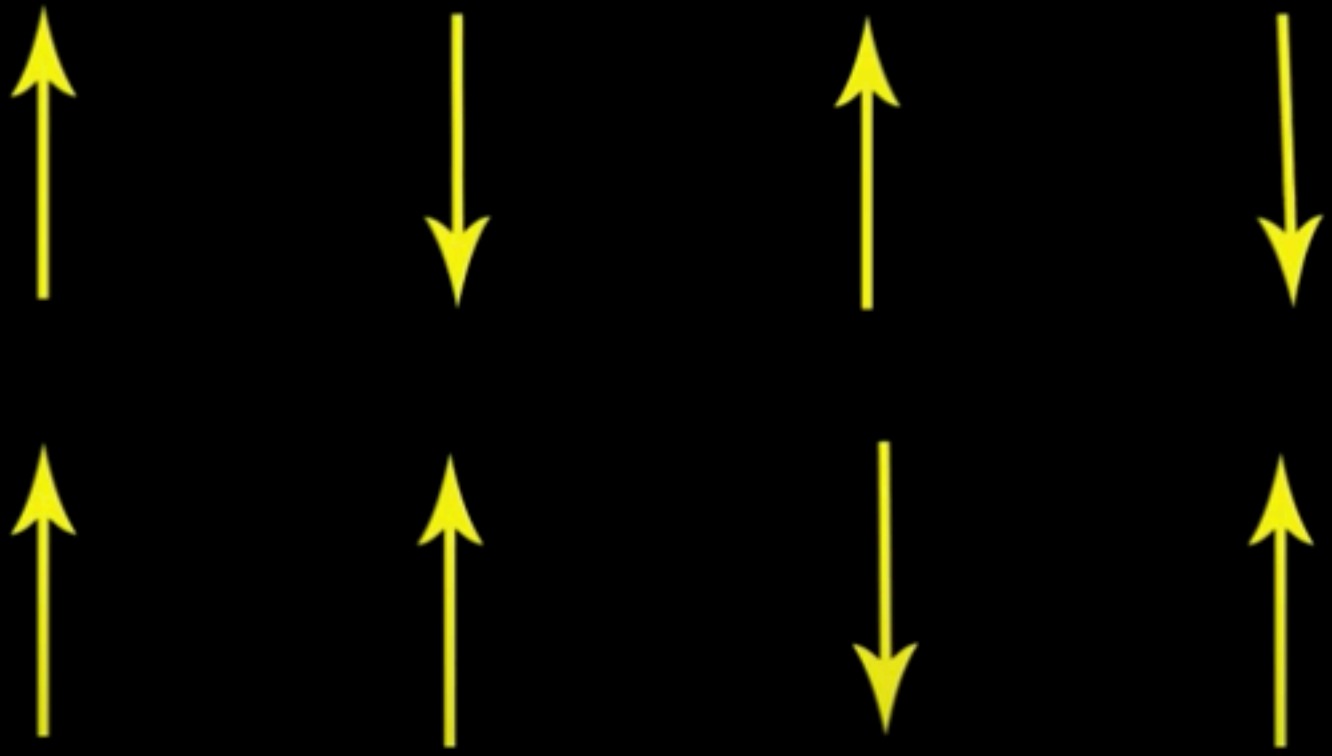


Strong Magnetisation

Net Alignment – Highly Magnetized

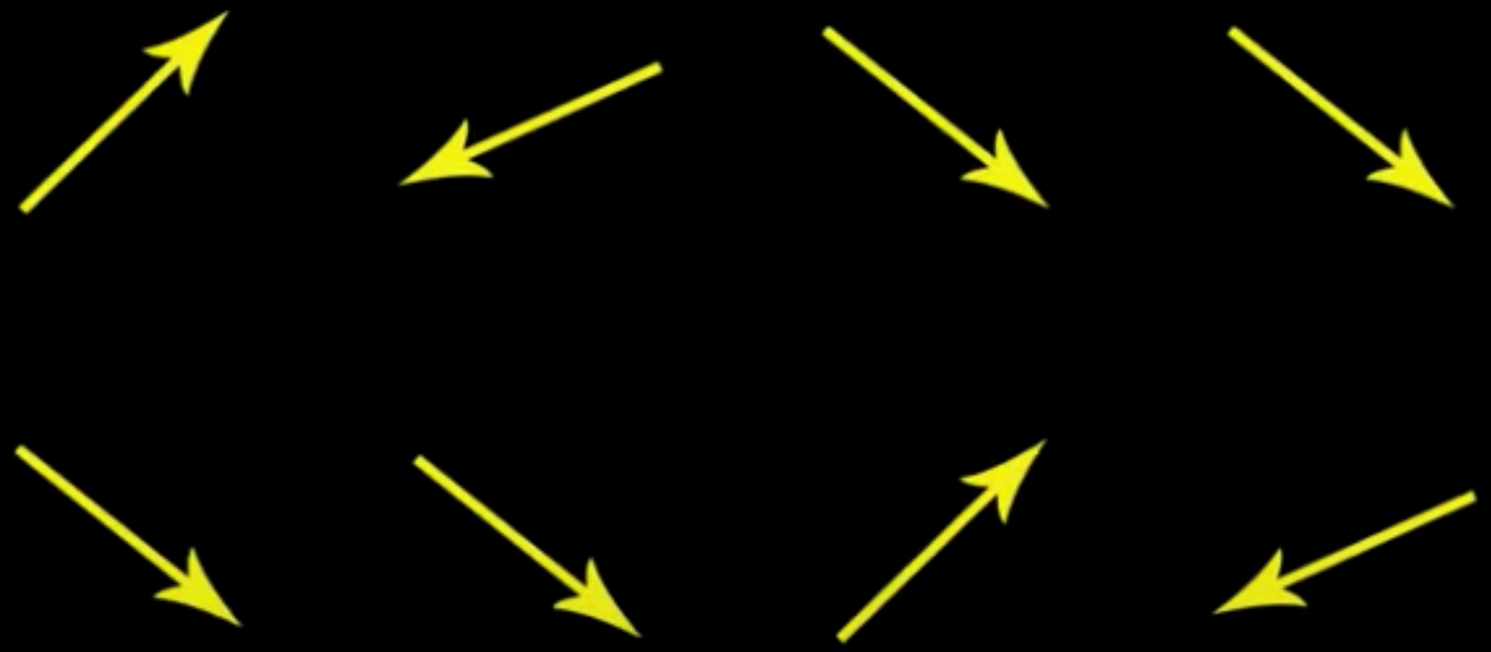


Weak Magnetisation



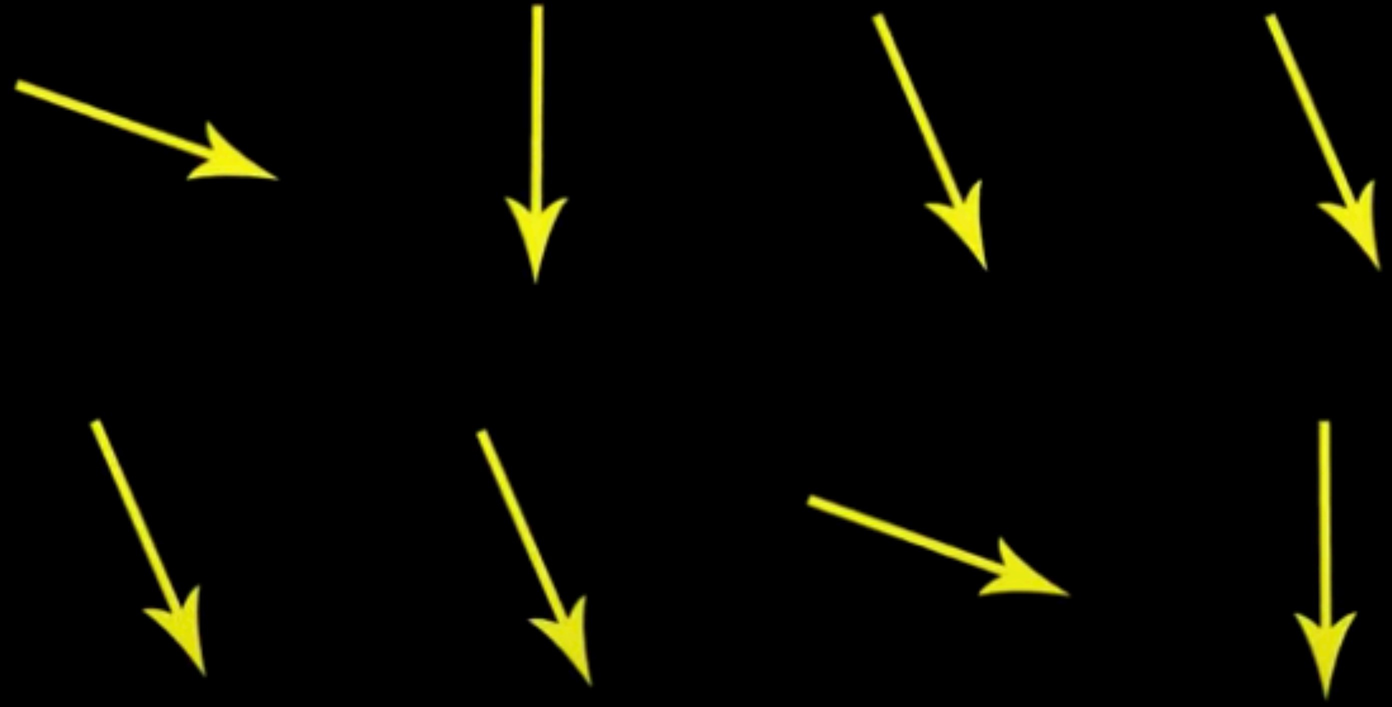
Heated

More disordered while being heated



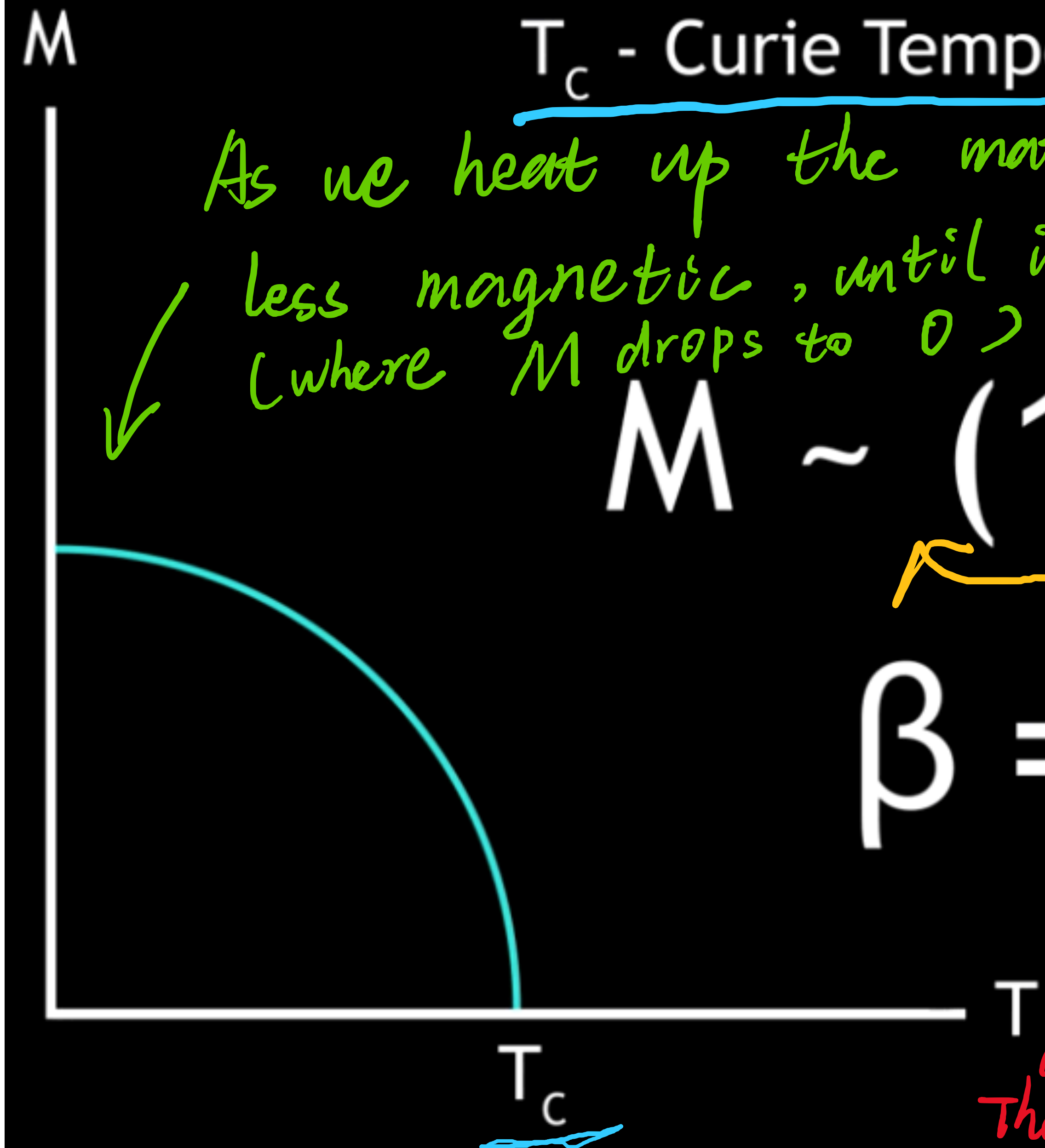
Cooled

less disordered as we cool it down



M - Magnetisation

T_C - Curie Temperature



As we heat up the material, it become less & less magnetic, until it reaches T_c. (where M drops to 0)

