Kinetics
&
Thermodynamics

Branch of Chemistry that studies reaction rates and reaction mechanisms

(i.e. how a reaction occurs, how fast it goes and the E changes that occur)

Measure a reaction rate 2 ways

- The rate (speed) at which the reactant is consumed

- The rate (speed) at which the product is formed

- **The rate is determined by the change in concentration per unit time**

As Δt increases
The reaction rate decreases
The rxn is slower

- **Concentration is expressed in (M)olarity**
- **[HCl] = 0.5M**

Rate of Reaction and Collision Theory

- In order for a chemical reaction to occur **effective collisions** must happen randomly between **species** so the bonds of the reactants can be broken and reformed into products.

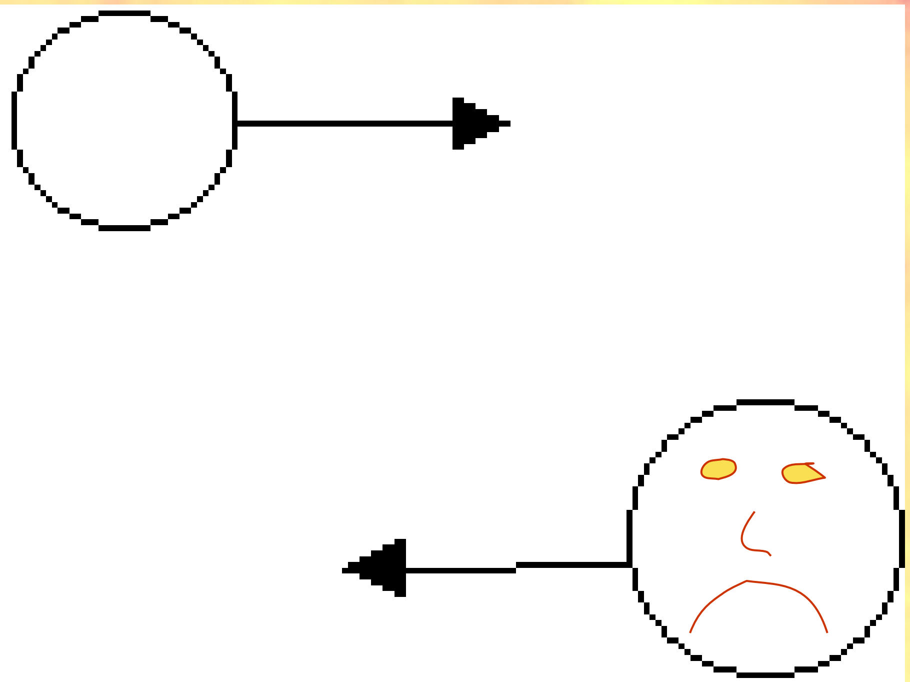
Effective Collisions:

result in
breaking or forming
a bond

Species: ions
molecules or
atoms

What does this mean???

………… the reactants have to bump into each other so they can be transformed into products



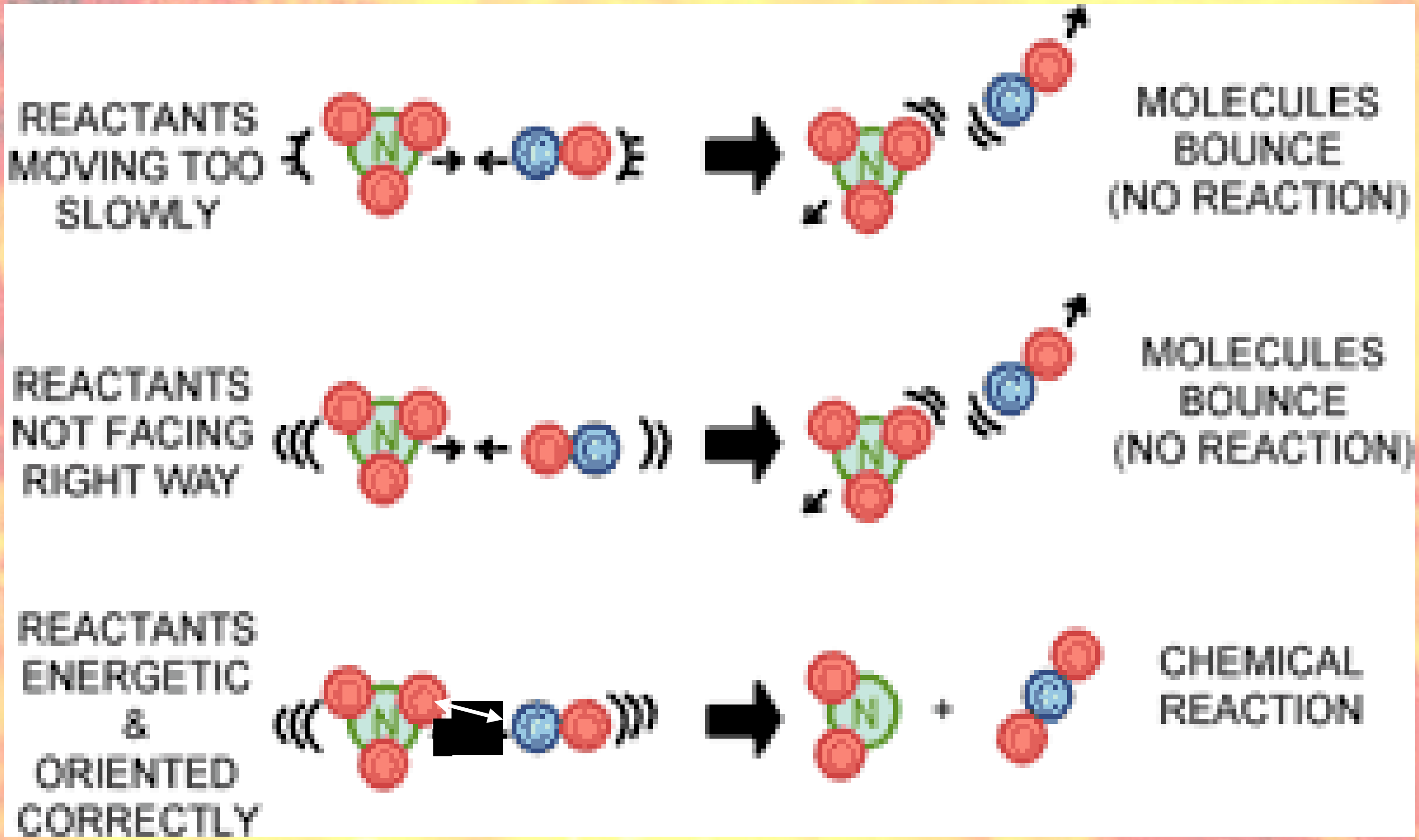
No collision

No reaction

- **Collisions are only effective if**
  - **they have enough kinetic energy to form products**
  - **this minimum amount of kinetic energy is <u>activation energy</u>**

