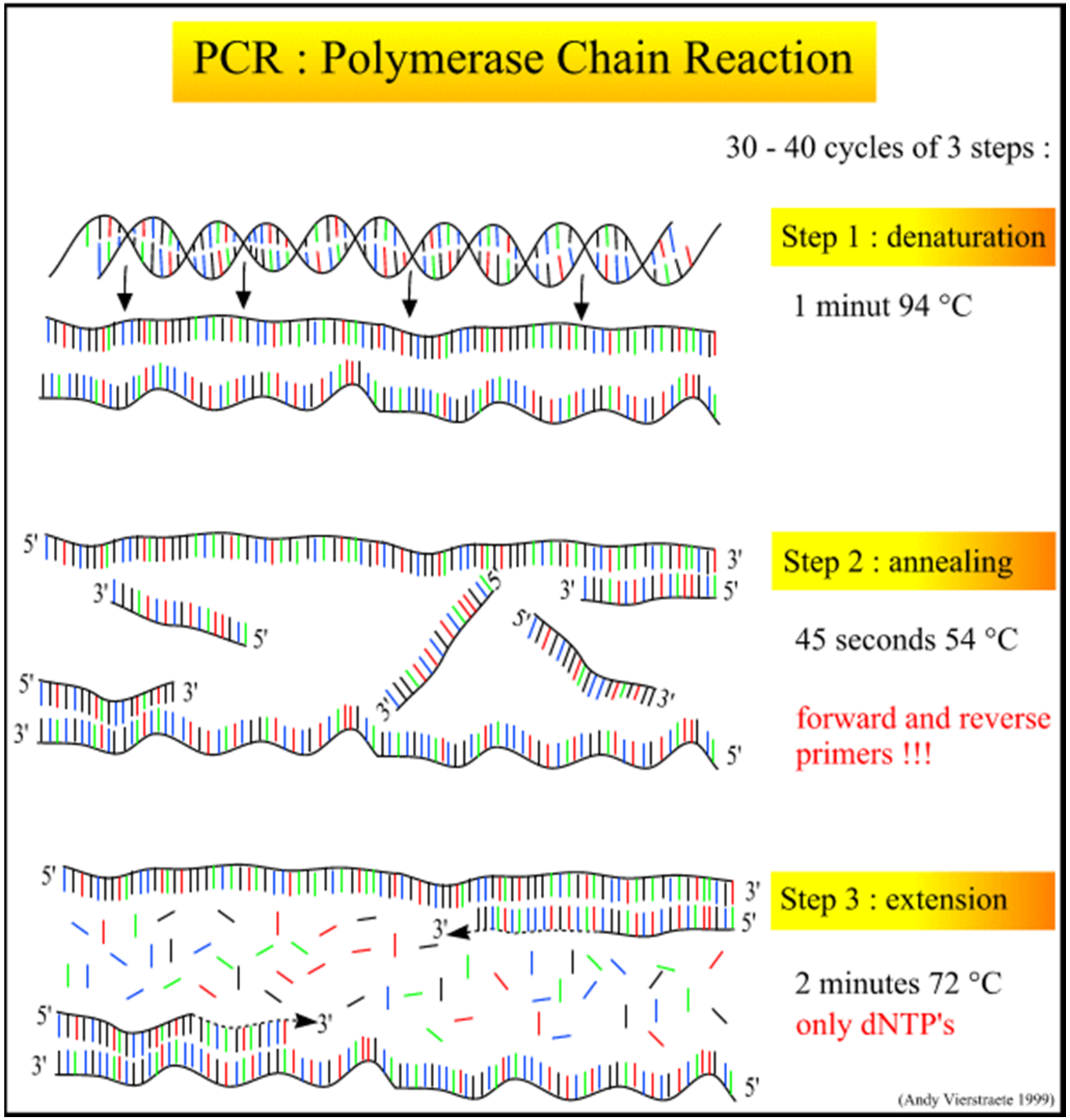
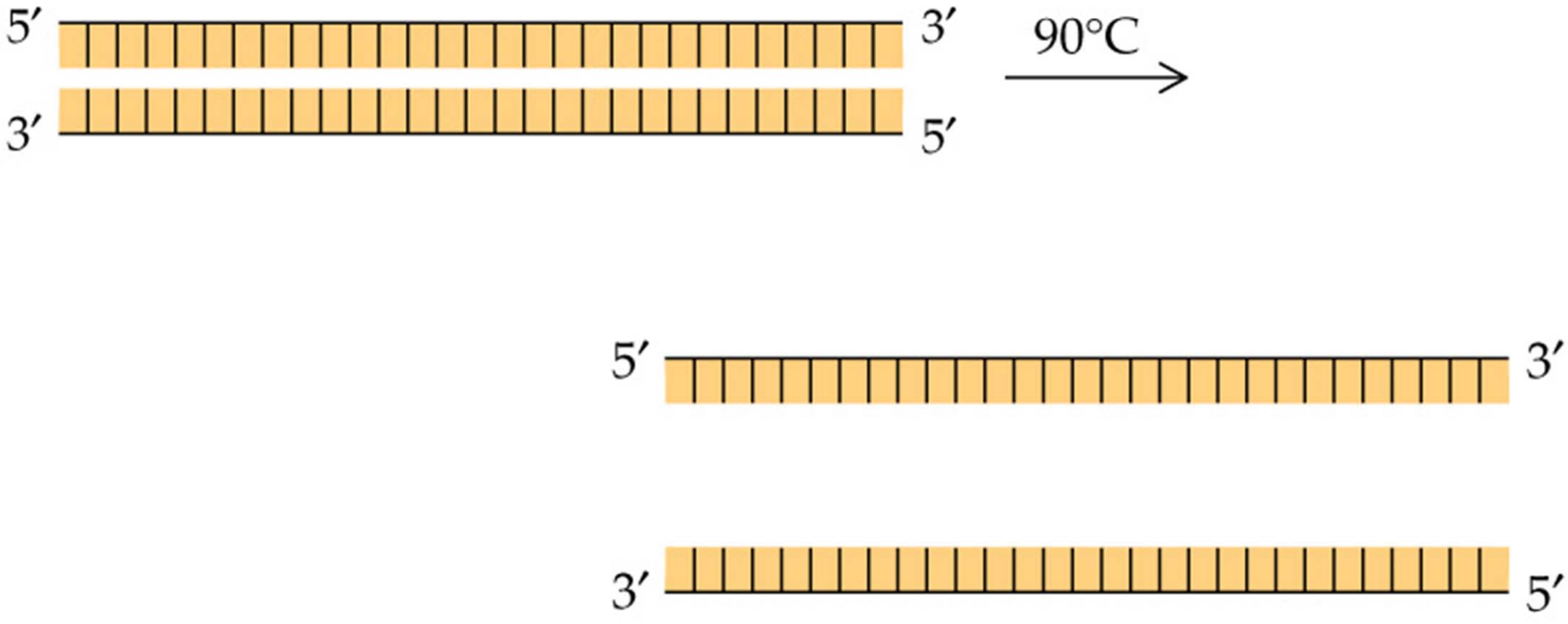
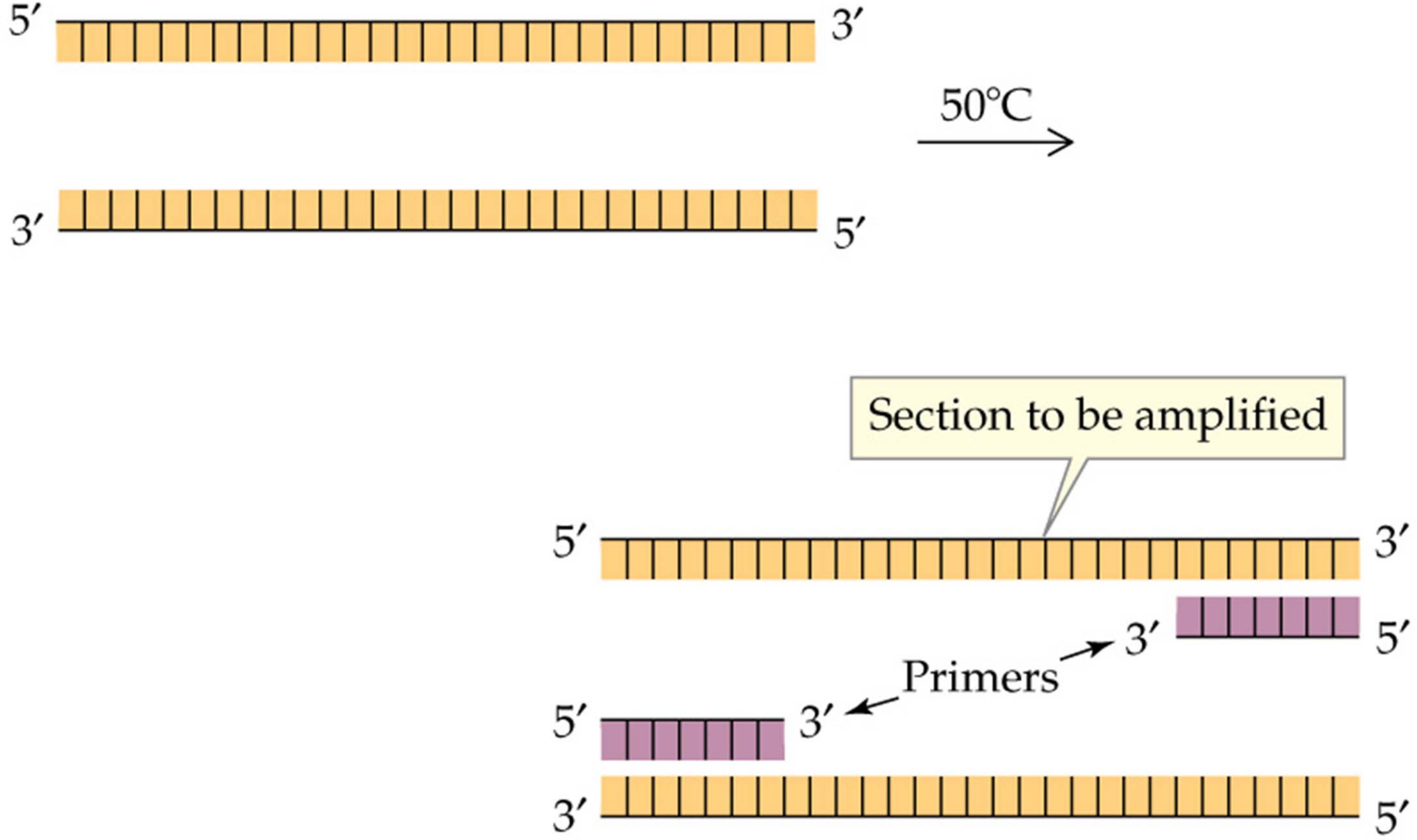
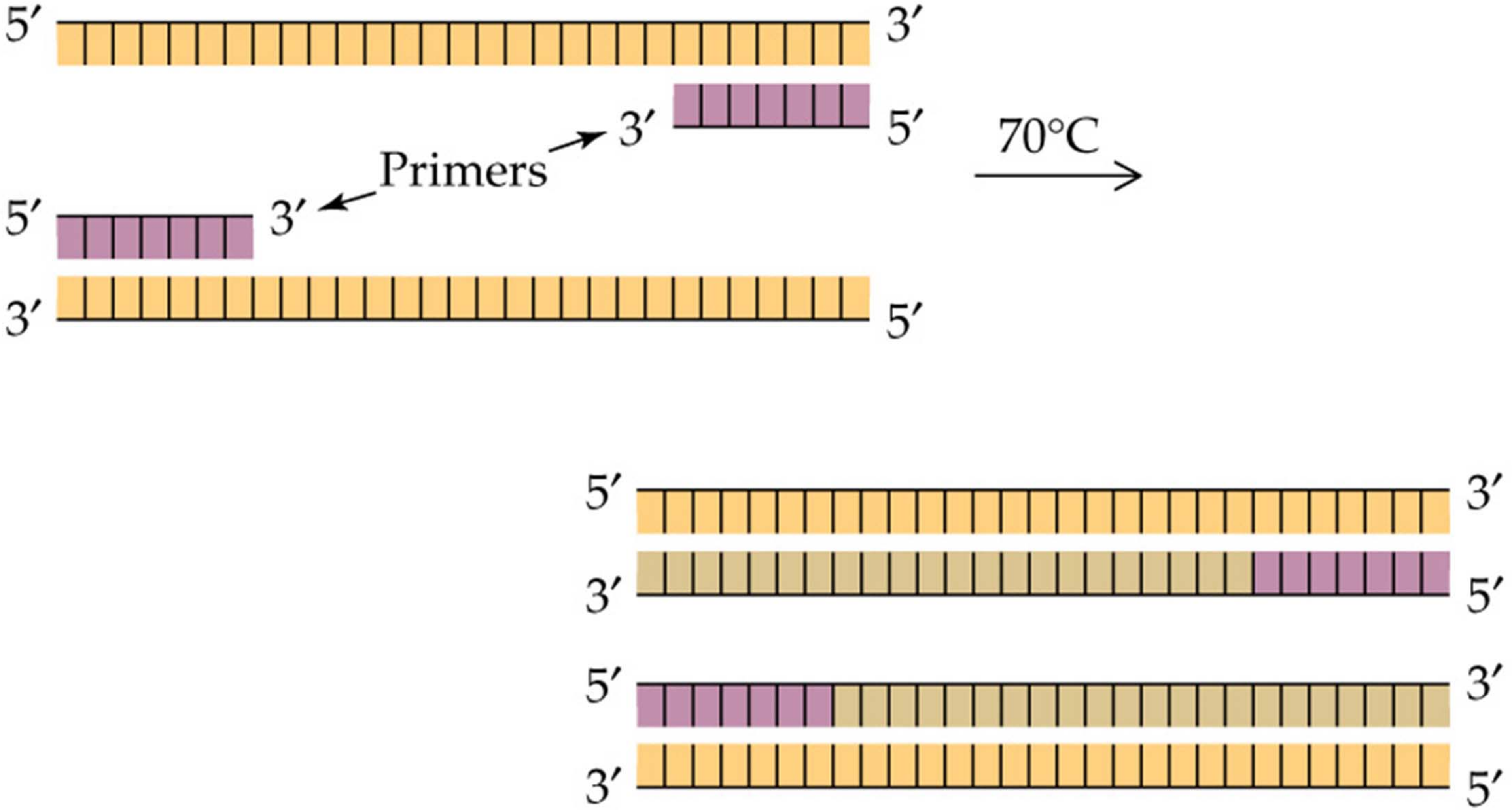
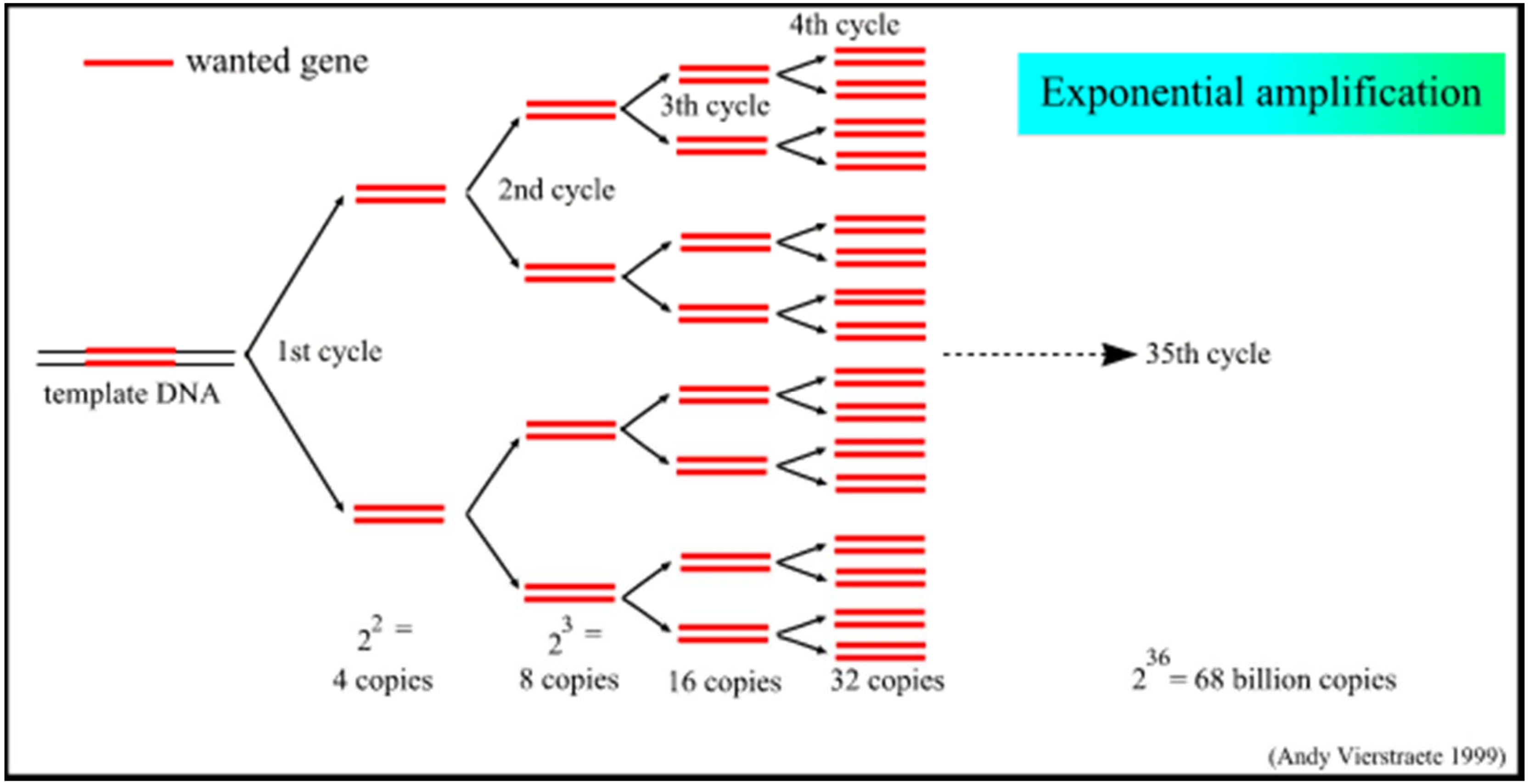

PCR : Polymerase Chain Reaction
30 - 40 cycles of 3 steps :
Step 1 : denaturation
1 minut 94 °C
Step 2 : annealing
45 seconds 54 °C
forward and reverse primers !!!
Step 3 : extension
2 minutes 72 °C
only dNTP's
5'
3'
(Andy Vierstraete 1999)