Exponent
(power)

$$M \sim \left(1 - \frac{T}{T_C}\right)^{\beta}$$

$$\beta = ?$$

It's found that the relationship between M & T follows some power law.

No matter what substance is being used, the chemistry of the substances are irrelevant to this power. The power is always the same!

For 2D substance (like Graphene), it's found that β is always around 0.125

Substance X $\beta = 0.125$

Substance Y $\beta = 0.125$

Substance Z $\beta = 0.125$

No matter what substances have been used, liquid or solid, the chemistry of the substance has no effect.

The power (β) always come out the same!

The actual purpose of this model is used to calculate some properties of the material, like T_c & M.

Ising Model

Curie Temperature - T_C

Magnetisation - M

Lars Onsager

He is able to find the exact solution to the 2-D Ising Model.

$$\frac{K_B T_C}{J} = \frac{2}{\ln(1+\sqrt{2})}$$

$$M = [1- \sinh^{-4}(2BJ)]^{1/8}$$

This exponent (β) is always $\frac{1}{8}$ for 2D materials.

These exponents are collectively known as critical exponents.

	2D	3D	4D
α	0	?	0
β	1/8	?	1/2
γ	7/4	?	1
δ	15	?	3
η	1/4	?	0
ν	1	?	1/2
ω	2	?	0

It was NOT just the magnetization thas has this property (such power law relationship)

Other quantities like heat Capacity also has power laws and their exponents (they might be α, γ, δ, ...) could be predicted exactly. Most importantly, they are the same to any substances.