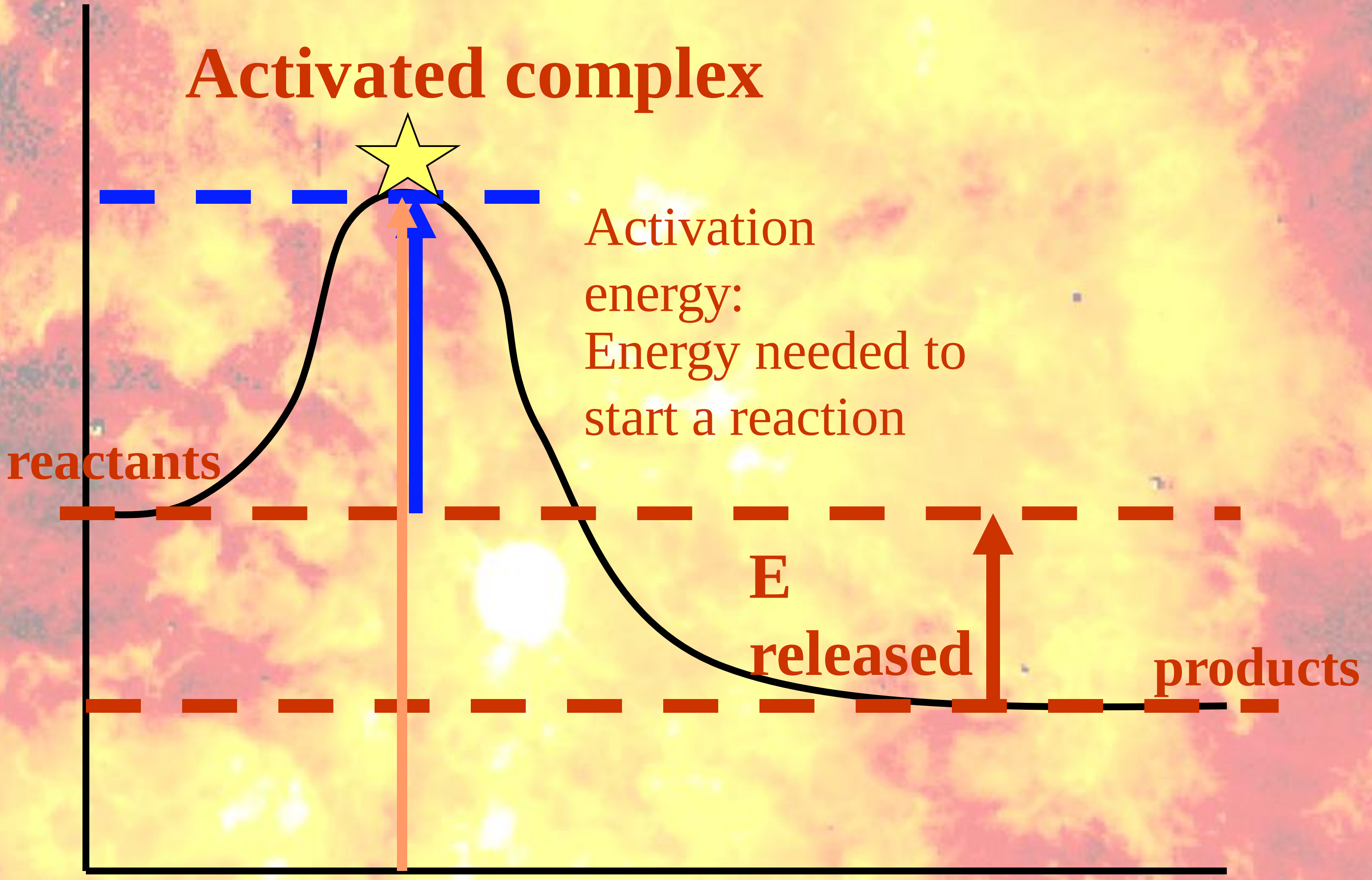
Energy necessary to start a reaction

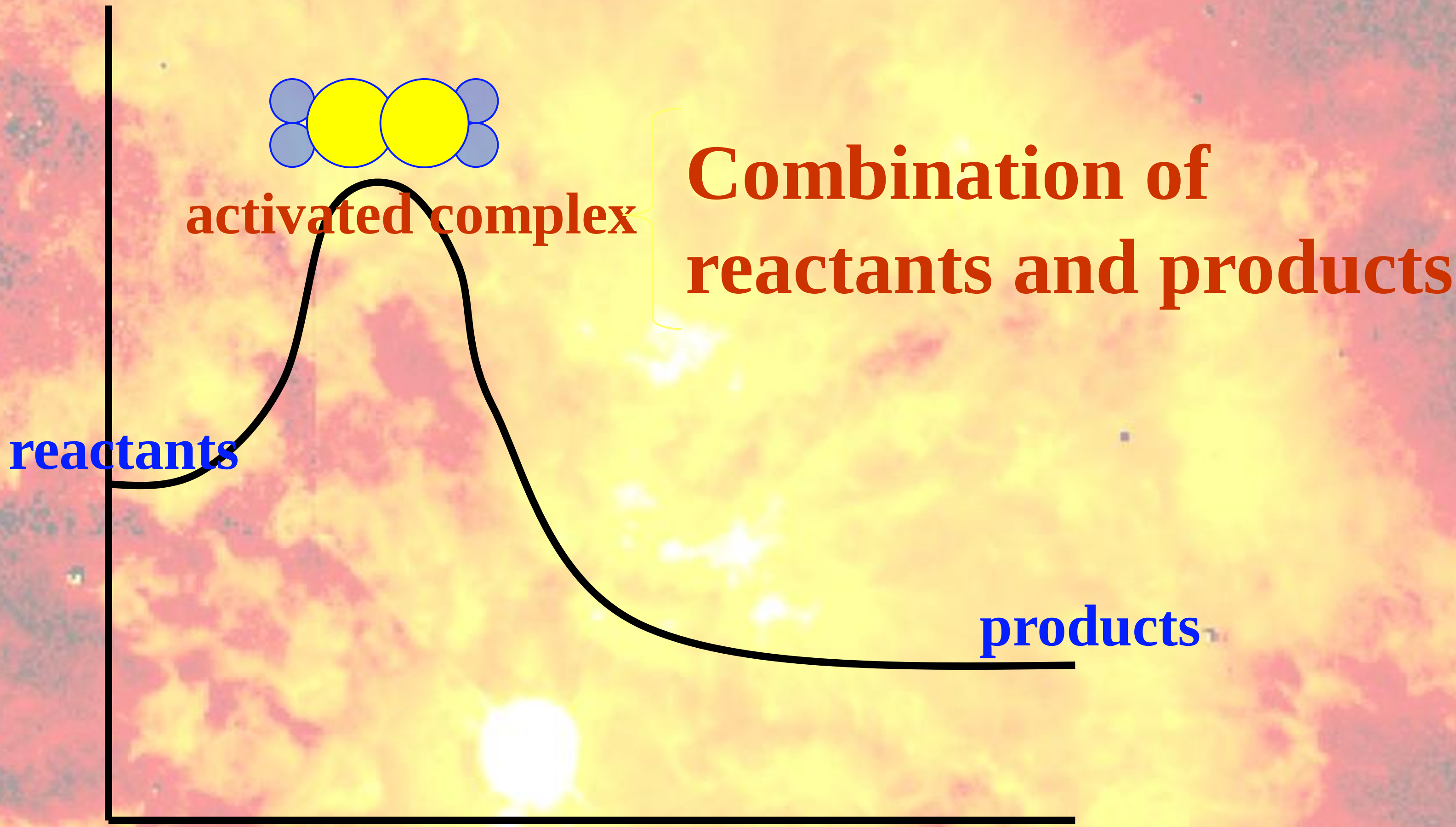
AND the molecules must be in the proper orientation


REACTANTS MOVING TOO SLOWLY
MOLECULES BOUNCE (NO REACTION)
REACTANTS NOT FACING RIGHT WAY
MOLECULES BOUNCE (NO REACTION)
REACTANTS ENERGETIC & ORIENTED CORRECTLY
CHEMICAL REACTION

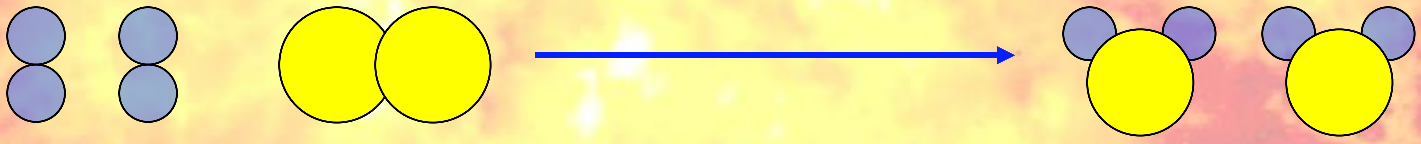
During a chemical reaction . . .

- **The effective collisions result in *temporary unstable particles with high potential energy***
  - **activated complexes**


Activated complex
Activation
energy:
Energy needed to
start a reaction
reactants
E
released
products



$$2H_2 + O_2 \longrightarrow 2\,H_2O$$



5 factors that determine the rate of reaction

1. The nature of the reactants
2. The temperature of the system
3. The concentration of the reactants
    - Increasing the pressure (GAS)
4. Surface area of the reactants
5. The use of a catalyst

Nature of the Reactants

- Reactions between *ionic* substances happen very quickly
- Reactions between *covalent* substances tend to happen slowly

- Solutions (aq) react faster than solids
- Liquids react faster than solids

WHY?

- **Electrons rearrange themselves more easily in ionic reactions b/c of higher e-neg** *differences*
- **Particles of a liquid move throughout the substance ∴ more frequent effective collisions**
  - **solid particles do not**

Temperature of Reactants

- **Usually, an <u>increase in temp</u>. increases the rate chemical reactions**

WHY?

They move faster

- **If you increase temperature of the system, the KE of the particles increases, and *effective collisions are going to happen more often***

Concentration of Reactants

- **An increase in the concentration of the reactants will increase the rate of reaction**