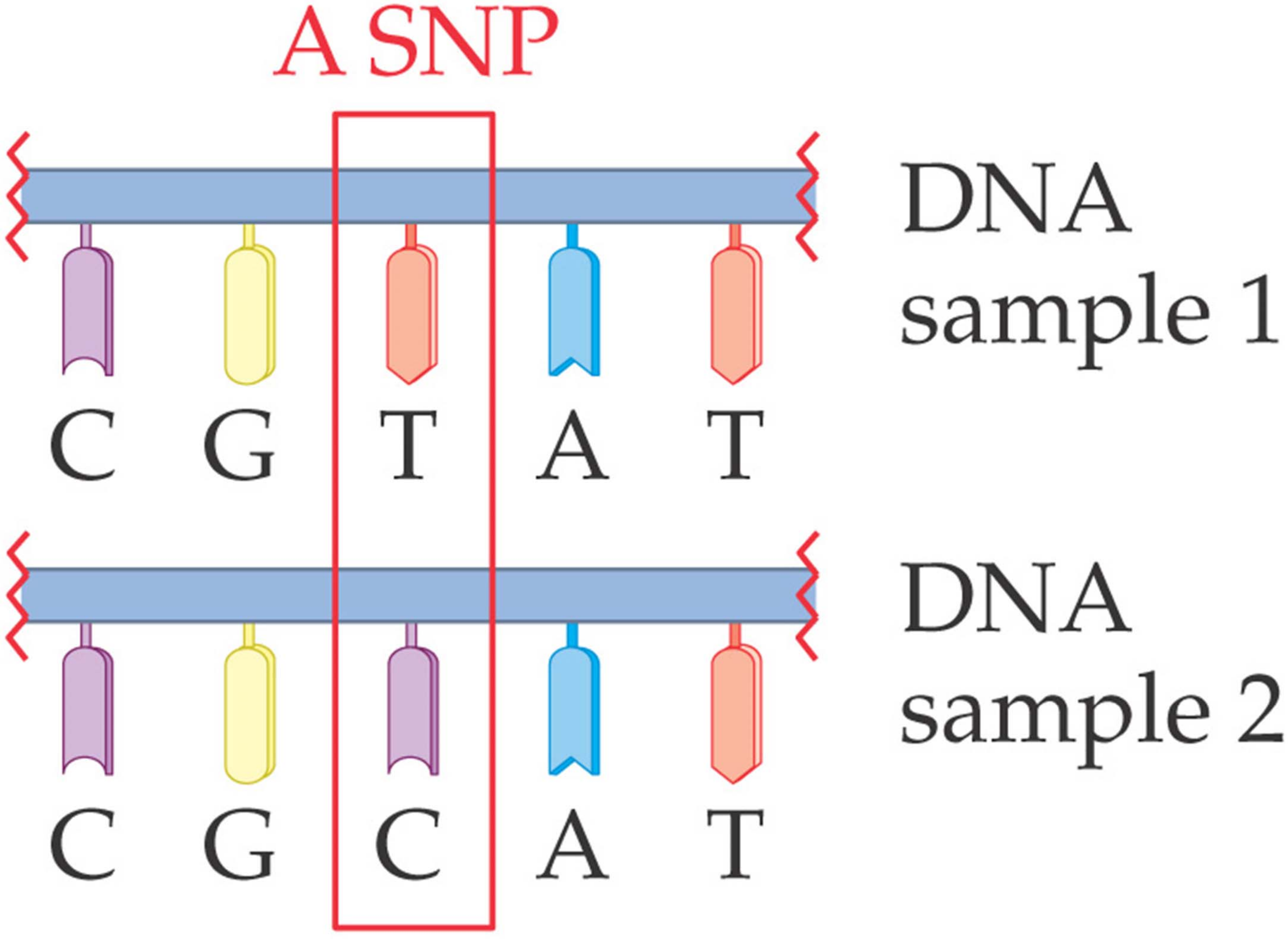

5′
3′
3′
5′
90°C
5′
3′
3′
5′

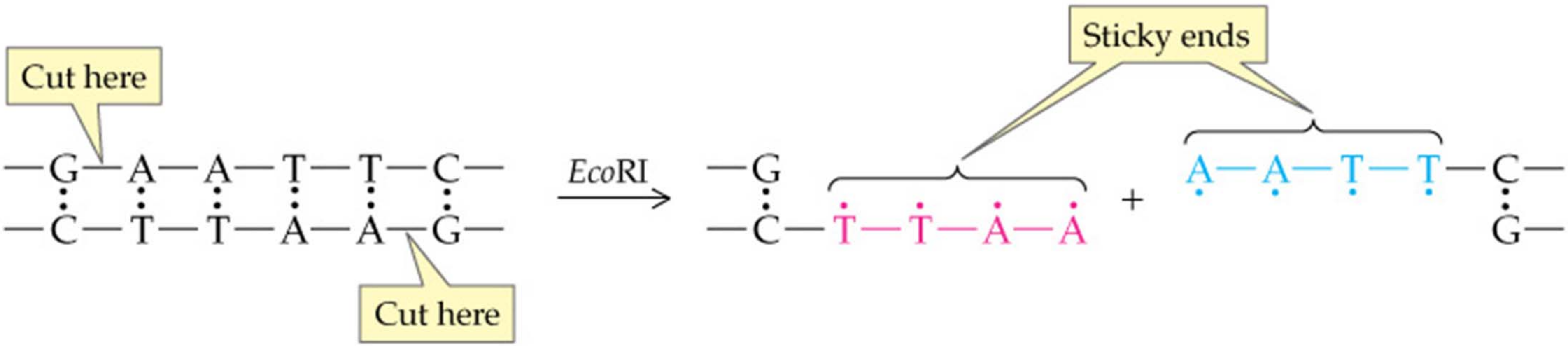

5′
3′
3′
5′
50°C
Section to be amplified
5′
3′
3′
5′
Primers
5′
3′
3′
5′

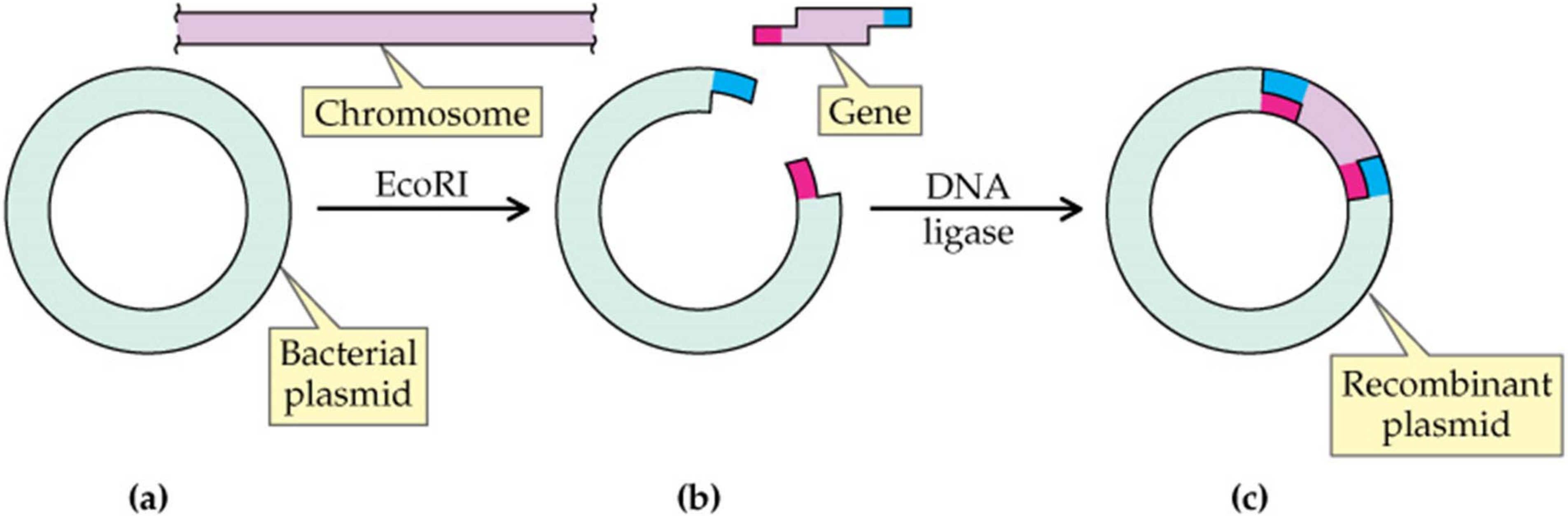


5′
3′
3′
5′
Primers
5′
3′
70°C
3′
5′
5′
3′
3′
5′
5′
3′
3′
5′


wanted gene
Exponential amplification
template DNA
1st cycle
2nd cycle
3th cycle
4th cycle
35th cycle
2^2 =
4 copies
2^3 =
8 copies
16 copies
32 copies
2^36 = 68 billion copies
(Andy Vierstraete 1999)

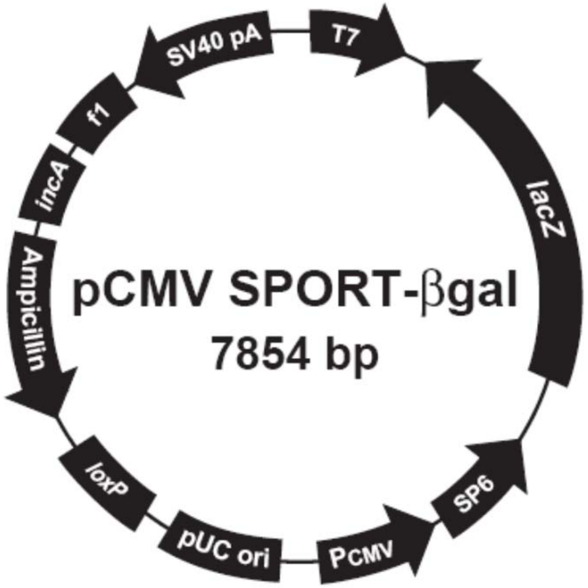

A SNP
DNA
sample 1
C G T A T
DNA
sample 2
C G C A T

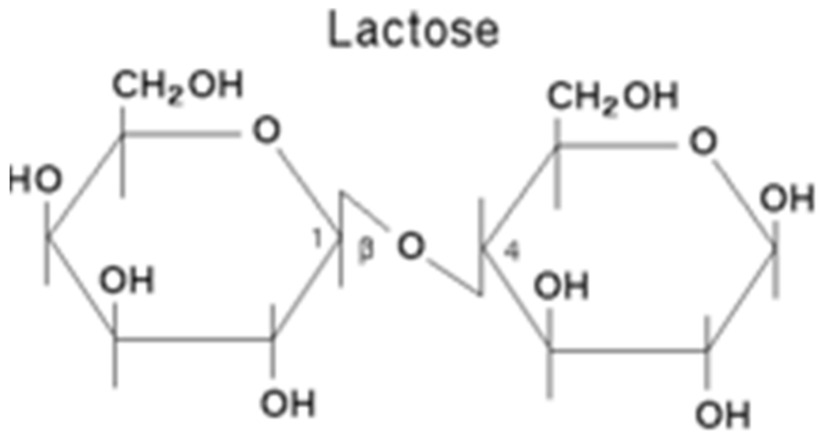

Cut here
—G—A—A—T—T—C—
—C—T—T—A—A—G—
Cut here
EcoRI
Sticky ends
—G
—C—T—T—A—A
+
A—A—T—T—C—
G—


Chromosome
Gene
EcoRI
DNA ligase
Bacterial plasmid
Recombinant plasmid
(a)
(b)
(c)

β-Galactosidase

The enzyme that splits lactose into glucose and galactose. Coded by a gene (lacZ) in the lac operon of Escherichia coli.





PUC is a family of plasmids that have an ampicillin resistance gene and more importantly a *lacZ* gene. A functional lacZ gene will produce the protein β - galactosidase. Bacterial colonies in which β - galactosidase is produced, will form blue colonies in the presence of the substrate 5 - bromo - 4 - chloro - 3 - indolyl - b - D - galactoside or as it is more commonly referred to, X-gal.

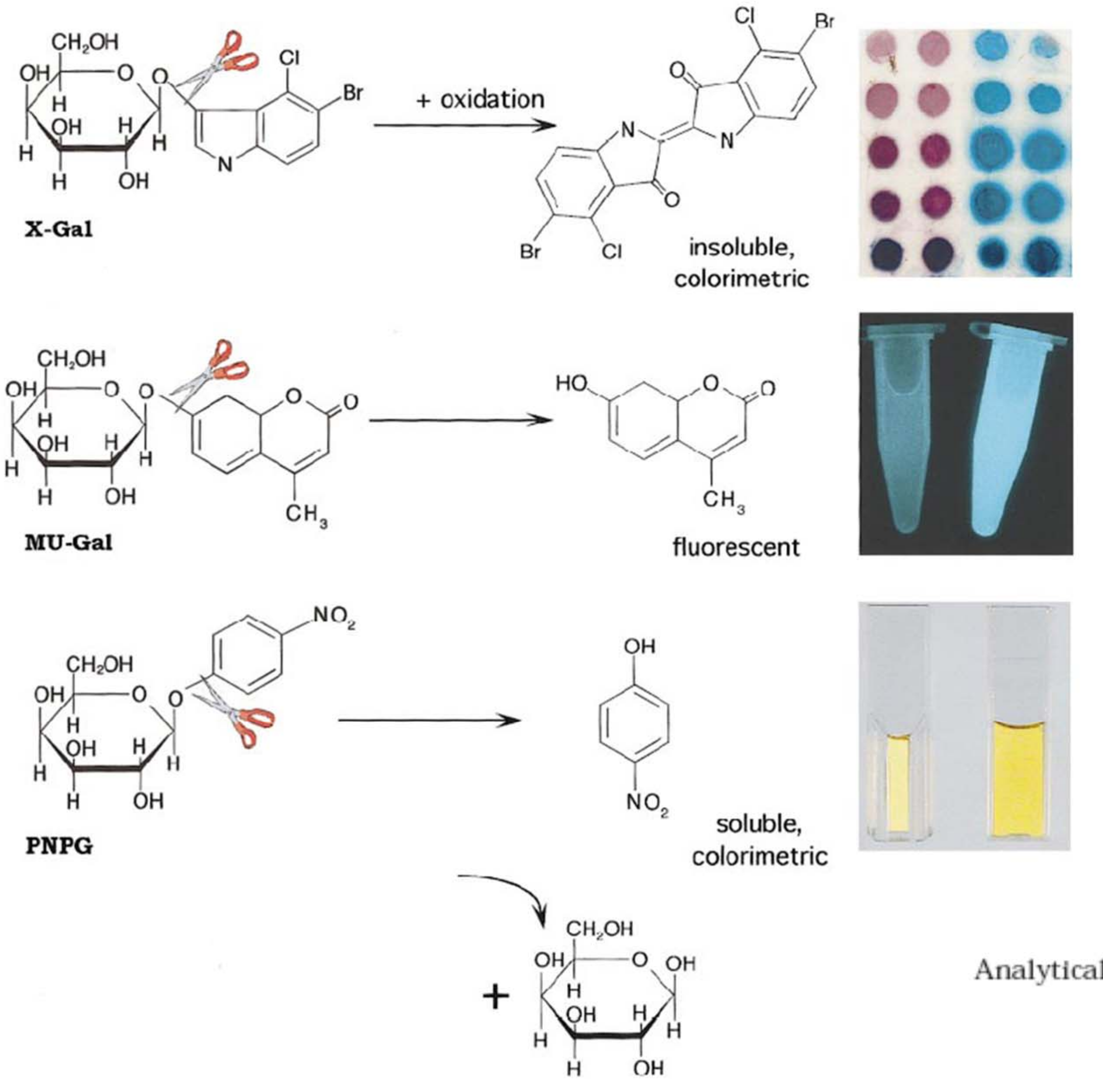


FIG. 1. Enzymatic function of β-galactosidase in cleaving indicator substrates. β-gal cleaves β-D-galactoside containing substrates with a diverse range of aglycone groups, targeting between the glycosyl oxygen and anomeric carbon as indicated (scissors). Substrates shown indicate commonly used indicators for assays on β-gal function on plates (X-Gal) or for liquid assay by measure of fluorescence (MU-Gal or MUG) or color (ONPG). Top left, X-Gal is 5-bromo-4-chloro-3-indolyl-β-D-galactoside, and when cleaved and oxidized produces the insoluble dye 5-bromo-4-chloro-indigo, as described previously (22). Right panel, top, yeast colonies expressing β-gal and exposed to X-Gal (right half) or the closely related compound Magenta-Gal (left half, see Biosynth, Inc., or Diagnostic Chemicals Limited). Middle left, MUG is methylumbelliferyl-β-D-galactoside, and when cleaved by β-gal produces the fluorescent product methylumbelliferone (first described in (102)). Right panel, middle, shows yeast lysates expressing β-gal exposed to MUG, under long-wave UV. Bottom left, PNPG and ONPG are closely related nitrophenol-β-D-galactosides with similar assay properties, e.g., (103), whose cleavage releases the yellow product nitrophenol (right panel, bottom); PNPG is shown.