  1.5M vs. 4M

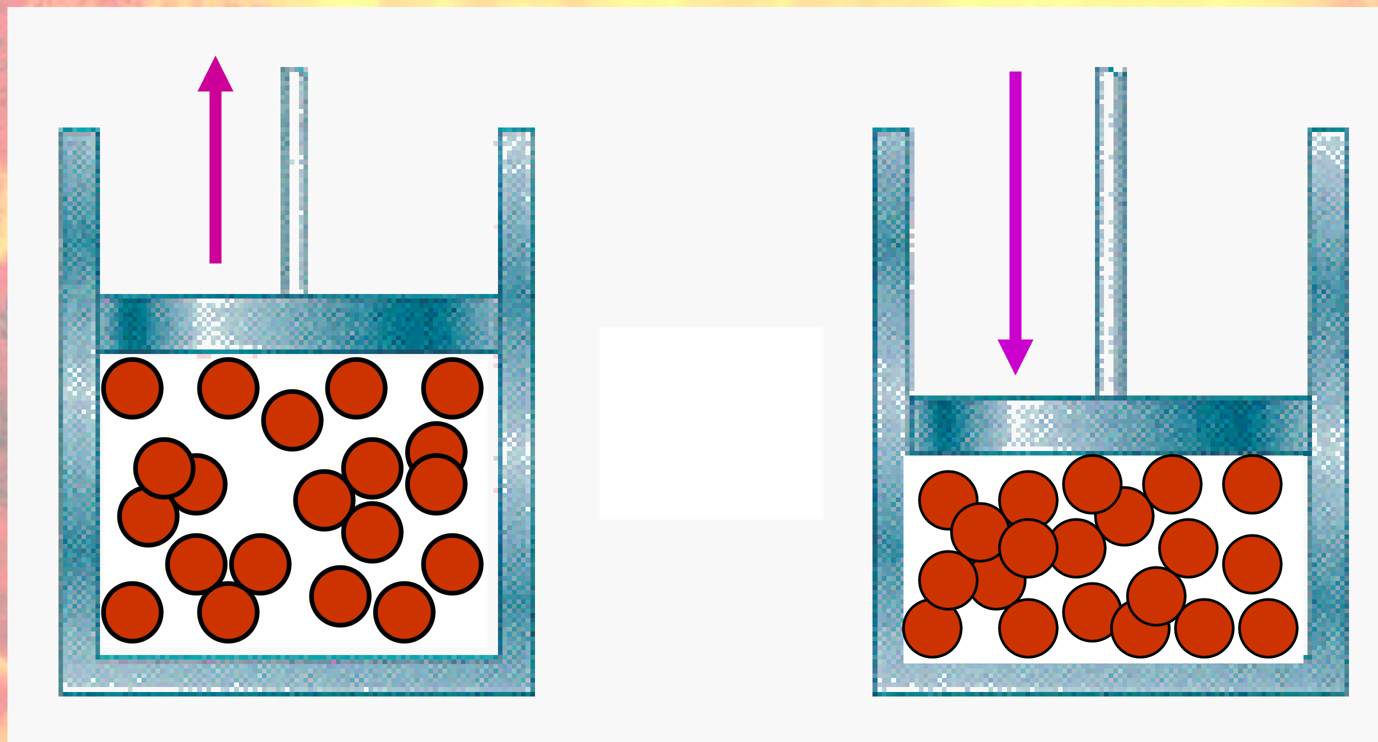
BECAUSE . . . ***effective collisions are going to happen more frequently***

Increasing GAS concentration

- **Increasing pressure will increase the rate of reaction IF at least one of the reactants is a gas**

WHY?

- **the molecules move closer together** ***increasing the number of effective collisions***



Decreased pressure Increased pressure

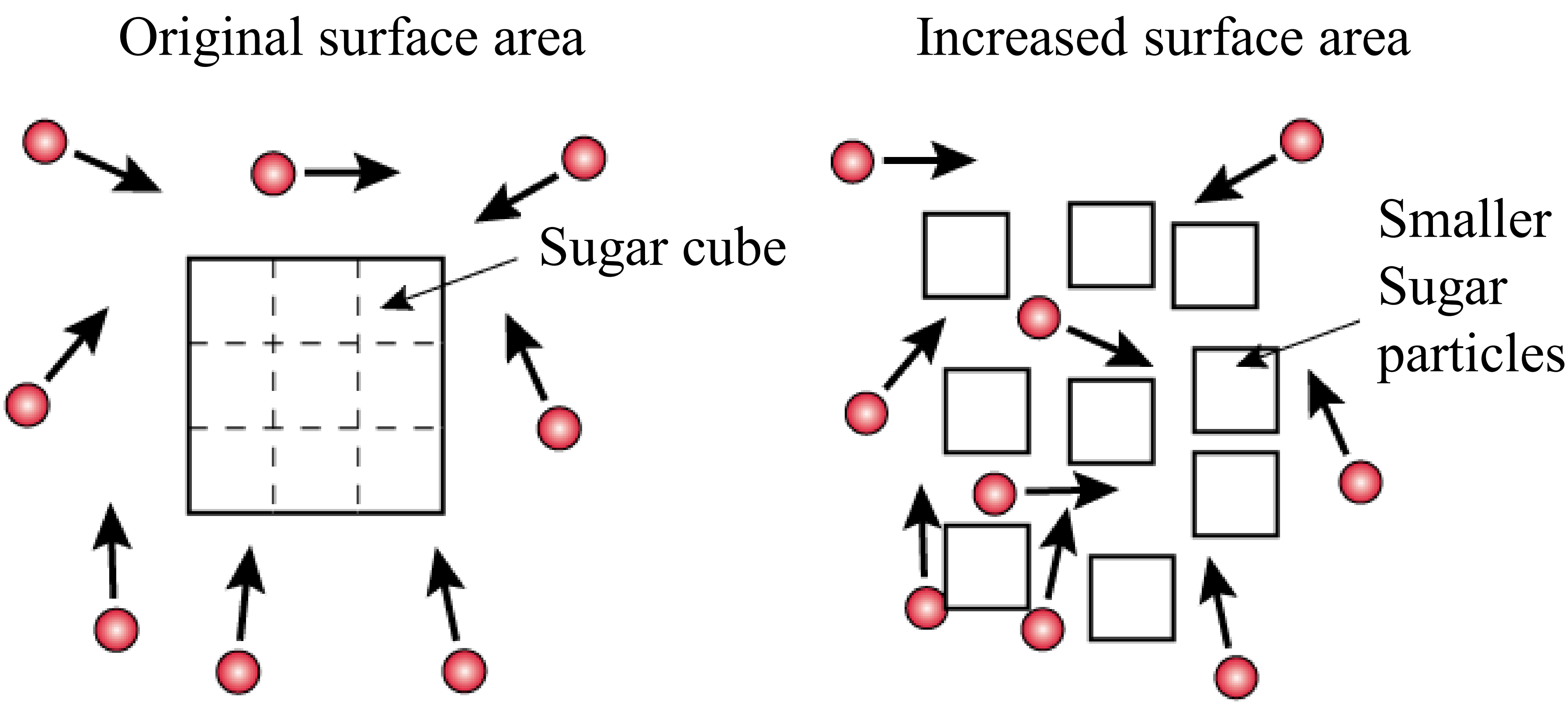
Sometimes you can’t change the concentration of the substance (if you have a pure substance) 100%

but you can *increase its surface area*

Surface Area and Reaction Rate

- Increasing the surface area of the reactants will increase the rate of reactions

WHY?