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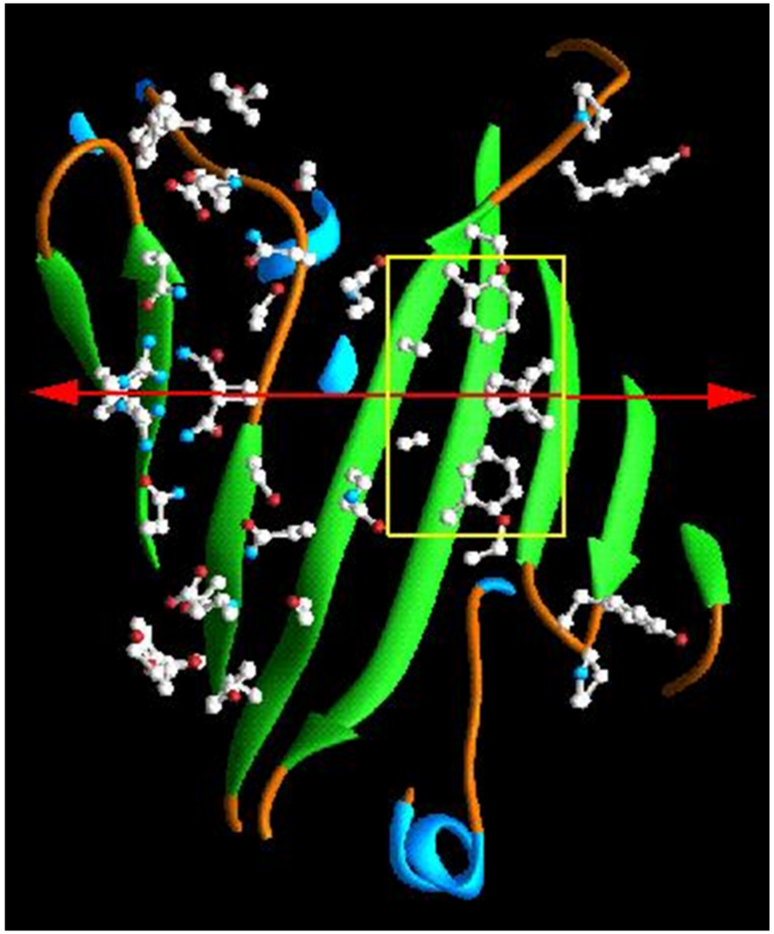
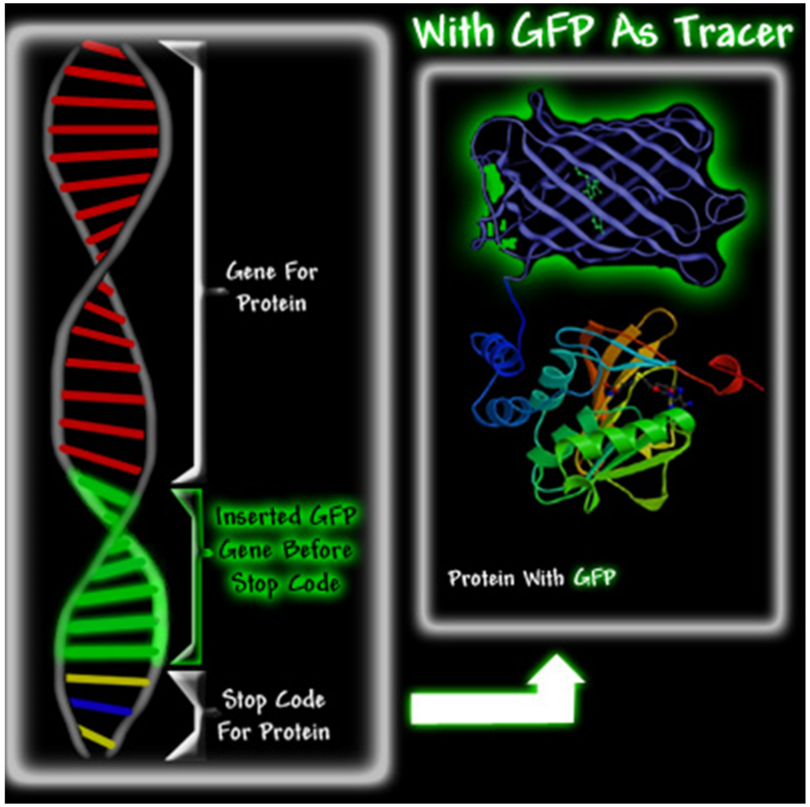
Green Fluorescent Protein (GFP)

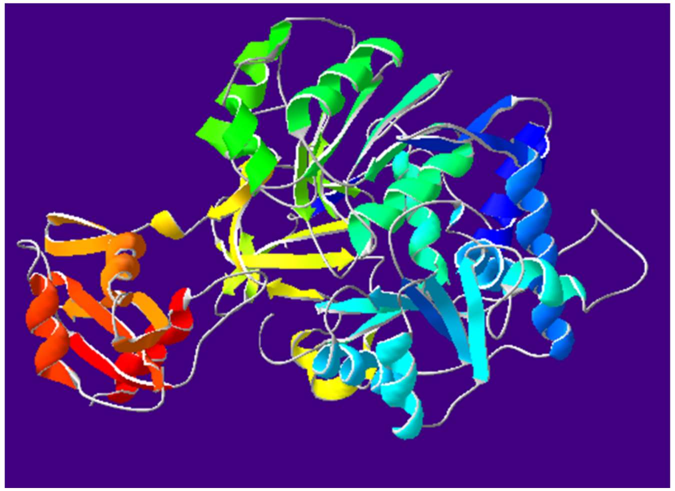


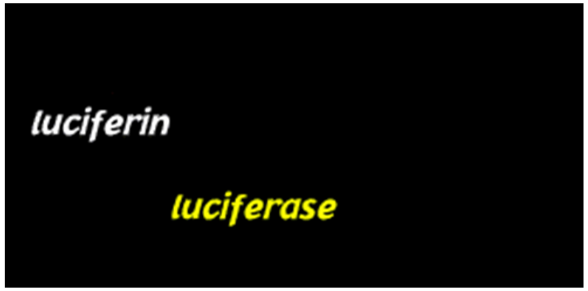
The **green fluorescent protein** (**GFP**) is a protein from the jellyfish *Aequorea victoria* that fluoresces green when exposed to blue light.



GFP Rats

Luciferase



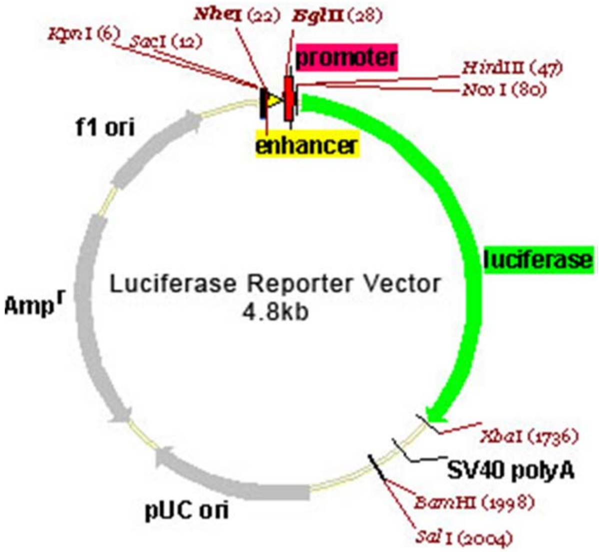


Luciferase is a generic name for enzymes commonly used in nature for bioluminescence. The name itself is derived from *Lucifer*, which means *light-bearer*. The most famous one is firefly luciferase from the firefly *Photinus pyralis*. In luminescent reactions, light is produced by the oxidation of a luciferin (a pigment), sometimes involving Adenosine triphosphate (ATP). The rates of this reaction between luciferin and oxygen are extremely slow until they are catalyzed by luciferase, often mediated by the presence of calcium ions (an analog of muscle contraction). The reaction takes place in two steps:

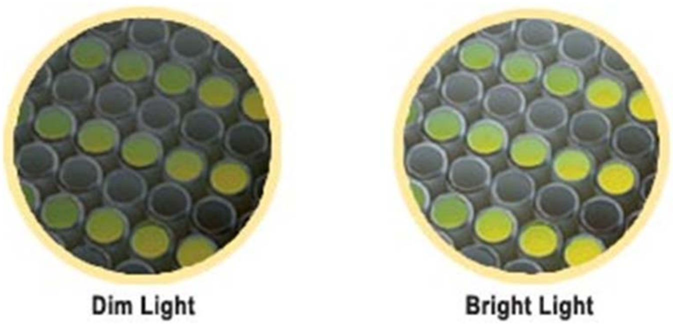
luciferin + ATP → luciferyl adenylate + PPi

luciferyl adenylate + O2 → oxyluciferin + AMP + light

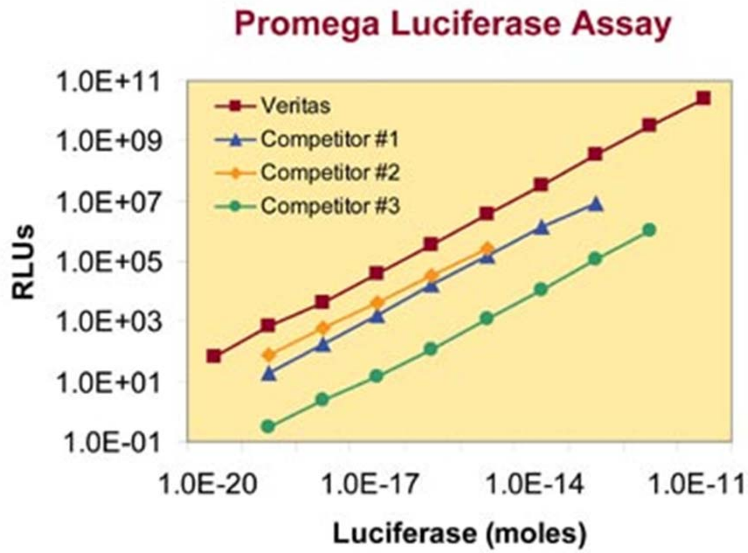
Luciferase



NheI (22)
BglII (28)
KpnI (6)
SacI (12)
promoter
HindIII (47)
NcoI (80)
f1 ori
enhancer
luciferase
Luciferase Reporter Vector
4.8kb
Amp^r
XbaI (1736)
SV40 polyA
BamHI (1998)
pUC ori
SalI (2004)



Dim Light
Bright Light



Promega Luciferase Assay
Veritas
Competitor #1
Competitor #2
Competitor #3
RLUs
1.0E+11
1.0E+09
1.0E+07
1.0E+05
1.0E+03
1.0E+01
1.0E-01
1.0E-20
1.0E-17
1.0E-14
1.0E-11
Luciferase (moles)

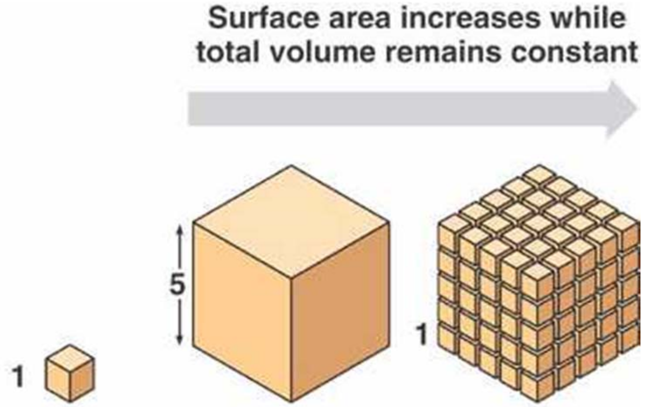
Second letter

First letter	U		C		A		G		Third letter
U	UUU UUC UUA UUG	Phe Leu	UCU UCC UCA UCG	Ser	UAU UAC UAA UAG	Tyr Stop Stop	UGU UGC UGA UGG	Cys Stop Trp	U C A G
C	CUU CUC CUA CUG	Leu	CCU CCC CCA CCG	Pro	CAU CAC CAA CAG	His Gin	CGU CGC CGA CGG	Arg	U C A G
A	AUU AUC AUA AUG	Ile Met	ACU ACC ACA ACG	Thr	AAU AAC AAA AAG	Asn Lys	AGU AGC AGA AGG	Ser Arg	U C A G
G	GUU GUC GUA GUG	Val	GCU GCC GCA GCG	Ala	GAU GAC GAA GAG	Asp Glu	GGU GGC GGA GGG	Gly	U C A G

Nanomaterials

- Metals and Alloys
  - Fe, Al, Au
- Semiconductors
  - Band gap, CdS, TiO_2, ZnO
- Ceramic
  - Al_2O_3, Si_3N_4, MgO, , SiO_2, ZrO_2
- Carbon based
  - Diamond, graphite, nanotube, C60, graphene
- Polymers
  - Soft mater, block co-polymer
- Biological
  - Photonic, hydrophobic, adhesive,
- Composites

Surface to Volume Ratio



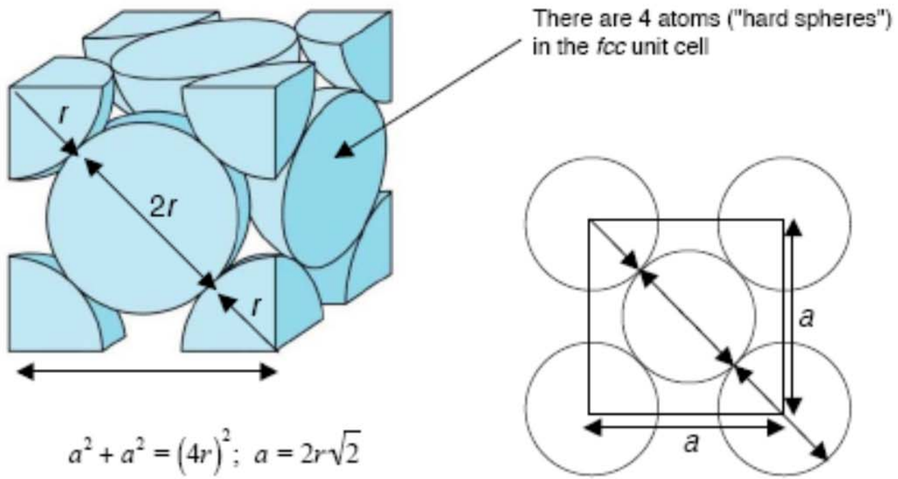
Total surface area (height × width × number of sides × number of boxes)	6	150	750
Total volume (height × width × length × number of boxes)	1	125	125
Surface-to-volume ratio (surface area / volume)	6	1.2	6

Surface to Volume Ratio

Au: AAA
Atomic mass: 196.967
Density 19.31
Radii =0.144 nm

Number of Au atoms in 1 m	$3.4\ 10^{9}$
Volume of Au atom	$4.19\ 10^{28}$
Surface area Au atom	$7.22\ 10^{19}$
Surface/volume ratio	$1.72\ 10^{-9}$

fcc



$$a^2 + a^2 = (4r)^2; \; a = 2r\sqrt{2}$$

$$V_{unit\ cell} = a^3 = \left(2r\sqrt{2}\right)^3 = 16(r)^3\sqrt{2}$$

$$V_{unit\ cell} = a^3 = \left(2r\sqrt{2}\right)^3 = 16(0.5\text{nm})^3\sqrt{2} = \mathbf{2.828\ nm^3}$$

$$\frac{10^{27}\ \text{nm}^3}{2.828\ \text{nm}^3} = \mathbf{3.536x10^{26}\ nano\ \ unit\ cells}$$

$$\text{Collective Area} = 3.536x10^{26}\ \text{nano unit cells}\left(\frac{4\ \text{spheres}}{\text{unit cell}}\right)\left(\frac{4\pi r^2}{\text{sphere}}\right) = \mathbf{4.44x10^{27}\ nm^2}$$

$$\frac{S_{spheres}}{S_{unit\ cell}} = \frac{4.44x10^9\ \text{m}^2}{6.0x10^9\ \text{m}^2} = \mathbf{0.74}$$

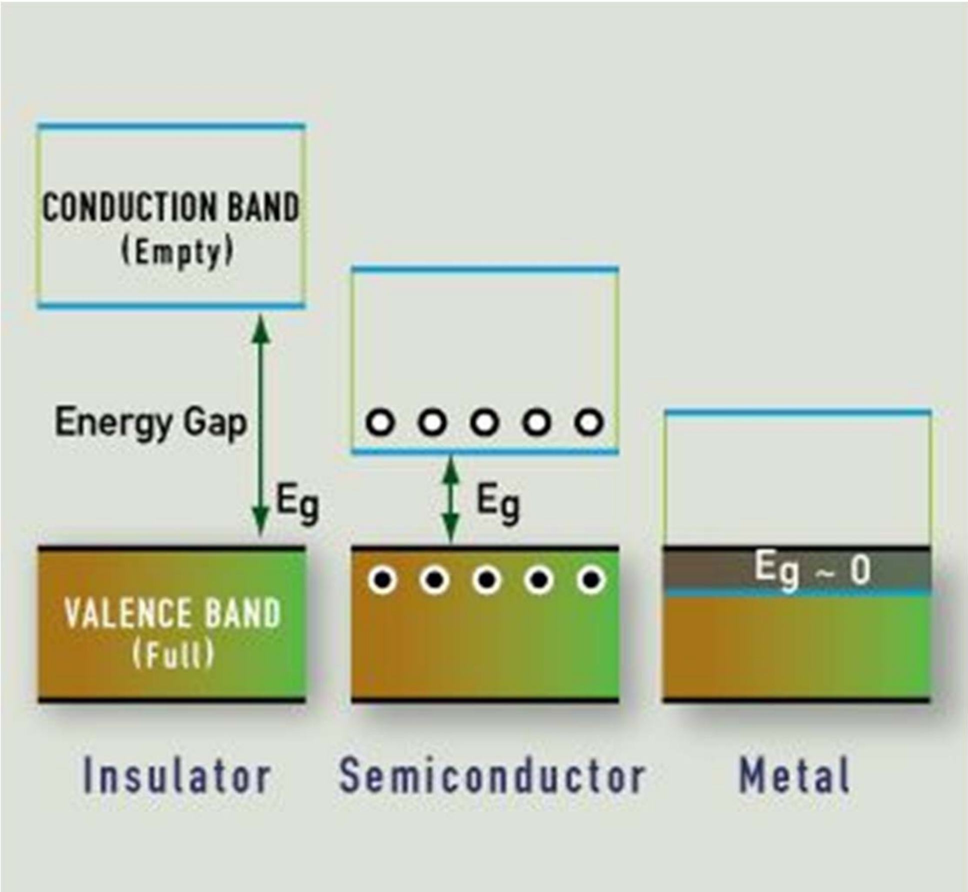
Packing Fraction

$$\mathrm{APF} = \frac{N_{\mathrm{atoms}} V_{\mathrm{atom}}}{V_{\mathrm{crystal}}}$$

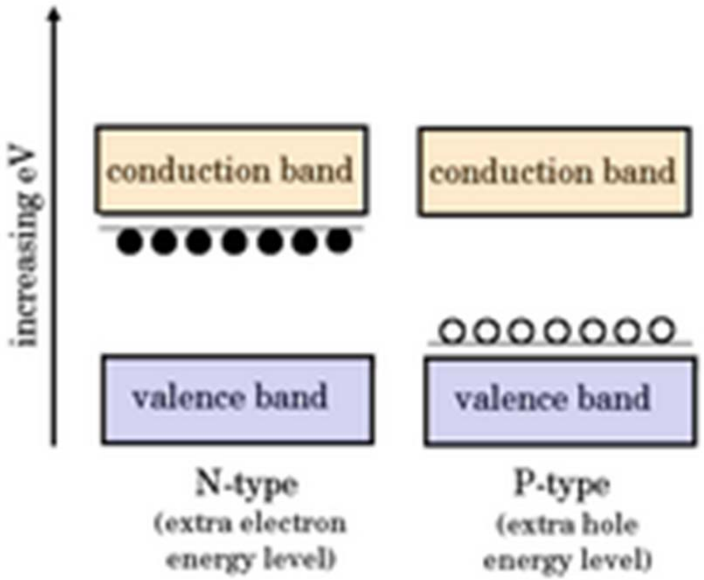
Surfaces

- Collective surface area of nanocube 1 nm
- Porous materials
  - Micropore (<2 nm)
  - Mesopore (2 nm ~ 50 nm)
  - Marcopore (> 50nm)
- Void volume
  - $V_{pore}/V_{material}$

Bandgap

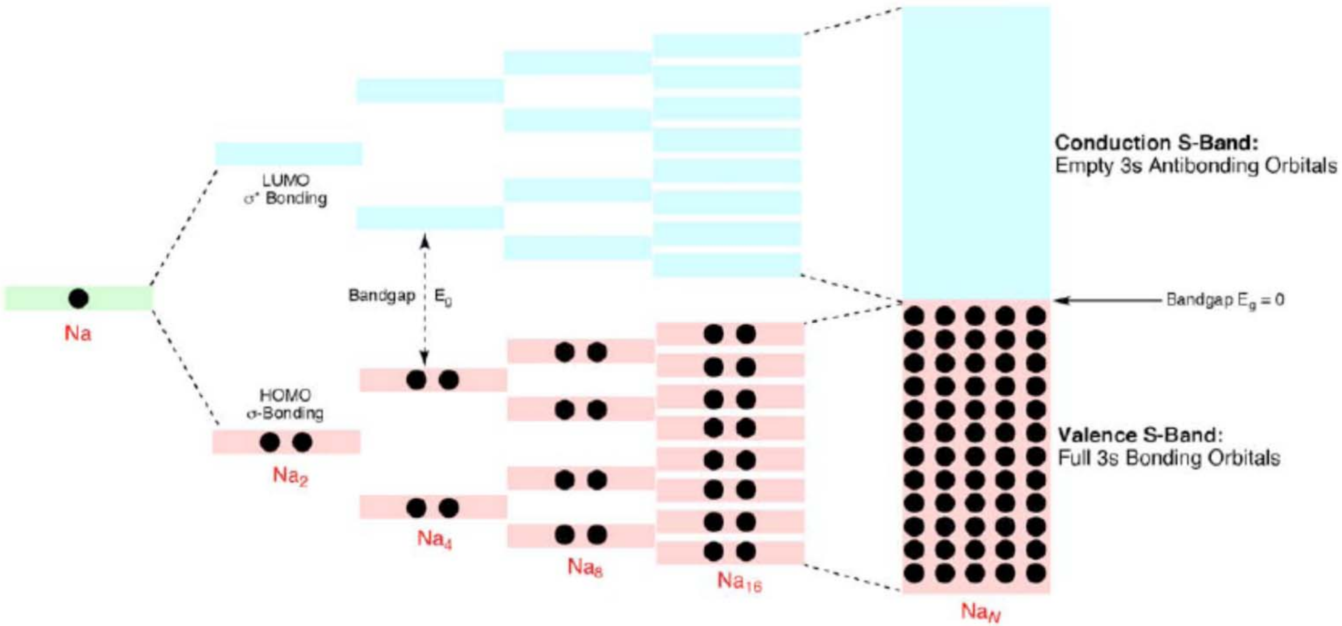


CONDUCTION BAND
(Empty)
Energy Gap
Eg
Eg
Eg ~ 0
VALENCE BAND
(Full)
Insulator
Semiconductor
Metal

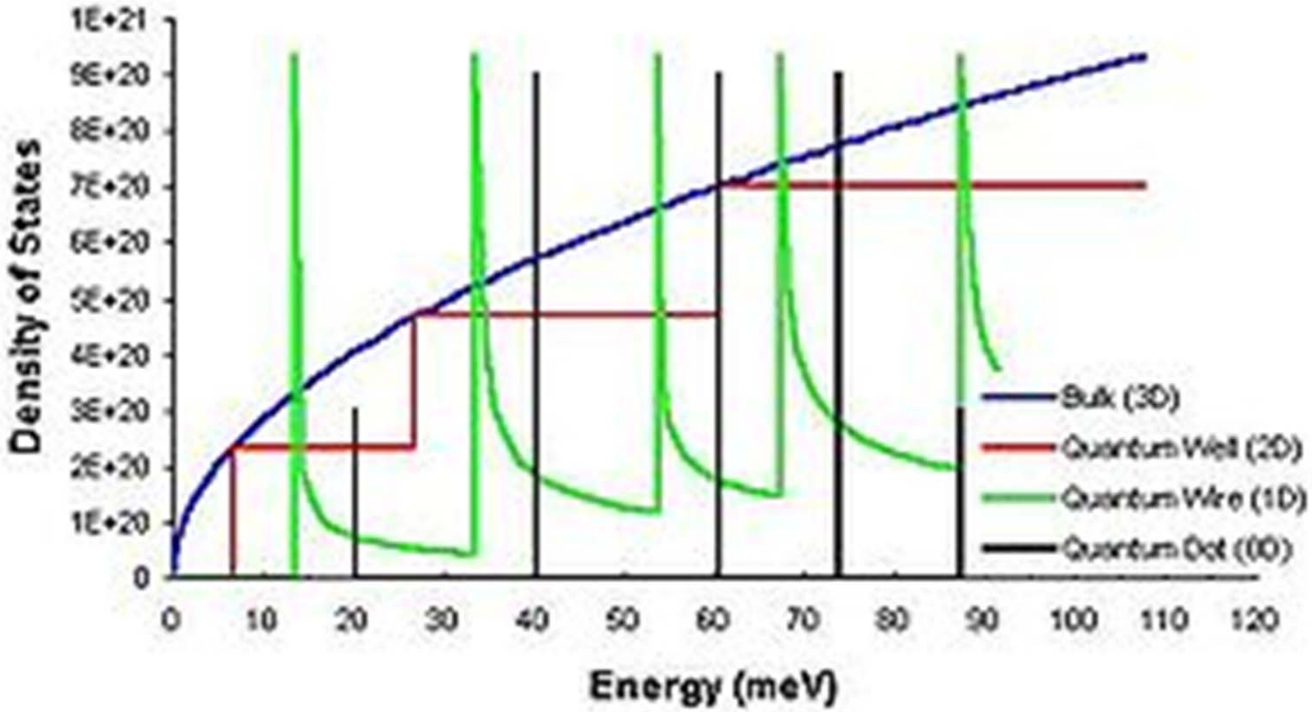


increasing eV
conduction band
conduction band
valence band
valence band
N-type
(extra electron
energy level)
P-type
(extra hole
energy level)

Bandgap

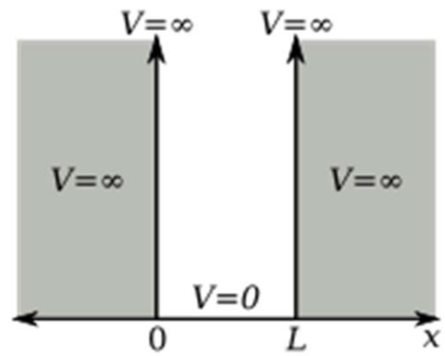

LUMO
σ* Bonding
Bandgap
E_0
HOMO
σ-Bonding
Na
Na_2
Na_4
Na_8
Na_{16}
Na_N
Conduction S-Band:
Empty 3s Antibonding Orbitals
Bandgap $E_g = 0$
Valence S-Band:
Full 3s Bonding Orbitals

Density of State



Particle in a Box

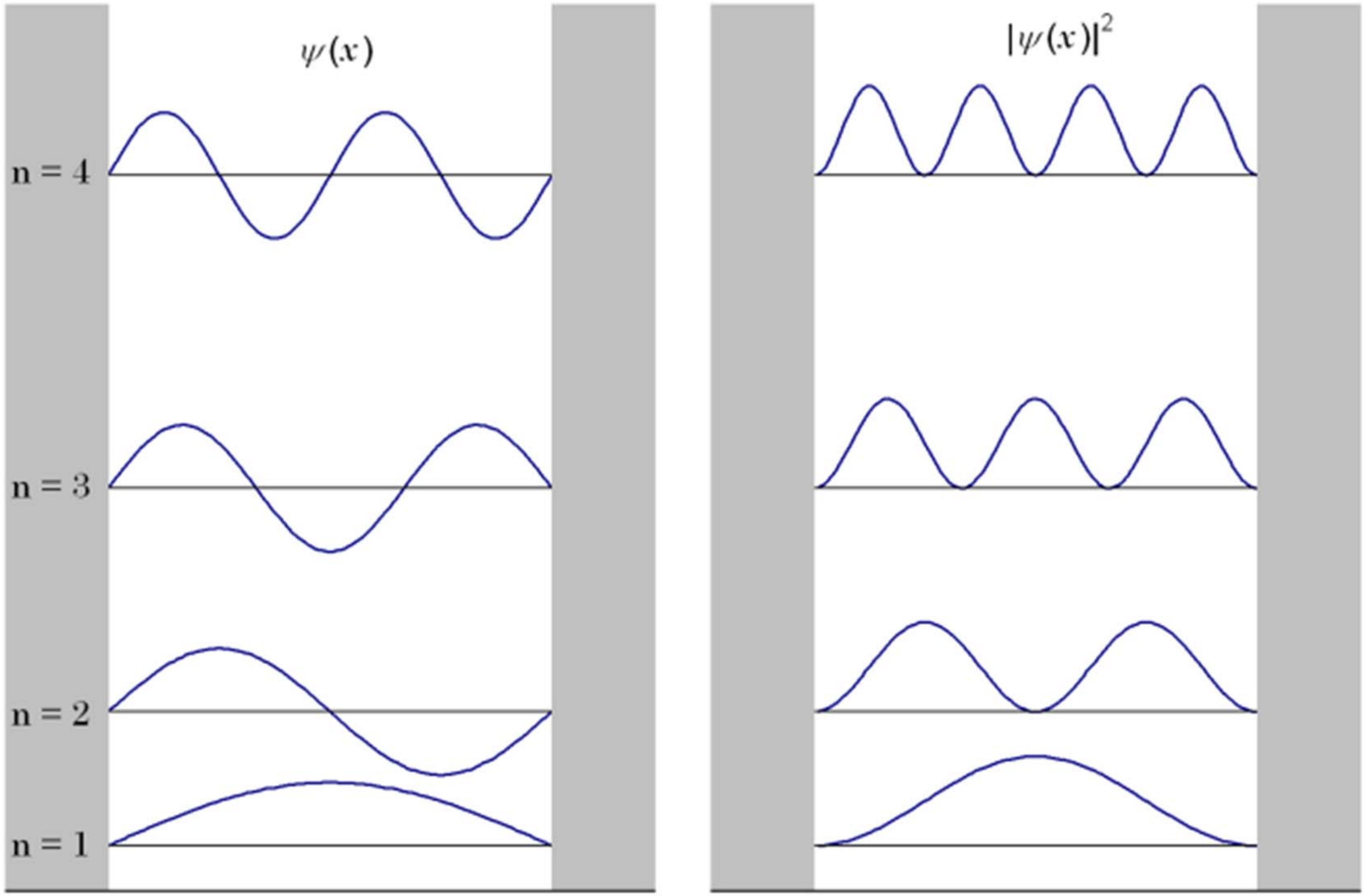
$$-\frac{\hbar^2}{2m}\frac{\mathrm{d}^2\psi(x)}{\mathrm{d}x^2} + V(x)\psi(x) = E\psi(x) \quad (1)$$



$$\psi_n = \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi x}{L}\right)$$

$$E_n = \frac{\hbar^2\pi^2}{2mL^2}n^2$$

Particle in a Box



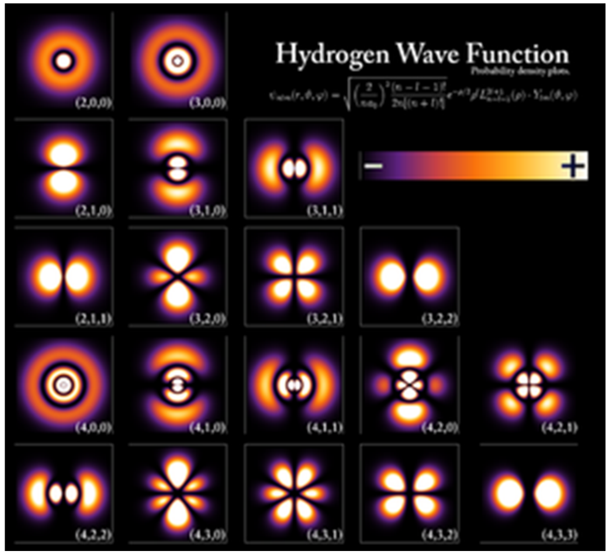
$$\psi_{n_x,n_y} = \sqrt{\frac{4}{L_x L_y}} \sin\left(\frac{n_x \pi x}{L_x}\right) \sin\left(\frac{n_y \pi y}{L_y}\right)$$

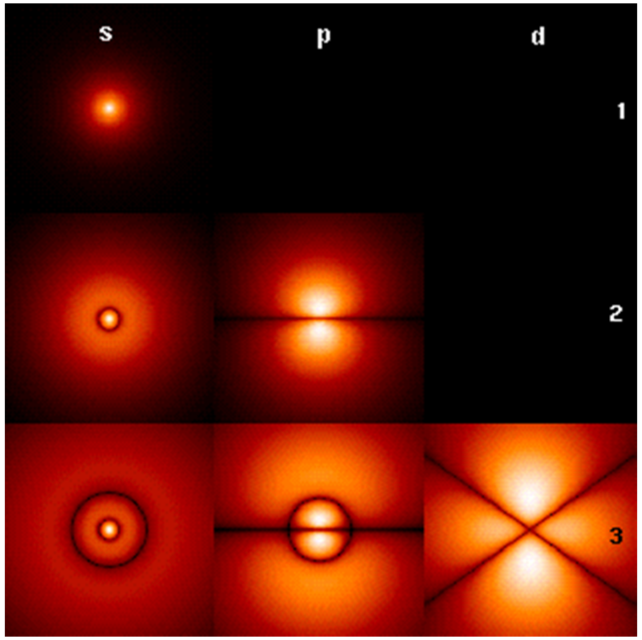
$$E_{n_x,n_y} = \frac{\hbar^2 \pi^2}{2m} \left[\left(\frac{n_x}{L_x}\right)^2 + \left(\frac{n_y}{L_y}\right)^2\right]$$

$$\psi_{n_x,n_y,n_z} = \sqrt{\frac{8}{L_x L_y L_z}} \sin\left(\frac{n_x \pi x}{L_x}\right) \sin\left(\frac{n_y \pi y}{L_y}\right) \sin\left(\frac{n_z \pi z}{L_z}\right) \quad (22)$$

$$E_{n_x,n_y,n_z} = \frac{\hbar^2 \pi^2}{2m} \left[\left(\frac{n_x}{L_x}\right)^2 + \left(\frac{n_y}{L_y}\right)^2 + \left(\frac{n_z}{L_z}\right)^2\right] \quad (23)$$

Wave Functions





$$i\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},\,t) = \hat{H}\Psi = \left(-\frac{\hbar^2}{2m}\nabla^2 + V(\mathbf{r})\right)\Psi(\mathbf{r},\,t) = -\frac{\hbar^2}{2m}\nabla^2\Psi(\mathbf{r},\,t) + V(\mathbf{r})\Psi(\mathbf{r},\,t)$$

$$V(r) = -\frac{1}{4\pi\epsilon_0}\frac{Ze^2}{r}$$

$$\psi_{n\ell m}(r,\vartheta,\varphi) = \sqrt{\left(\frac{2}{na_0}\right)^3\frac{(n-\ell-1)!}{2n(n+\ell)!}}e^{-\rho/2}\rho^\ell L^{2\ell+1}_{n-\ell-1}(\rho)\cdot Y^m_\ell(\vartheta,\varphi)$$

Linear combination of atomic orbitals molecular orbital method

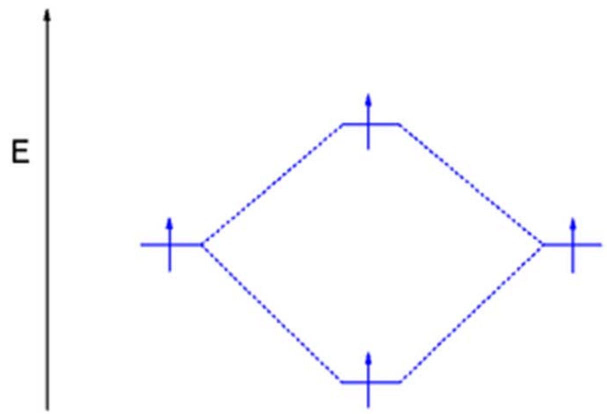
$$\phi_i = c_{1i}\chi_1 + c_{2i}\chi_2 + c_{3i}\chi_3 + \cdots + c_{ni}\chi_n$$

coefficient of AO_μ in MO_i

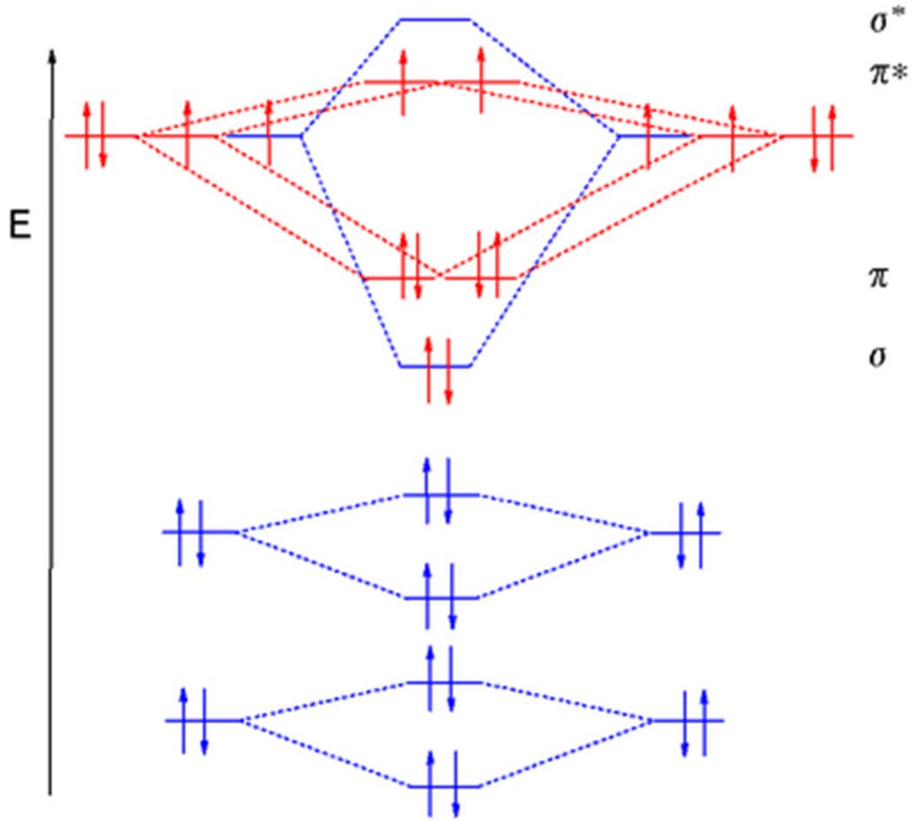
$$\psi_i = \sum_{\mu} c_{\mu i}\phi_\mu$$