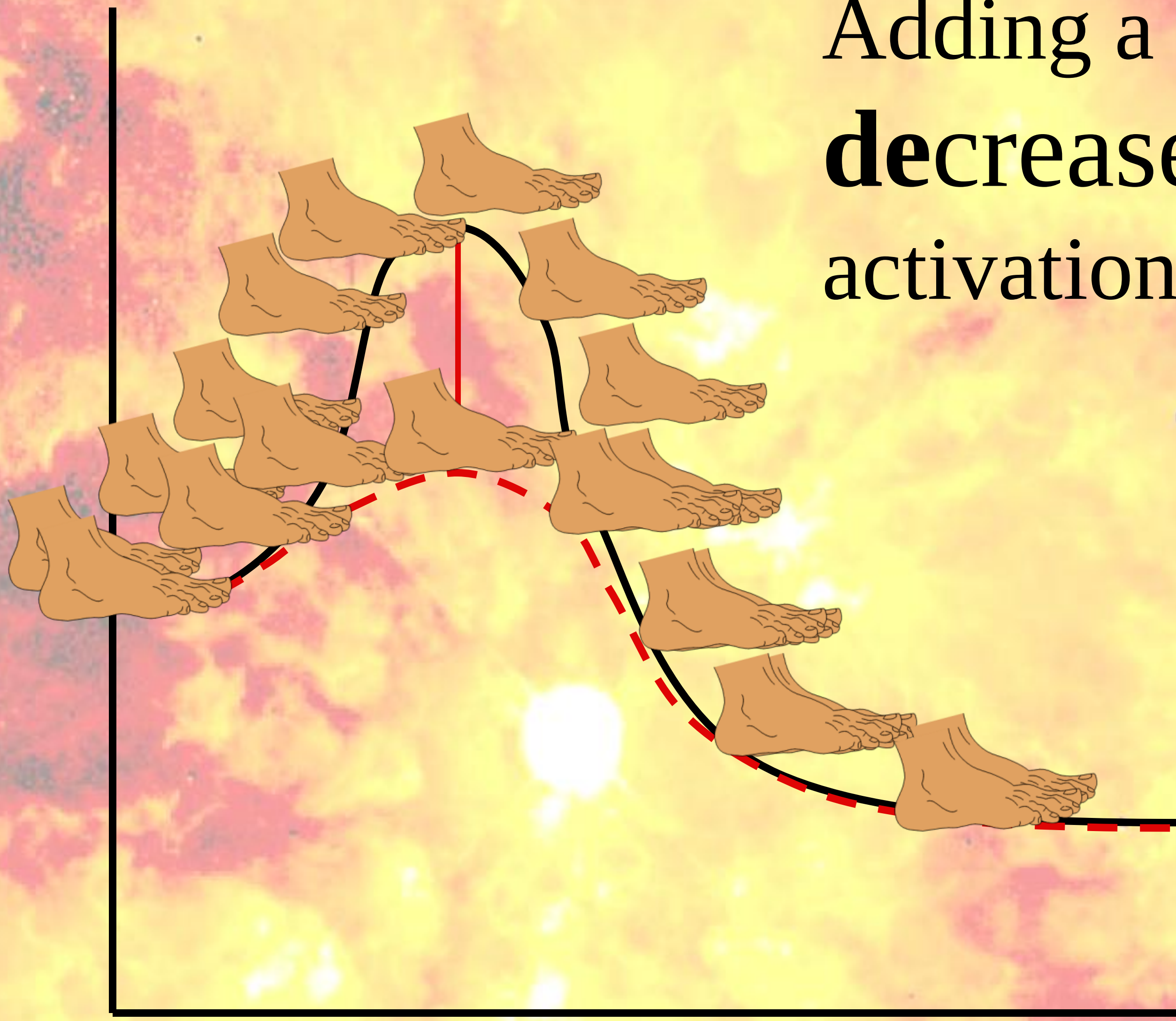
Increased surface area allows more of the reactant to be exposed . . . more *effective collisions* to happen . . .

Catalyst and Reaction Rate

- **A catalyst is a substance that speeds up a chemical reaction *without being changed* itself.**