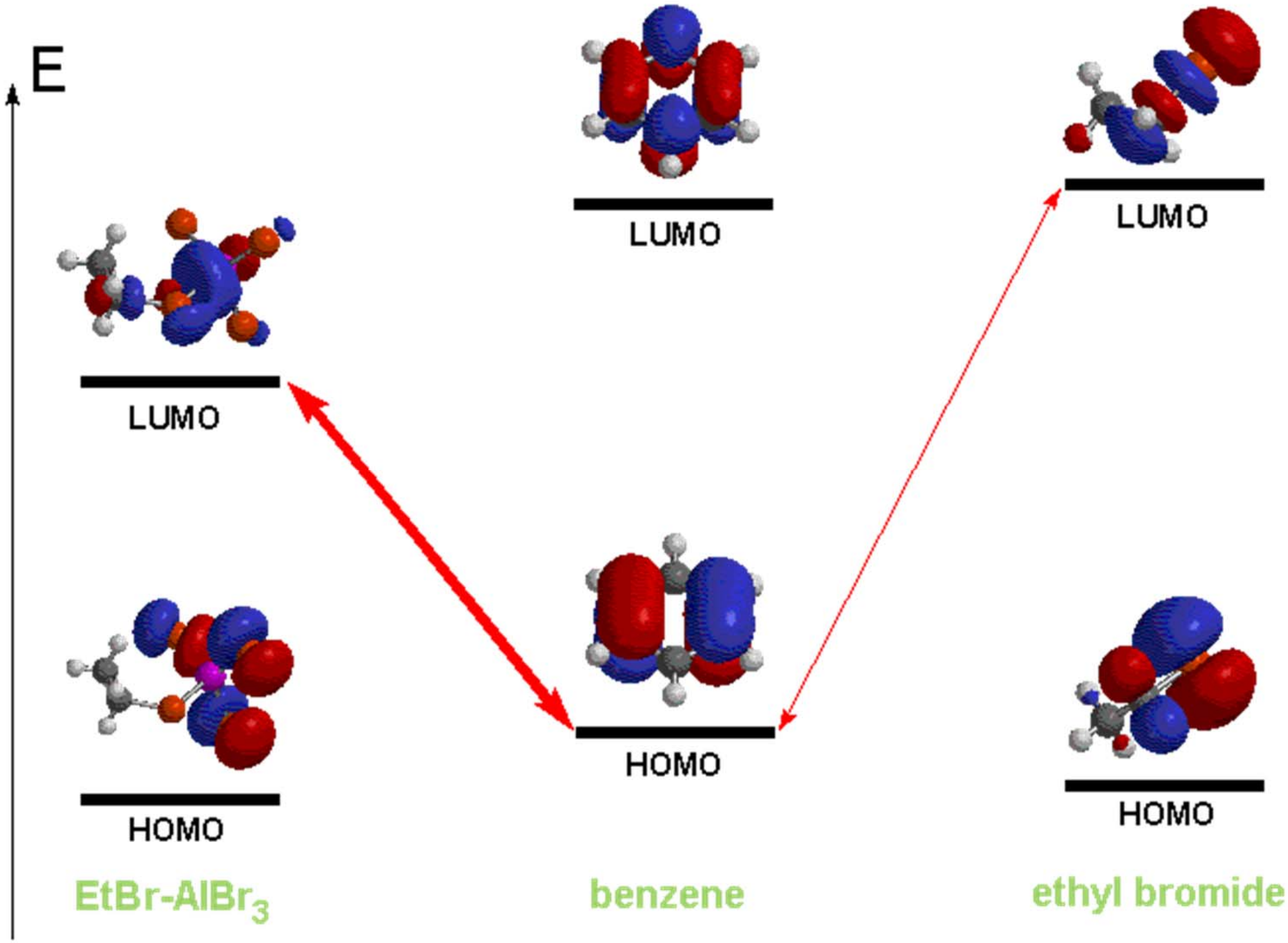
MO

AO

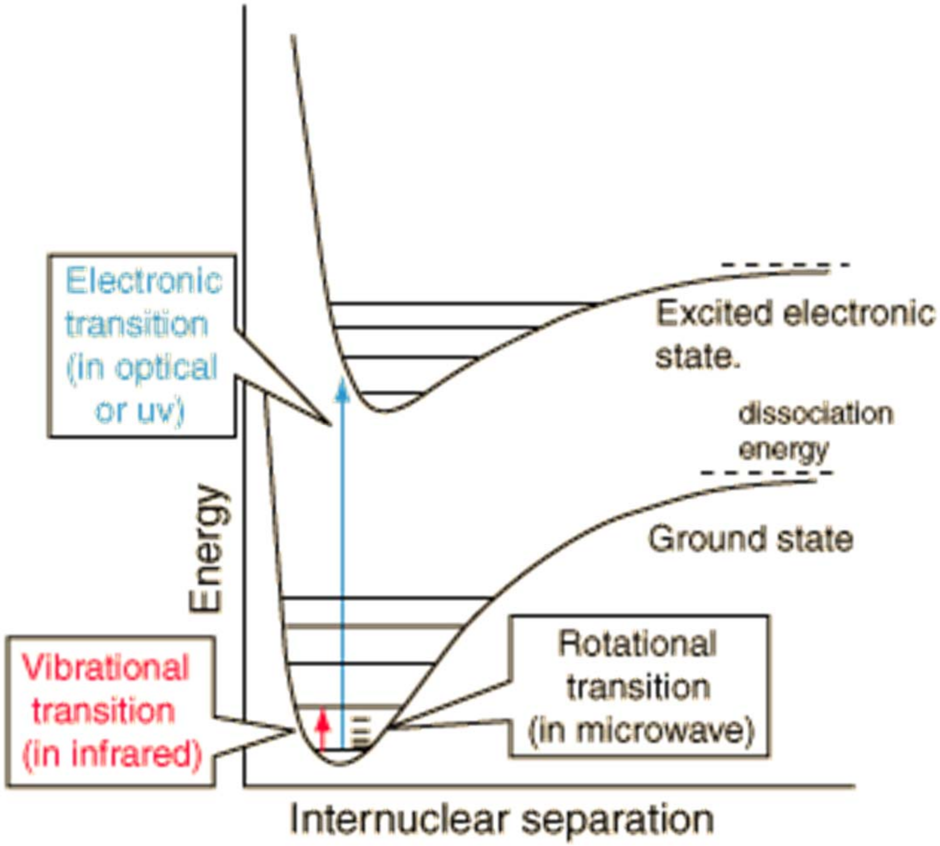


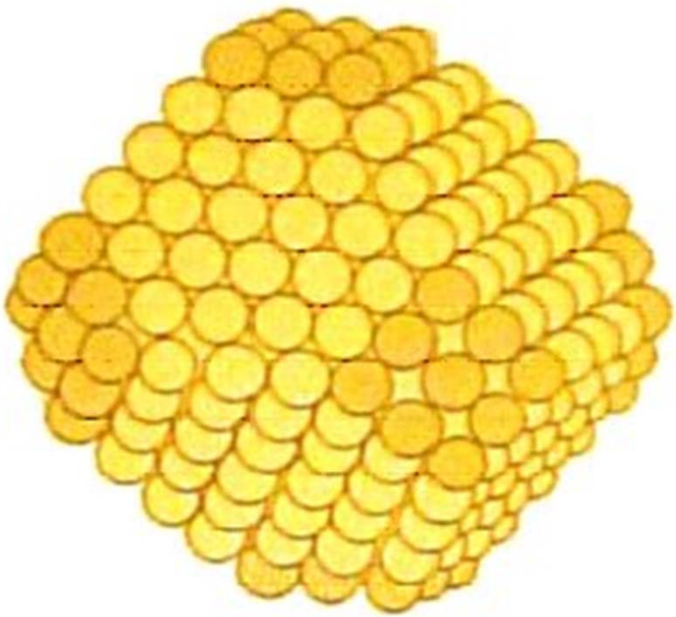
Oxygen





E
LUMO
LUMO
LUMO
HOMO
HOMO
HOMO
EtBr-AlBr$_3$
benzene
ethyl bromide


Electronic transition (in optical or uv)
Excited electronic state.
dissociation energy
Ground state
Energy
Vibrational transition (in infrared)
Rotational transition (in microwave)
Internuclear separation



GOLD CUBOCTAHAL CLUSTER

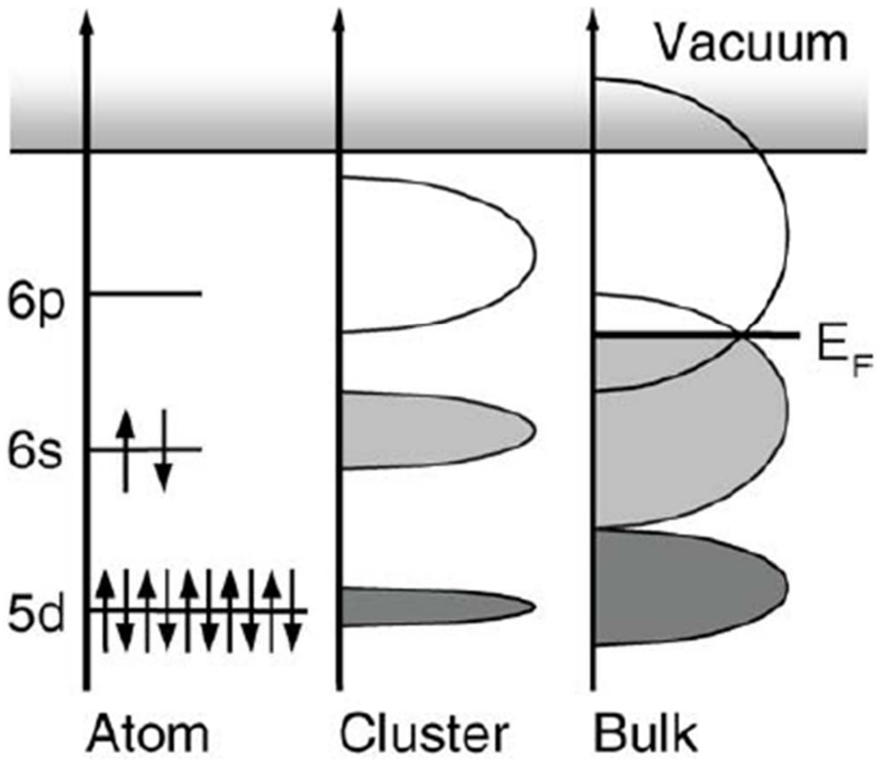


Figure 5 Energy diagram describing a generic Bloch-Wilson MIT in clusters (with specific reference to the energy levels of mercury). For sufficiently large clusters, the *s-p* band gap closes with increasing cluster size (shaded areas represent energy range with occupied electron levels). Overlap leads to a "continuous" DOS at E_F and to an Insulator to Metal transition.

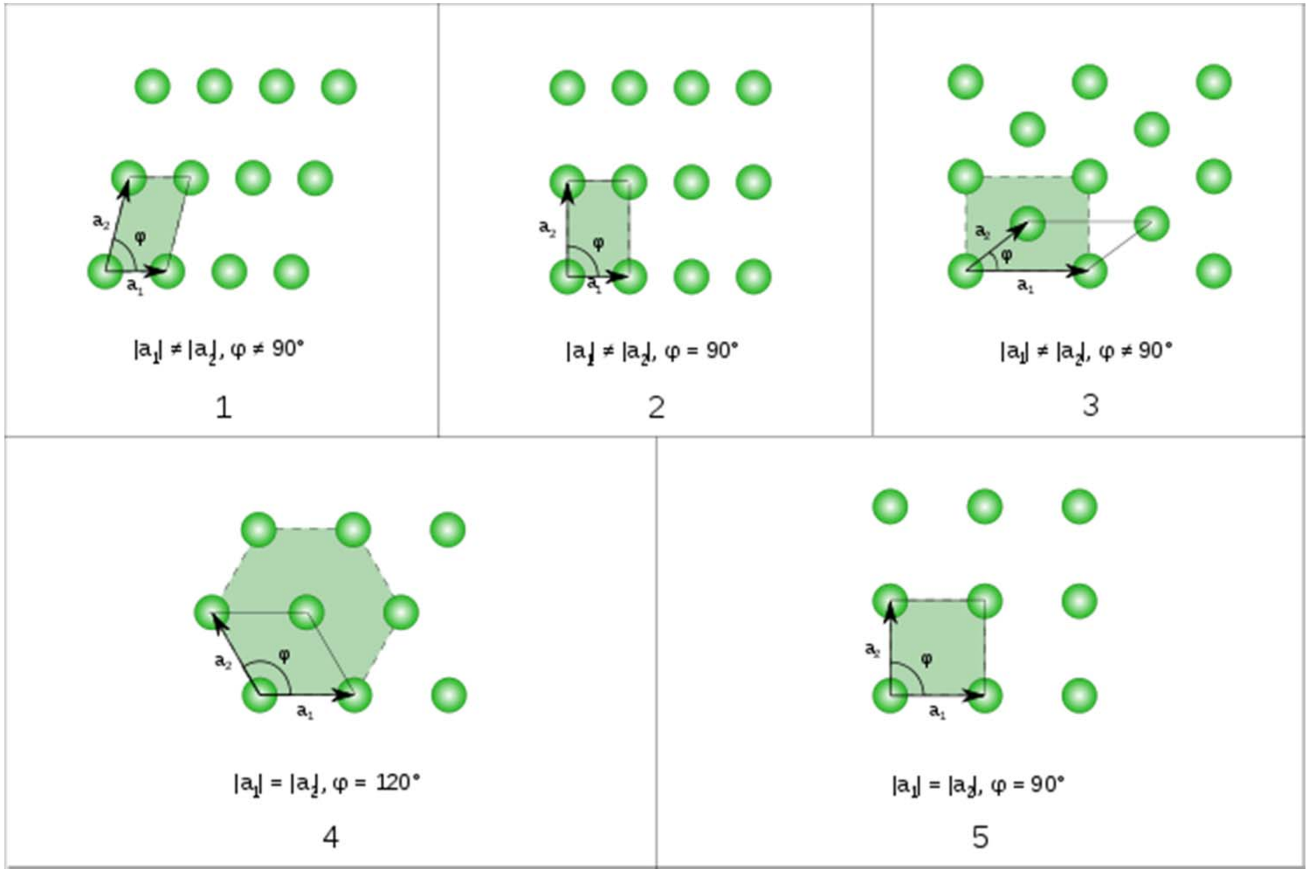
Bloch wave

$$\psi_{n\mathbf{k}}(\mathbf{r}) = e^{i\mathbf{k}\cdot\mathbf{r}} u_{n\mathbf{k}}(\mathbf{r})$$

A **Bloch wave** or **Bloch state**, named after Felix Bloch, is the wavefunction of a particle (usually, an electron) placed in a periodic potential.

$$\epsilon_n(\mathbf{k}) = \epsilon_n(\mathbf{k} + \mathbf{K}),$$

The five fundamental two-dimensional Bravais lattices



Unit Cell

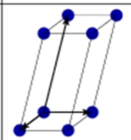
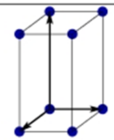
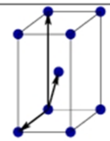
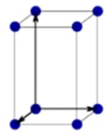
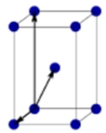
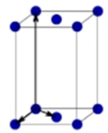
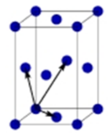
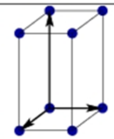
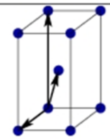
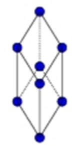
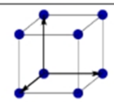
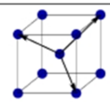
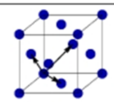
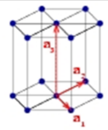
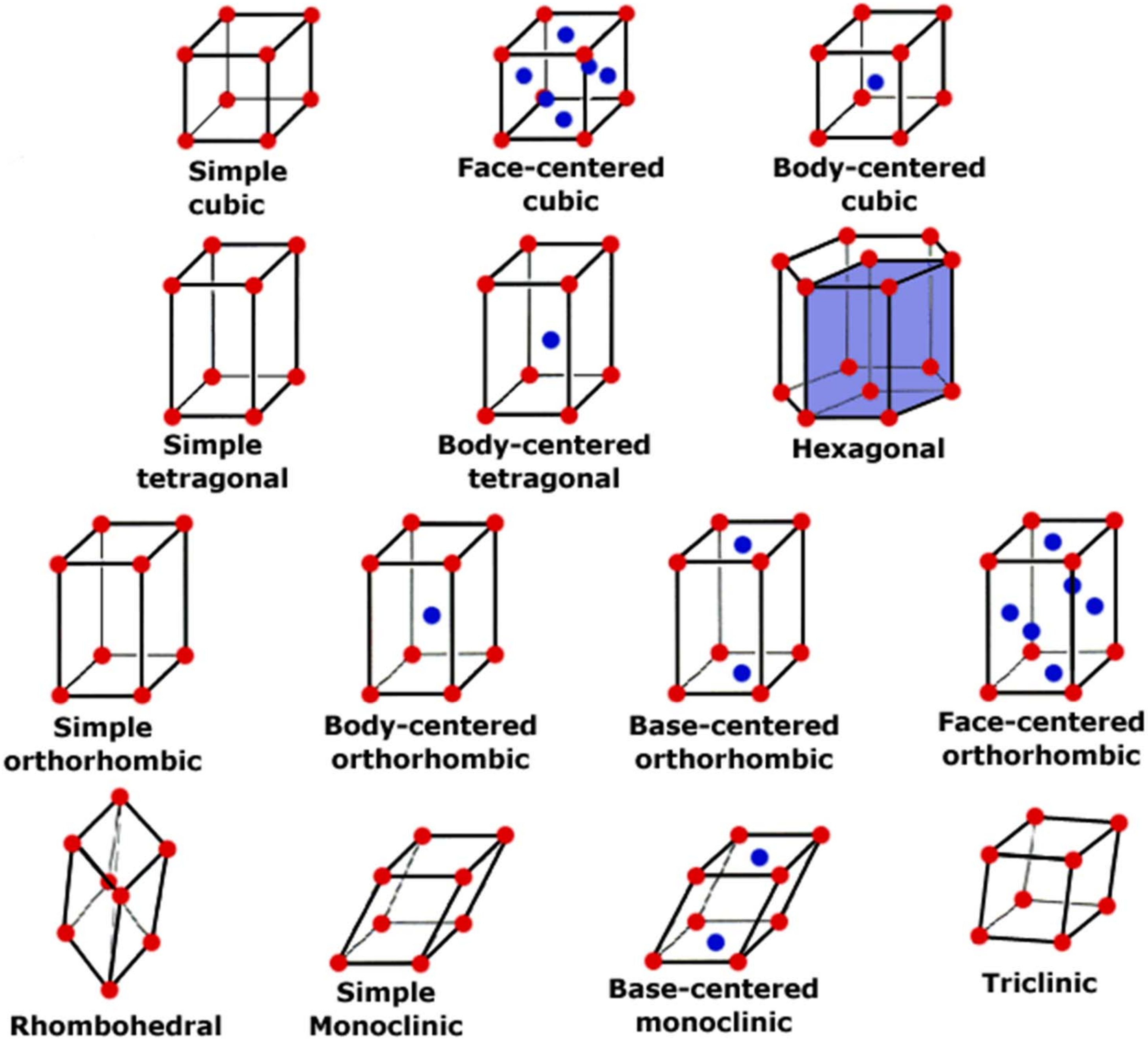
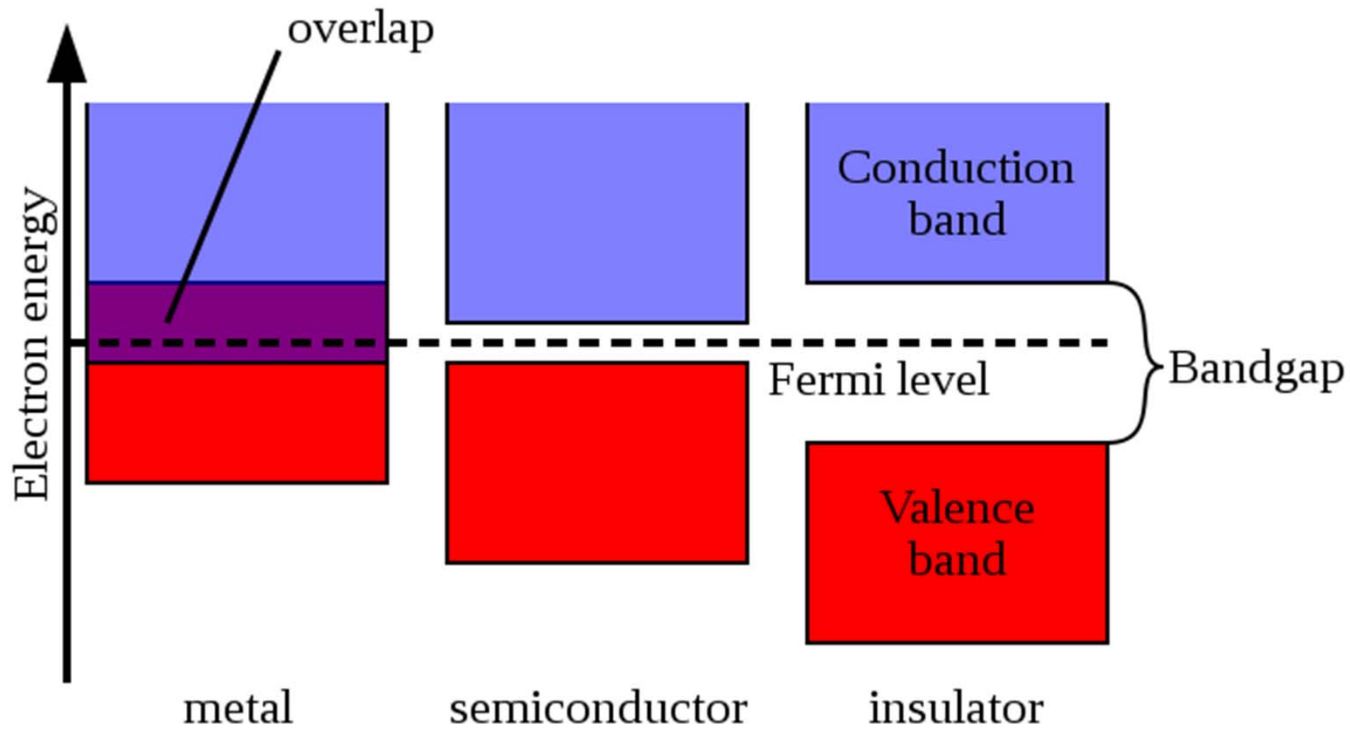
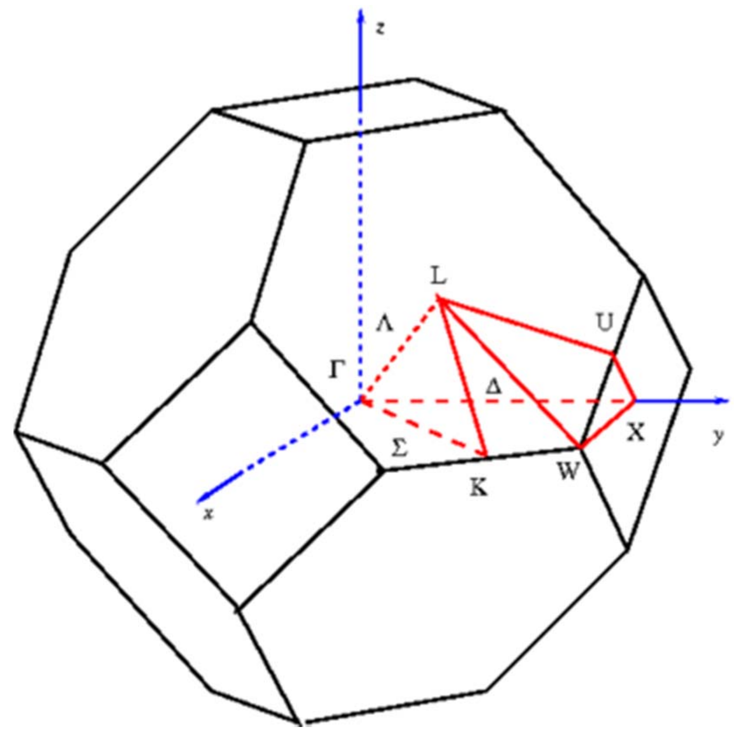
Bravais lattice	Parameters	Simple (P)	Volume centered (I)	Base centered (C)	Face centered (F)
Triclinic	$a_1 \neq a_2 \neq a_3$ $\alpha_{12} \neq \alpha_{23} \neq \alpha_{31}$				
Monoclinic	$a_1 \neq a_2 \neq a_3$ $\alpha_{23} = \alpha_{31} = 90°$ $\alpha_{12} \neq 90°$				
Orthorhombic	$a_1 \neq a_2 \neq a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} = 90°$				
Tetragonal	$a_1 = a_2 \neq a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} = 90°$				
Trigonal	$a_1 = a_2 = a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} < 120°$				
Cubic	$a_1 = a_2 = a_3$ $\alpha_{12} = \alpha_{23} = \alpha_{31} = 90°$				
Hexagonal	$a_1 = a_2 \neq a_3$ $\alpha_{12} = 120°$ $\alpha_{23} = \alpha_{31} = 90°$				