Enzymes are biological catalysts

Adding a catalyst **de**creases the activation E



Initial PE and final PE do not change

Potential Energy Diagrams

PE is stored in the bonds of a substance. Using PE diagrams we can study the

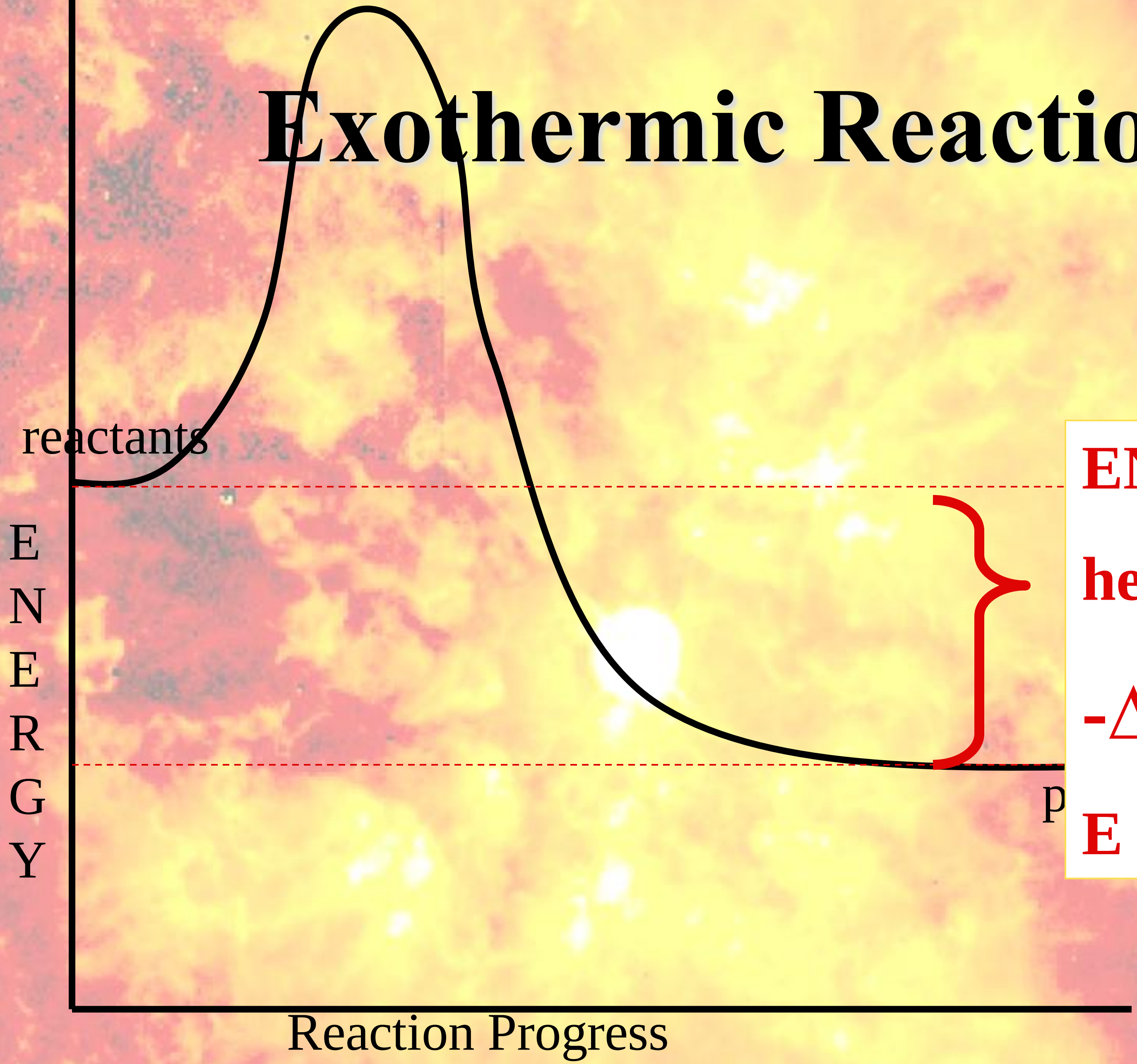
THERMODYNAMICS

of substances involved in reactions.

Enthalpy and ΔH

- The change in PE of a reaction is called Enthalpy
- Enthalpy is measured by ΔH
- $\Delta H = H_{(products)} - H_{(reactants)}$

Exothermic Reaction



ENTHALPY

heat of reaction

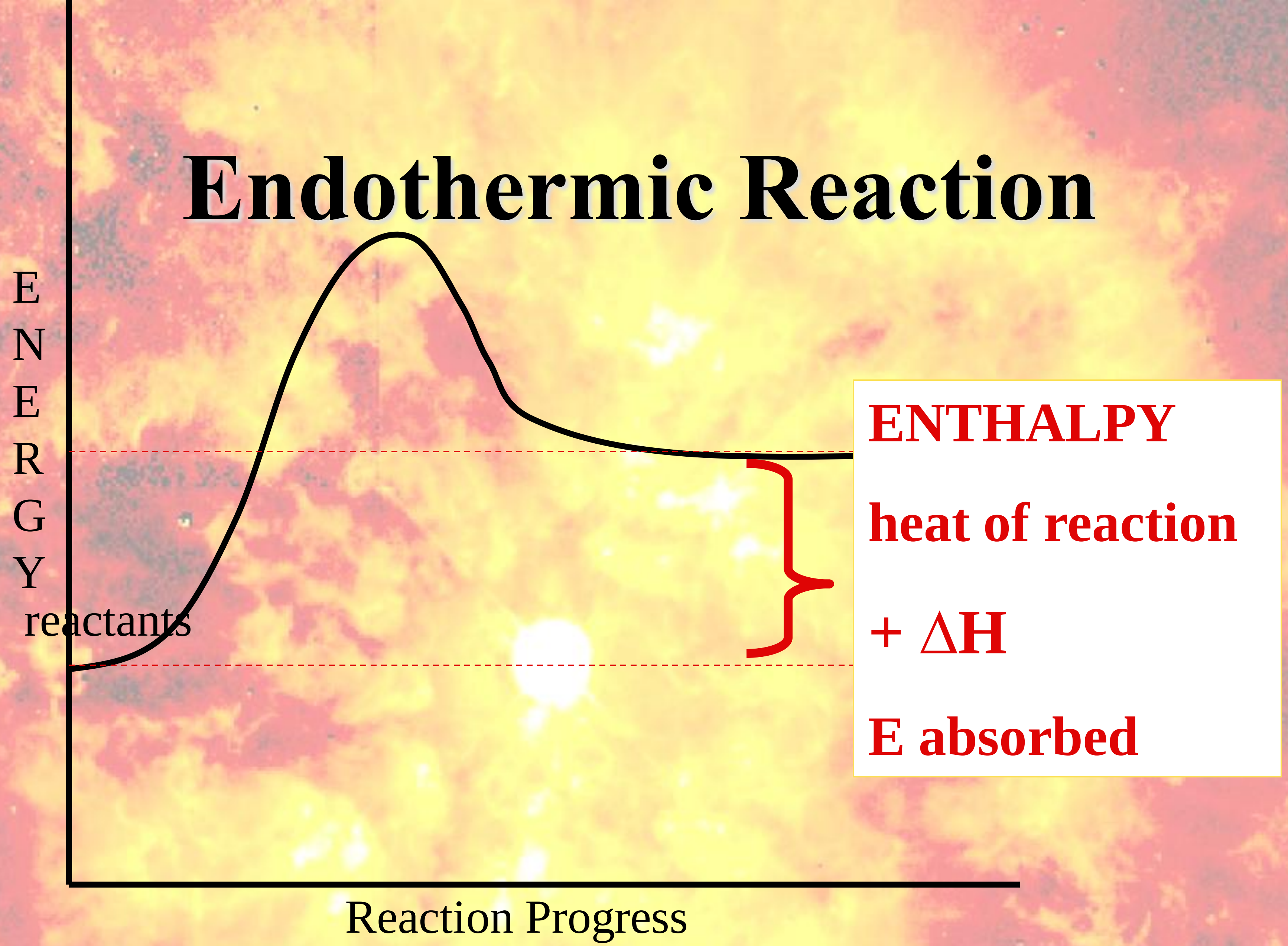
-ΔH

E released

Exothermic Reactions

- produce products with
  - low PE
  - few bonds
  - stable (don’t react easily)
  - negative ΔH