Table 1.1: Bravais lattices in three-dimensions.

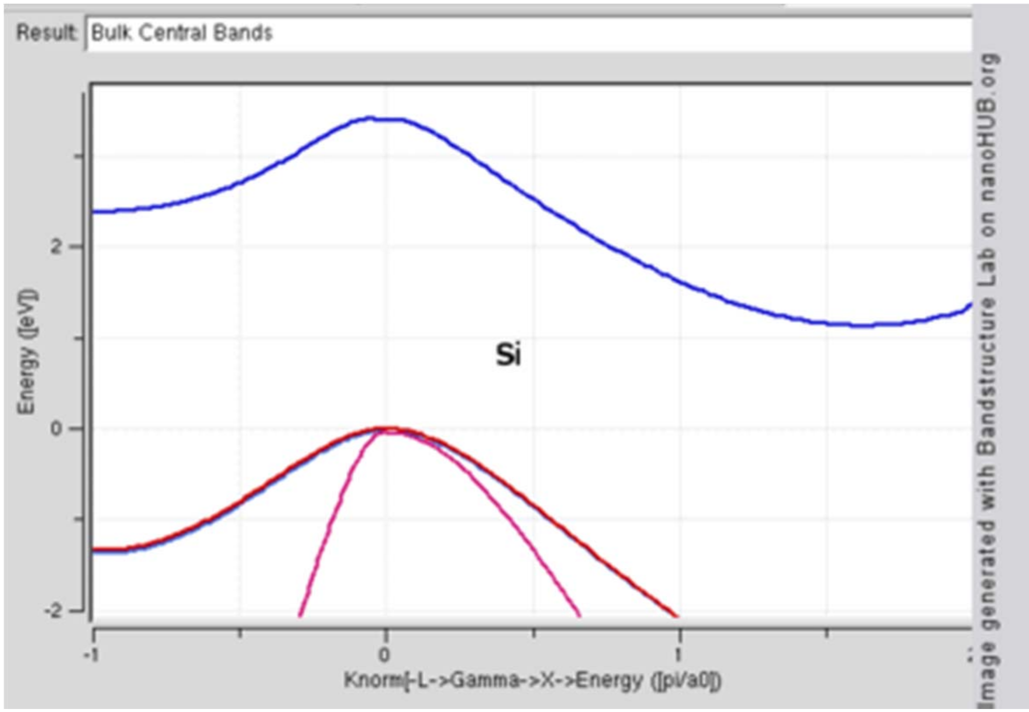

Simple cubic
Face-centered cubic
Body-centered cubic
Simple tetragonal
Body-centered tetragonal
Hexagonal
Simple orthorhombic
Body-centered orthorhombic
Base-centered orthorhombic
Face-centered orthorhombic
Rhombohedral
Simple Monoclinic
Base-centered monoclinic
Triclinic


overlap
Electron energy
Conduction band
Fermi level
Bandgap
Valence band
metal
semiconductor
insulator

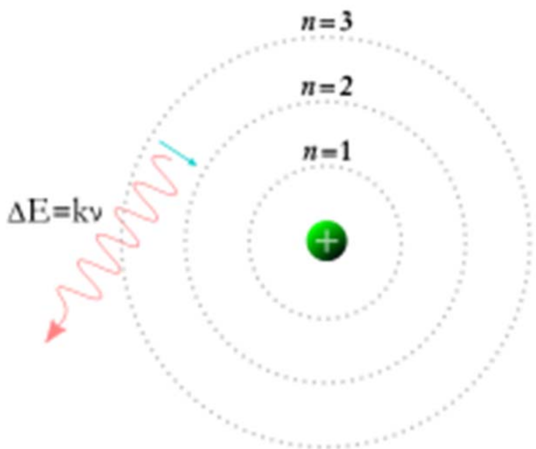
First Brillouin zone of FCC lattice showing symmetry labels

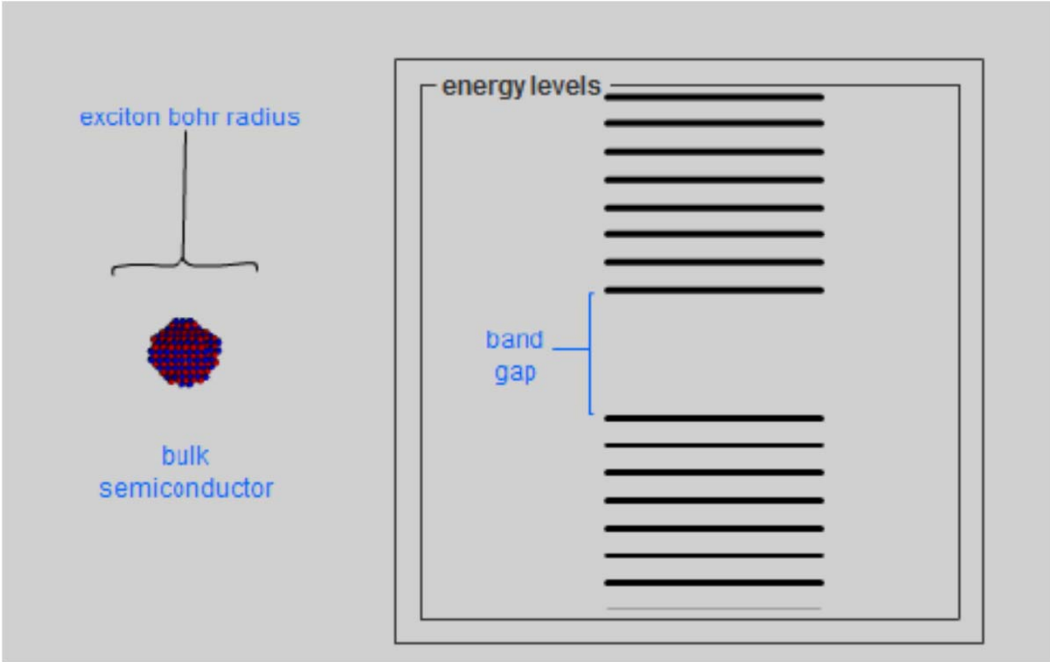


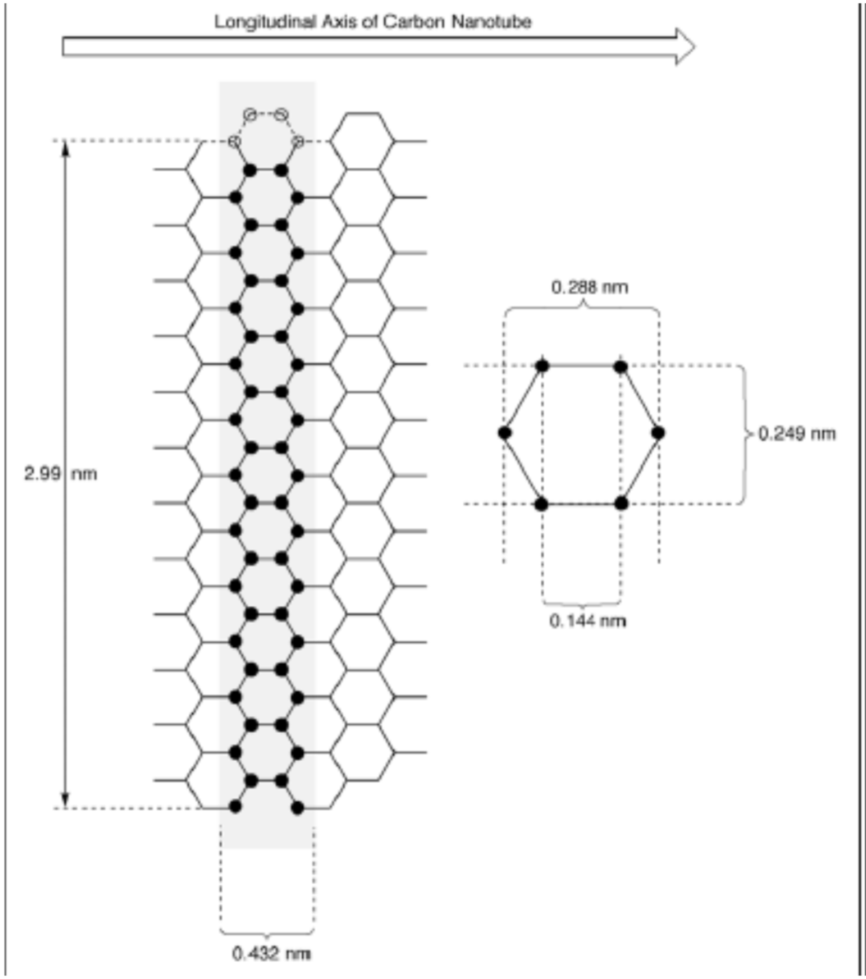
Band Structures



Bohr Exciton Radius







$$2a = 0.144 \text{ nm}$$

$$a = 0.072 \text{ nm}$$

$$\left(Altitude\right)^2 = a^2 + 2a^2 = a\sqrt{3}$$

$$\text{Minimal diameter} = 2 \cdot a\sqrt{3} = 2 \cdot \left(0.072\right)\text{nm} \cdot \sqrt{3}$$

$$\mathbf{= 0.249 \text{ nm}}$$

Circumference or Perimeter, $p = 12 \cdot 0.249 \text{ nm} = \mathbf{2.988 \text{ nm}}$

$$p = \pi d; \text{ the } d = \frac{p}{\pi} = \frac{2.988\text{nm}}{\pi} = \mathbf{0.951 \text{ nm}}$$

$$m = \left(\frac{12.011\text{g}}{\text{mol}}\right)\left(\frac{1 \text{ mol}}{6.022x10^{23} \text{ atoms}}\right) 48 \text{ atoms} = \mathbf{9.573x10^{-22}g}$$

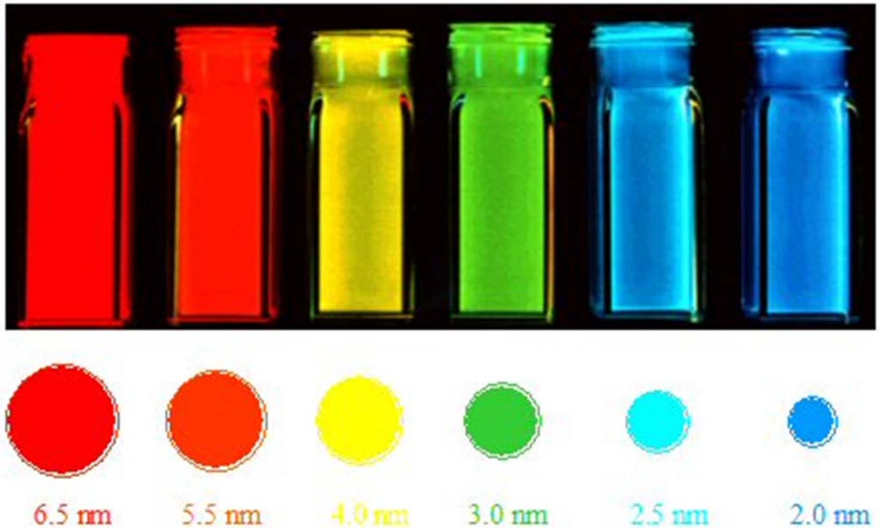
$$V_{unit\ cell} = 0.432\text{nm} \cdot \pi r^2 = 0.432\text{nm} \cdot \pi \cdot \left(\frac{0.951\text{nm}}{2}\right)^2 = \mathbf{0.307 \text{ nm}^3}$$

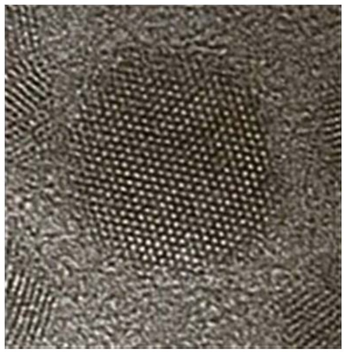
$$0.307\text{nm}^3\left(\frac{\text{cm}}{10^7\text{nm}}\right)^3 = \mathbf{3.07x10^{-22} \text{ cm}^3}$$

$$\rho = \frac{\text{g}}{\text{cm}^3} = \frac{9.573x10^{-22}\text{g}}{3.07x10^{-22} \text{ cm}^3} = \mathbf{3.12 \text{ g} \cdot \text{cm}^3}$$

$$S_{Unit-cell} = \frac{p \cdot W}{m} = \frac{2.99\text{nm} \cdot 0.432\text{nm}}{9.573x10^{-22}g}\left(\frac{\text{m}}{10^9\text{nm}}\right)^2 = \mathbf{1.35x10^3 \text{ m}^2 \cdot \text{g}^{-1}}$$

CdSe





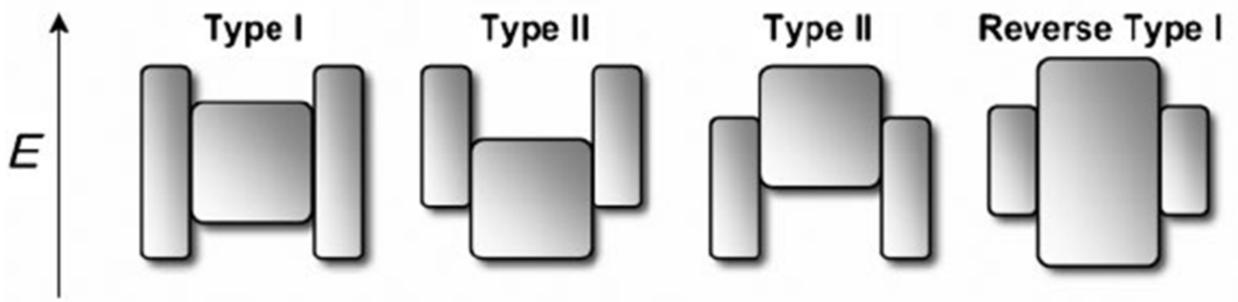
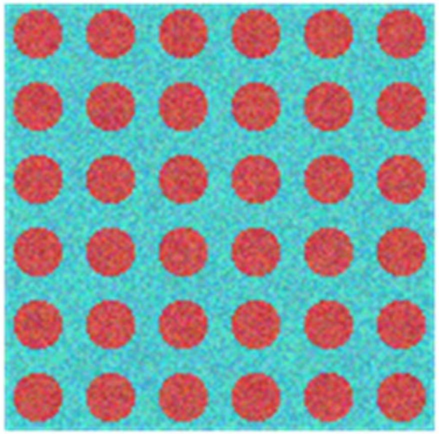
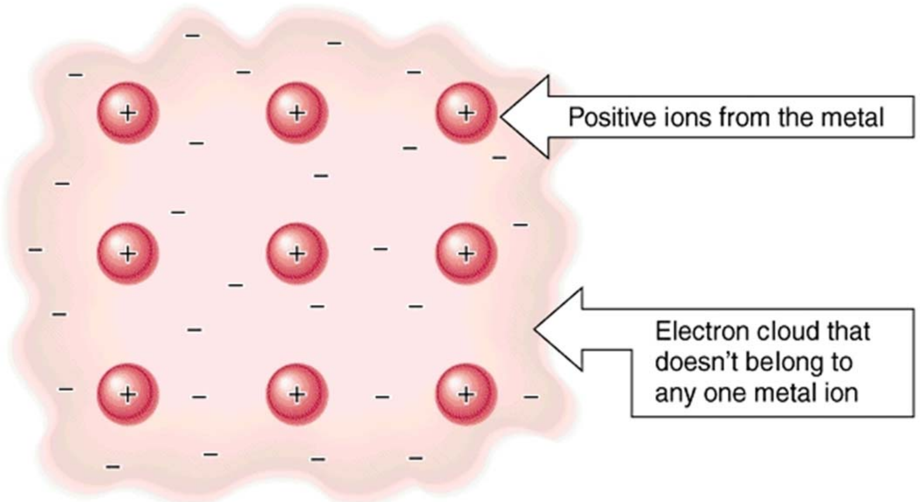


Figure 1. Schematic representation of the energy-level alignment in different core/shell systems realized with semiconductor NCs to date. The upper and lower edges of the rectangles correspond to the positions of the conduction- and valence-band edge of the core (center) and shell materials, respectively.