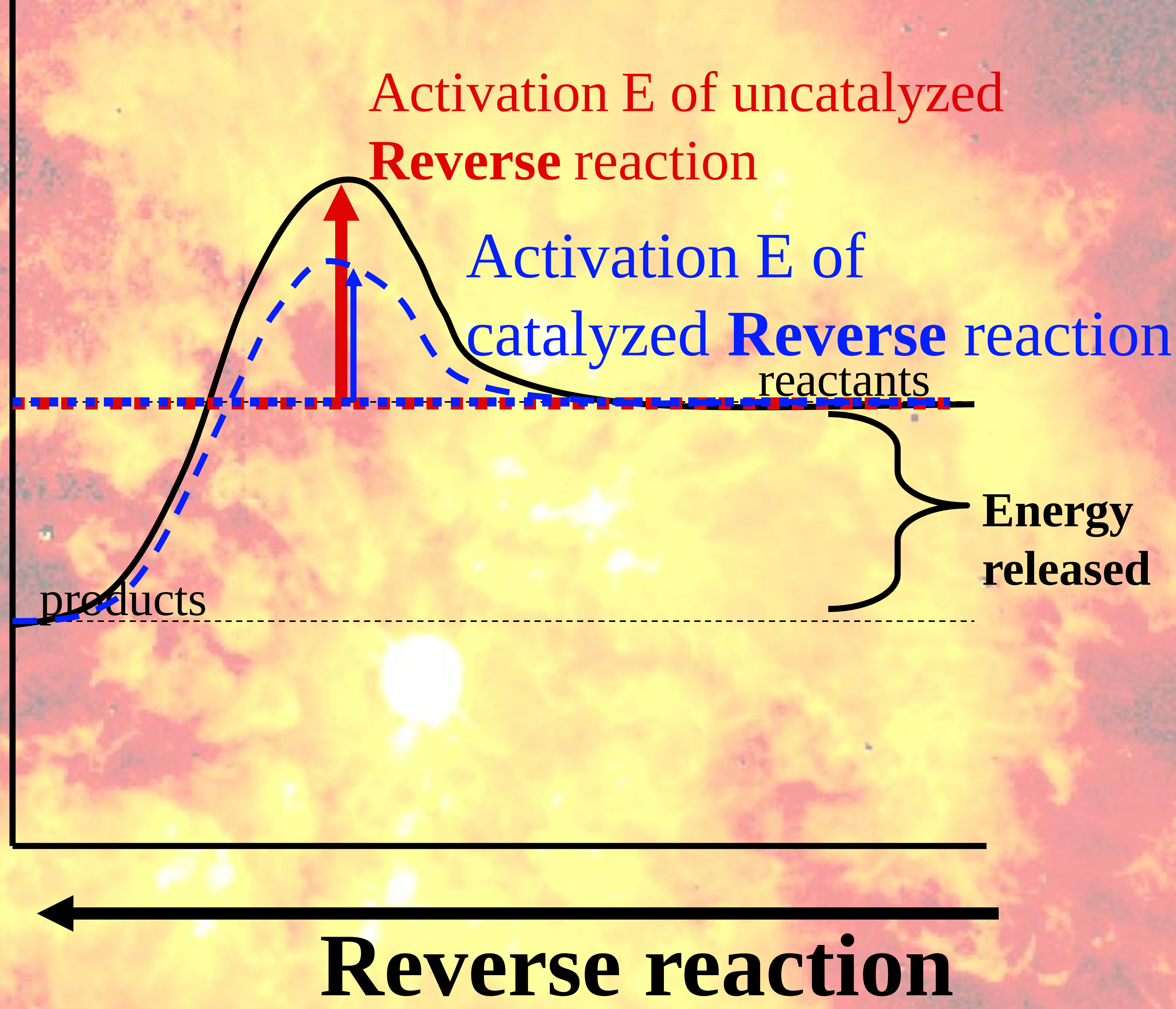
Endothermic Reaction



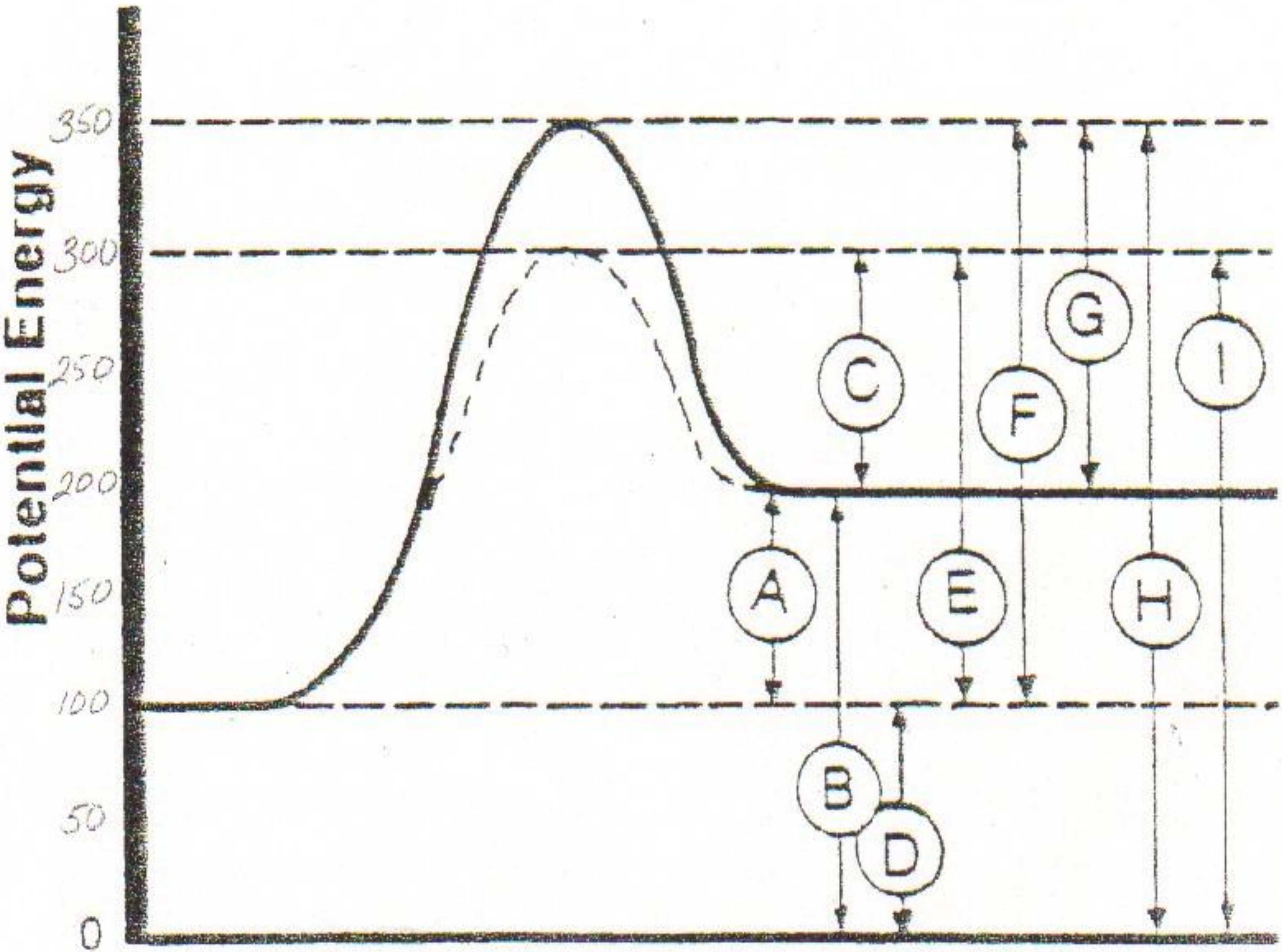
Endothermic Reactions

- produce products with
  - high PE
  - more bonds
  - unstable (react easily)

  $+\Delta H$



Activation E of uncatalyzed
Reverse reaction
Activation E of
catalyzed Reverse reaction
reactants
Energy
released
products
Reverse reaction



Potential Energy
350
300
250
200
150
100
50
0
A
B
C
D
E
F
G
H
I

Table I and Rxns

$$N_{2\,(g)} + 3H_{2\,(g)} \longrightarrow 2NH_{3\,(g)} + 91.8\ kJ$$

- **What type of reaction?**
- **What is ΔH?**
- **What is the heat of reaction for 1 mole of $NH_{3(g)}$?**

Table I

ΔH (kJ)

$N_{2\,(g)} + 3H_{2\,(g)} \rightarrow 2NH_{3\,(g)}$ - 91.8