Electron Sea

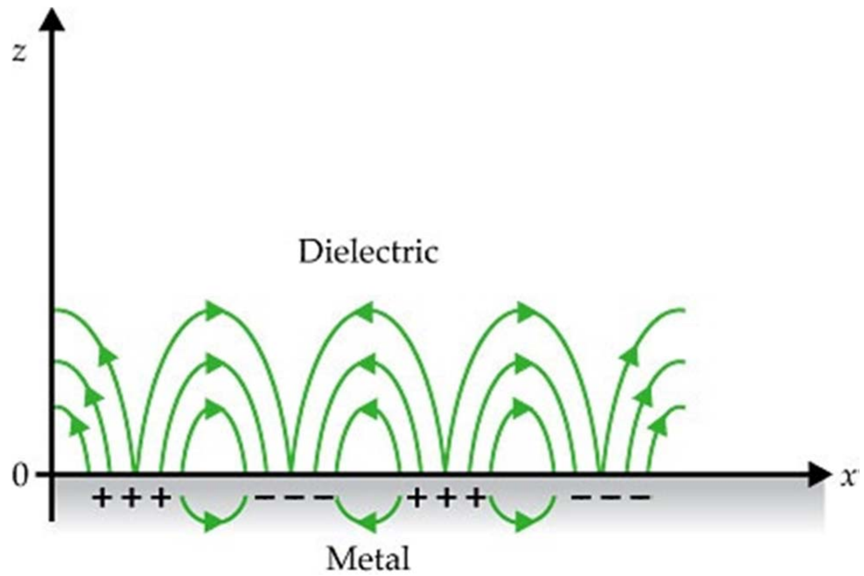




$$m\,\frac{d^2\,\delta x}{dt^2} = e\,E_x = -m\,{\omega_p}^2\,\delta x,$$

$${\omega_p}^2 = \frac{n\,e^2}{\epsilon_0\,m},$$

Surface Plasmonon



$$\varepsilon_m = 1 - \frac{\omega_p^2}{\omega^2}$$

TiO_2

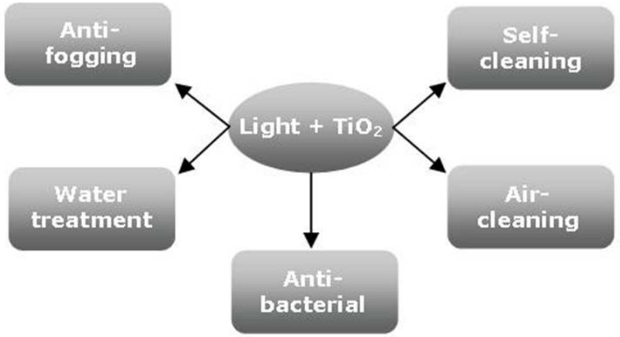
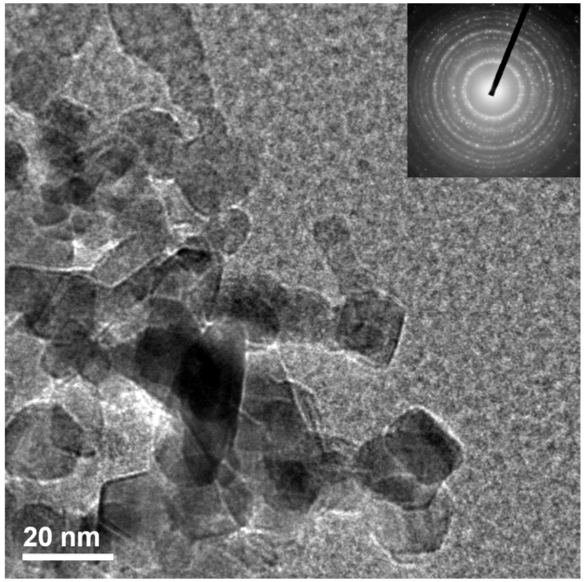
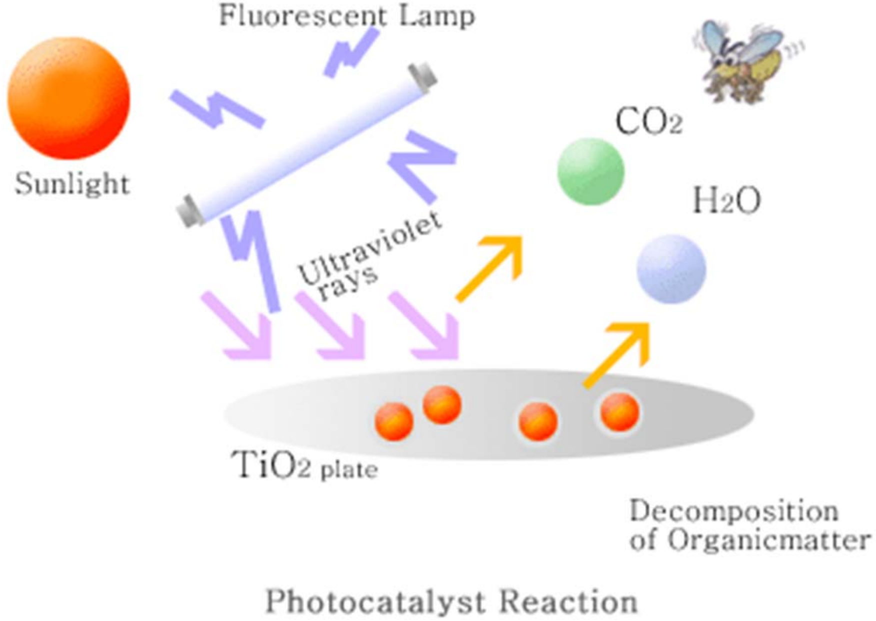
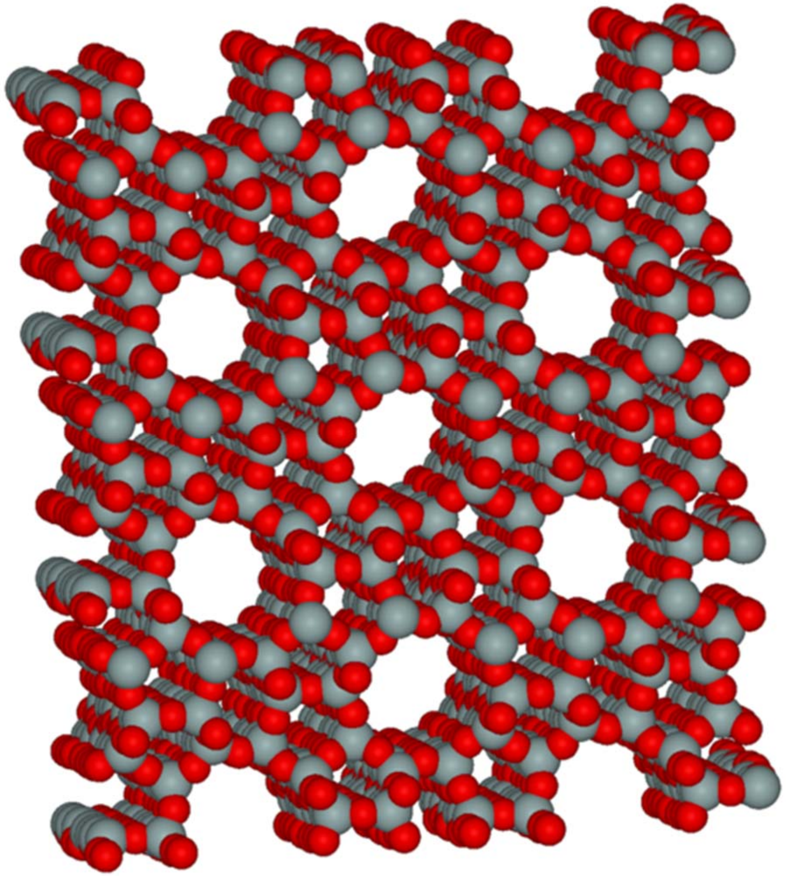


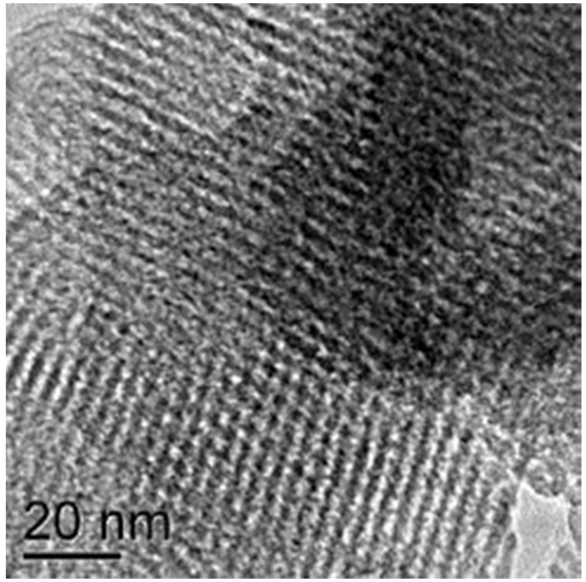
Figure 1. Major areas of activity in titanium dioxide photocatalysis



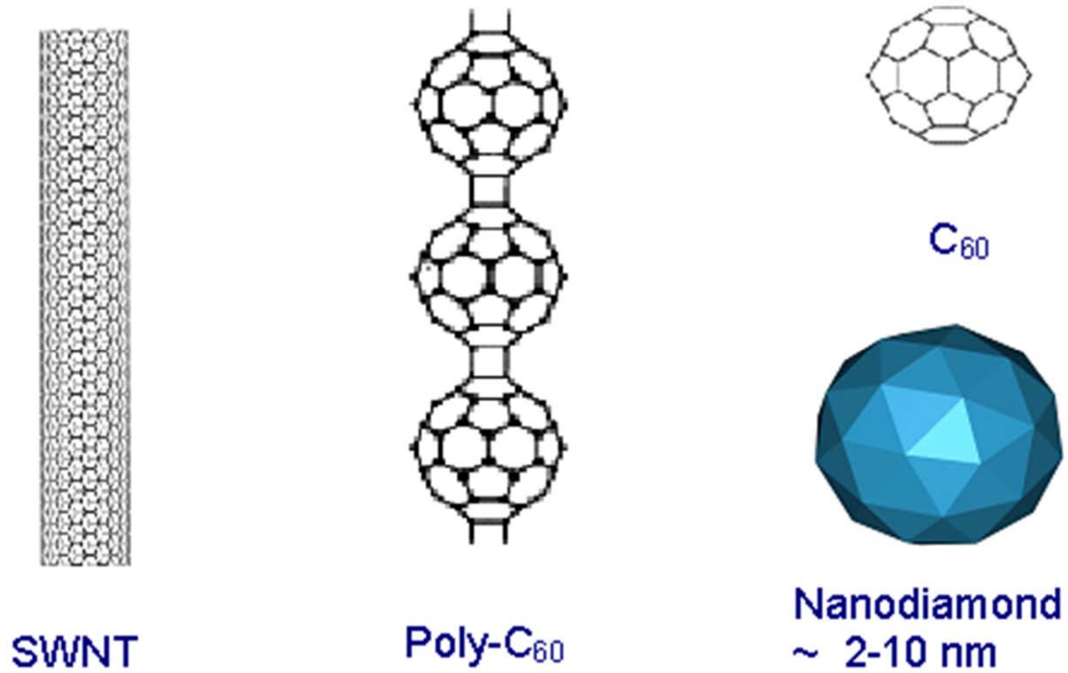


Zeolite

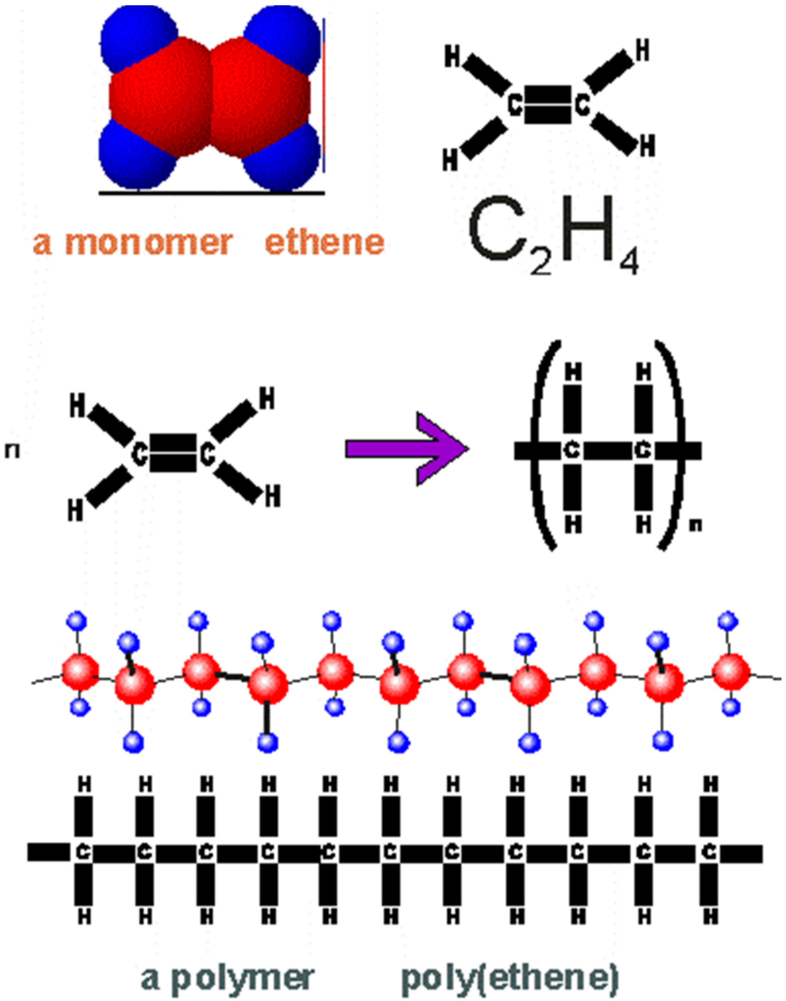




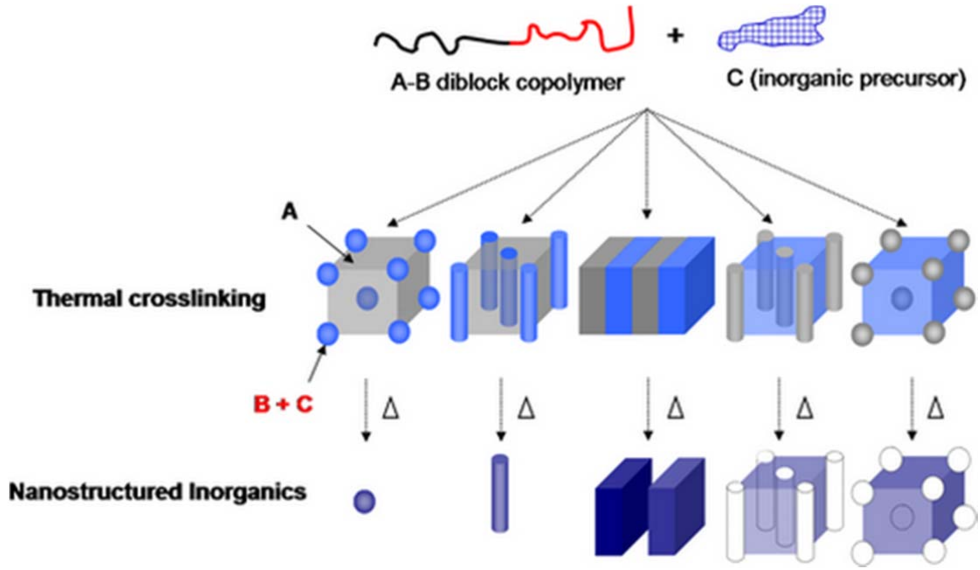
Carbon



Polymer

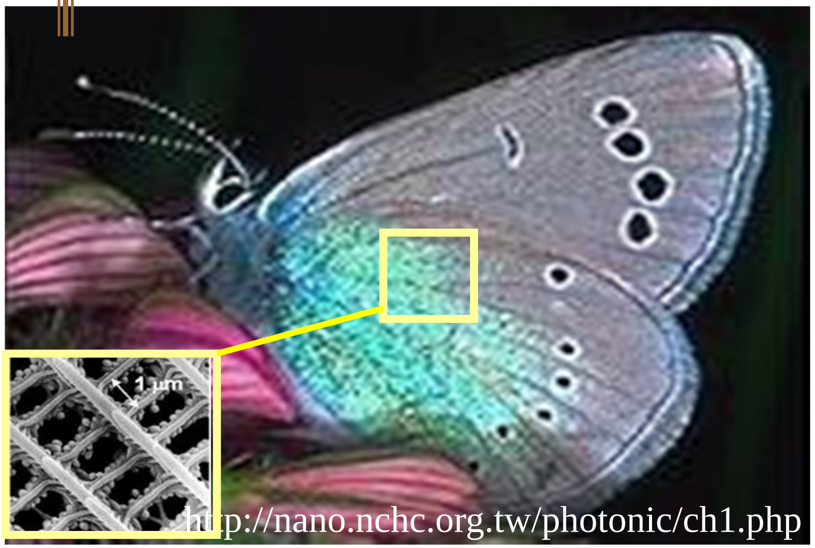


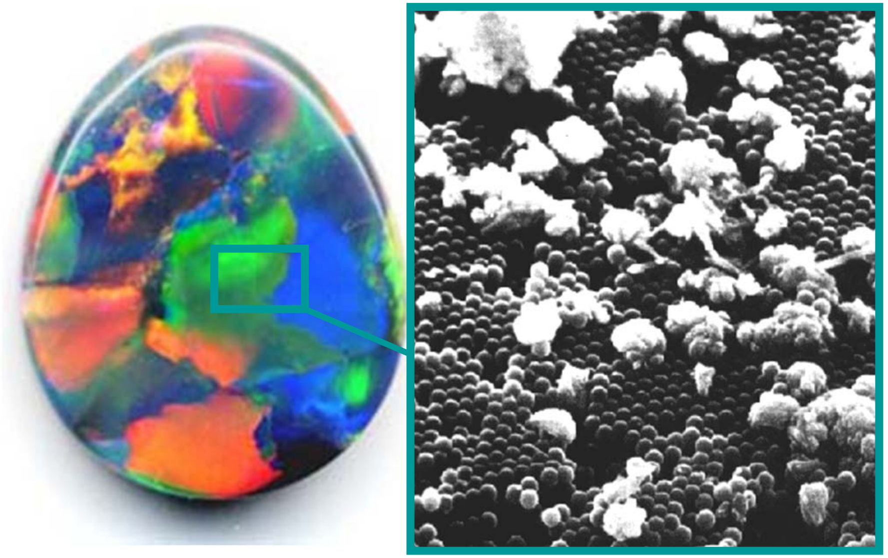
a monomer ethene
C_2H_4
n
a polymer poly(ethene)