- What type of reaction?
- Endothermic or Exothermic?
- What is ΔH?
- What is the heat of reaction for 1 mole of $NH_{3(g)}$?


o
r
d
d
i
r
e
s

Disorder


n
o
a
d
m
r

Random


a
c
s
o
h

Chaos


p
n
o
r
t
y
e

Why do things happen the way they do, and not in reverse?

Entropy

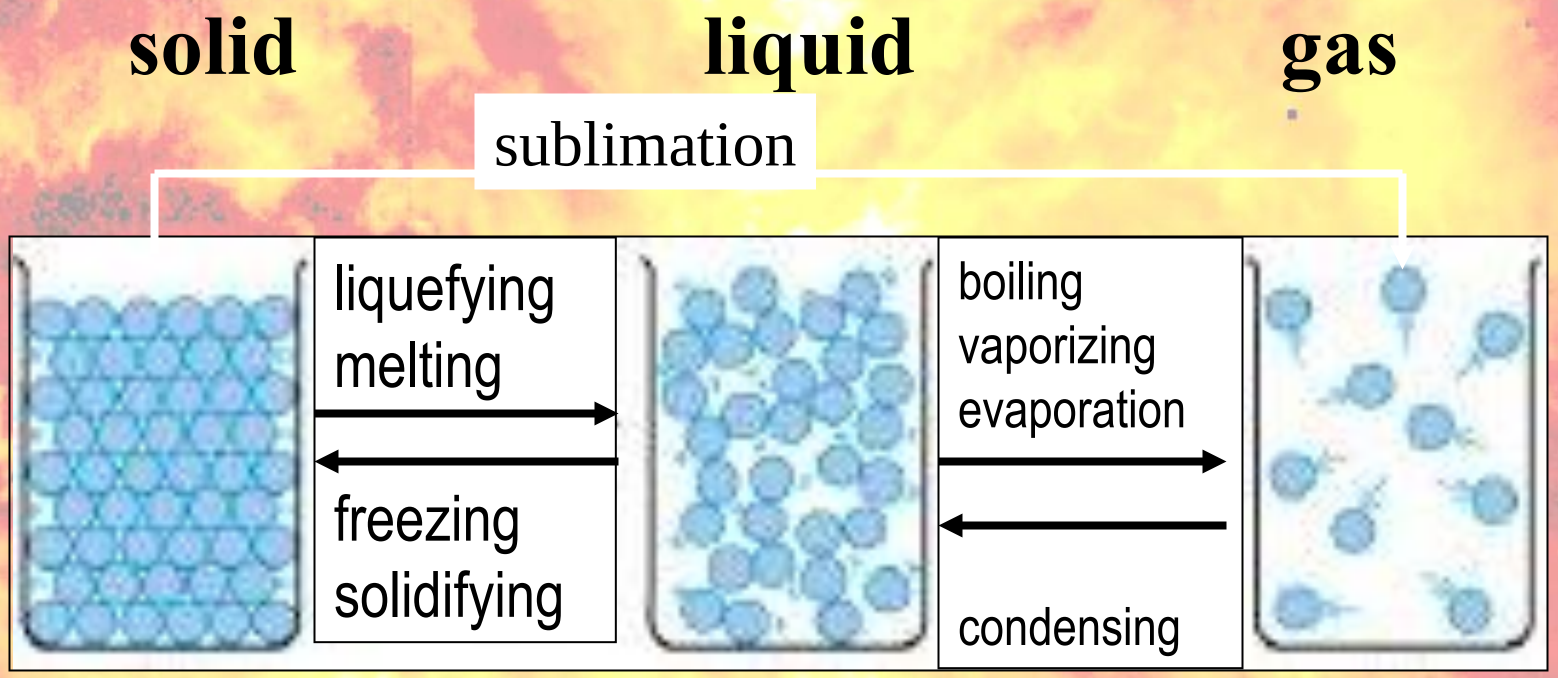
The universal trend towards entropy is irreversible

- When you drop a broken egg . . . It doesn't become whole
- When you shuffle a deck of cards . . . They don't go back to their original order
- If you put water into a cold soda . . . It will not freeze as the soda gets warmer

Entropy

- Measure of disorder or randomness of a system

States of Matter &Entropy



Entropy Increases

Energy Cu... Entropy