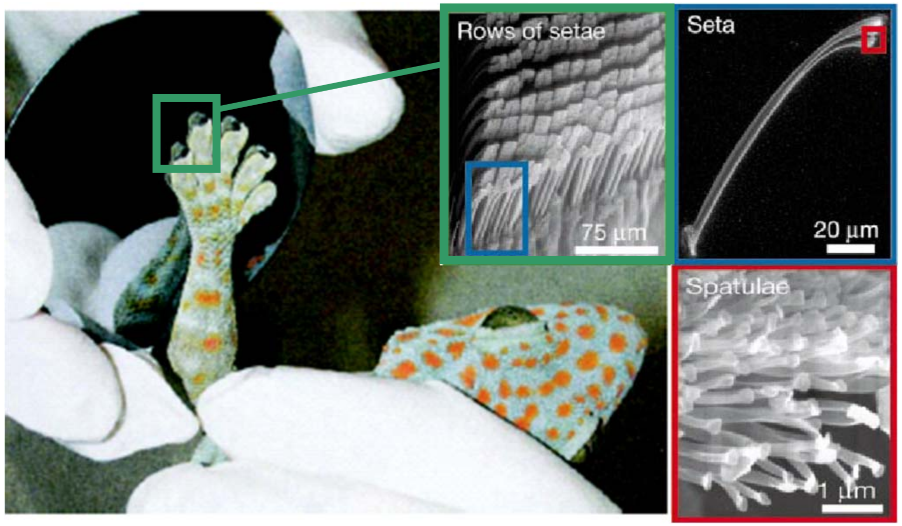


A-B diblock copolymer
+
C (inorganic precursor)
A
Thermal crosslinking
B + C
Δ
Nanostructured Inorganics

Nature Materials







Surface Energy

One face surface energy: γ

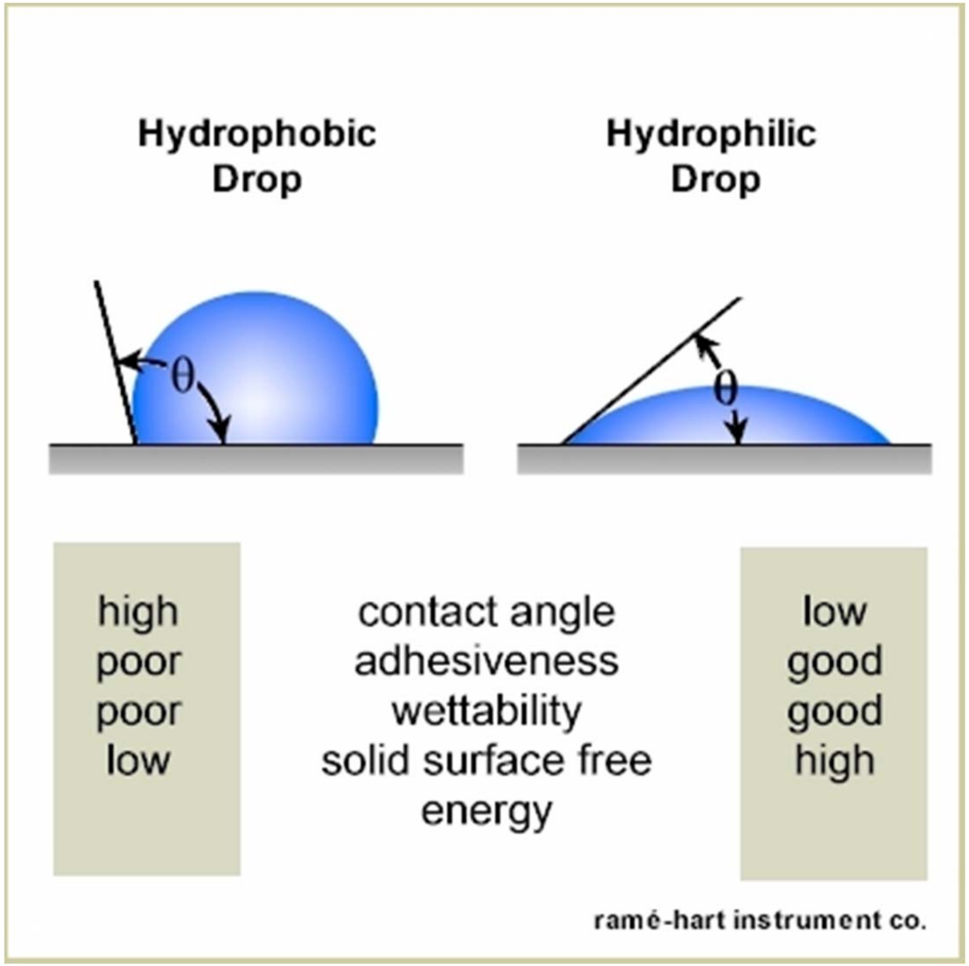
27 cube: 27 x 6 γ

3 x 9 cube line: 114 γ

3 x (3x3) square: 90 γ

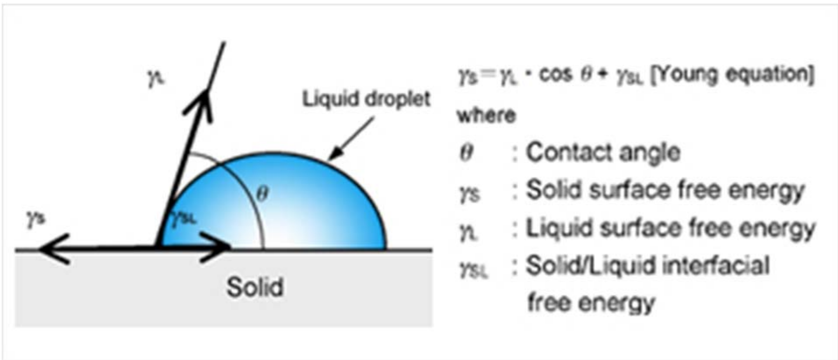
3 x 3 x 3 cube: 54 γ

Contact Angle



Young's Equation

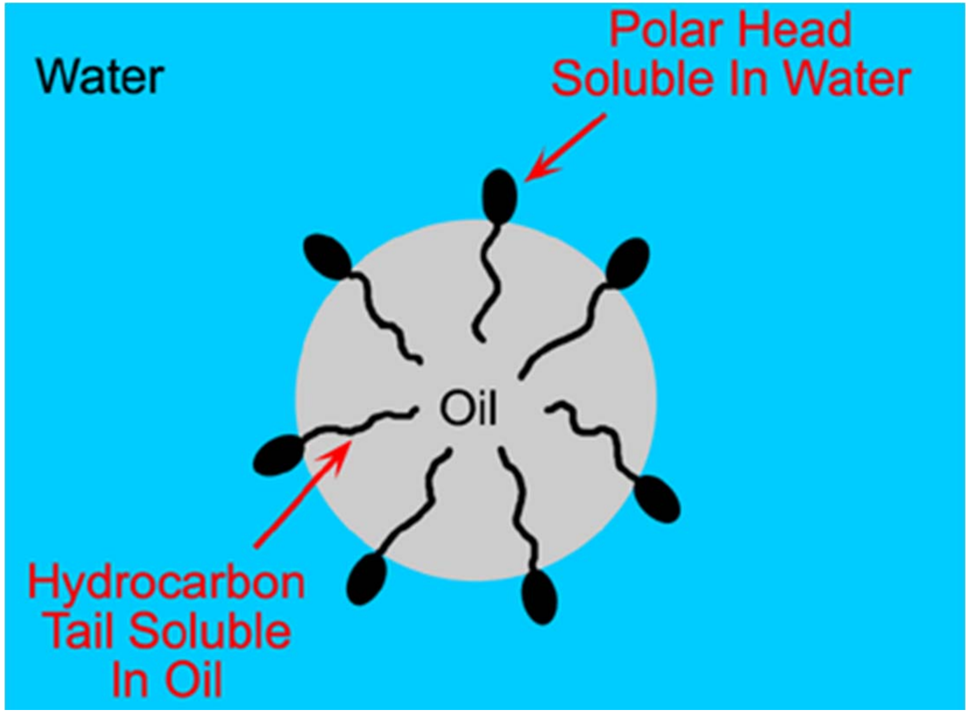
$$\gamma_{SL} + \gamma_{LV} \cos \theta_c = \gamma_{SV}$$



Surface Energy Minimization

- Surfactants
- DLVO
- Polymeric
- Nucleation
- Ostwald Ripening
- Sintering
- Restructure

Surfactant


Water
Polar Head
Soluble In Water
Oil
Hydrocarbon
Tail Soluble
In Oil

DLVO Theory

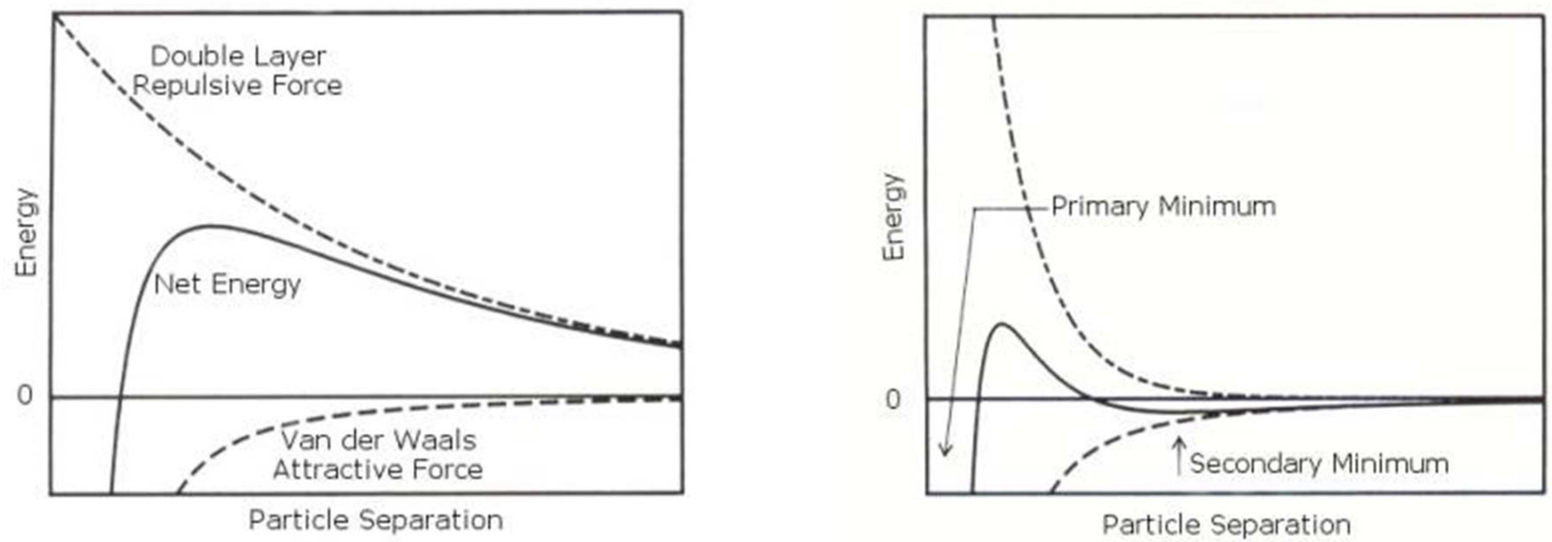
$$V_T = V_A + V_R + V_S$$

$$V_A = -A/(12 \pi D^2)$$

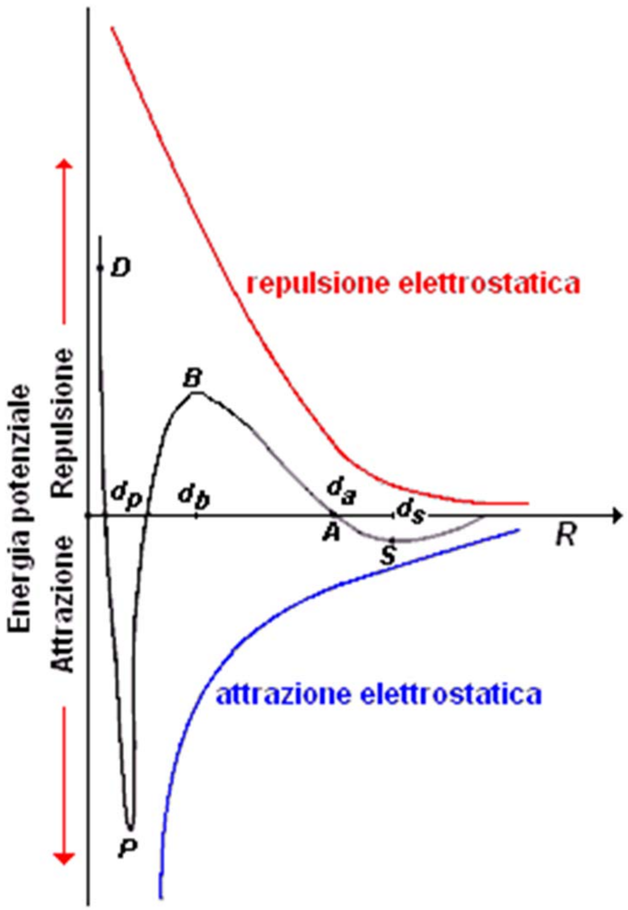
A is the Hamaker constant and D is the particle separation

$$V_R = 2 \pi \varepsilon a \xi^2 \exp(- \kappa D)$$

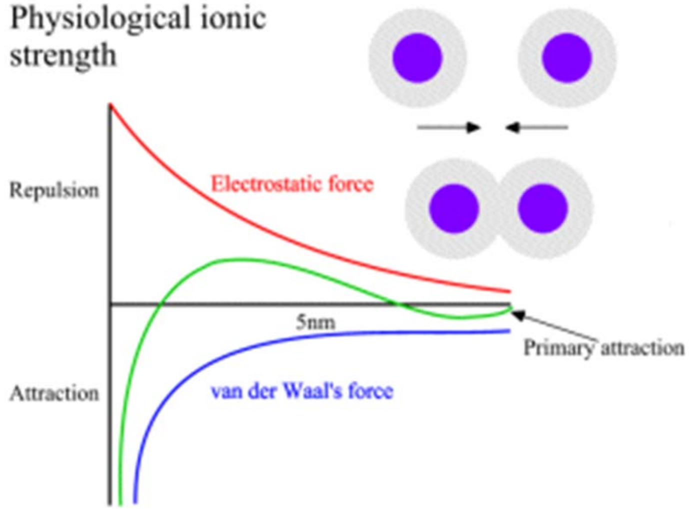
a is the particle radius, π is the solvent permeability,
κ is a function of the ionic composition and ξ is the zeta potential


Double Layer
Repulsive Force
Energy
Net Energy
0
Van der Waals
Attractive Force
Particle Separation
Energy
Primary Minimum
0
Secondary Minimum
Particle Separation

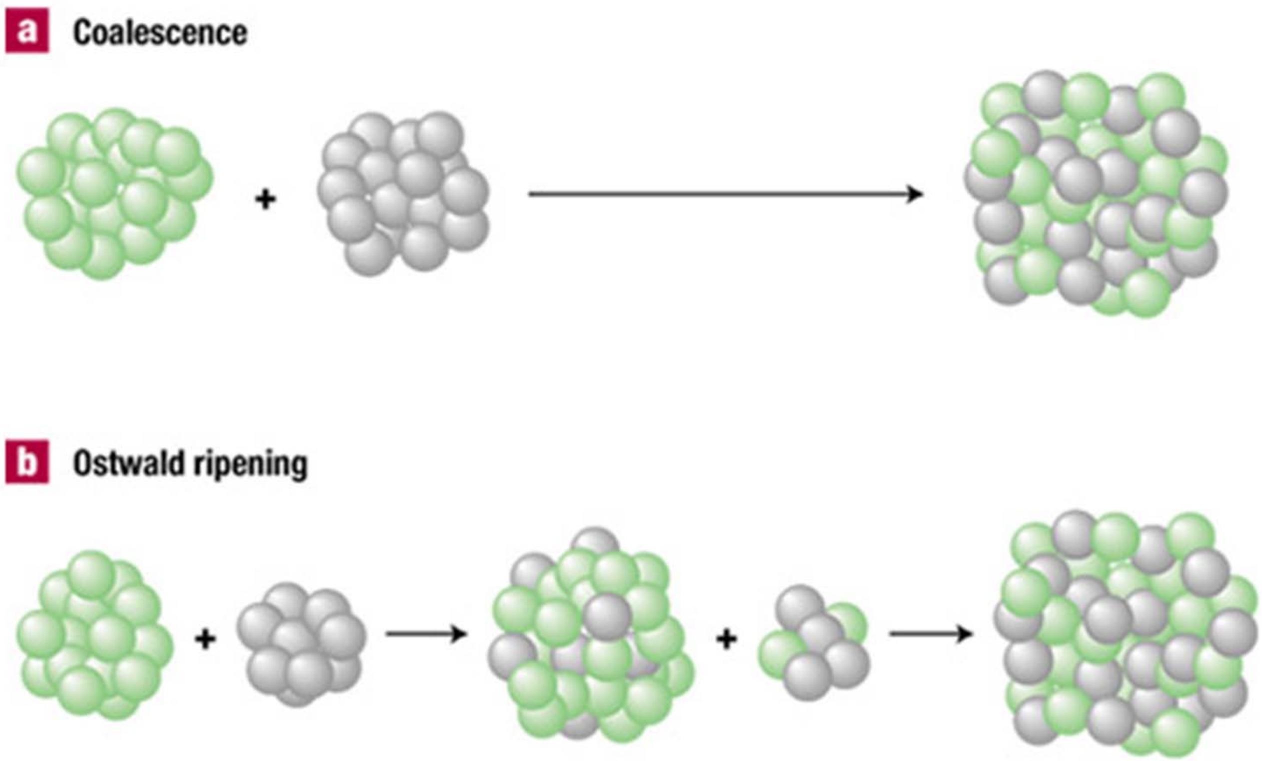
DLVO Theory



repulsione elettrostatica
attrazione elettrostatica
Energia potenziale
Repulsione
Attrazione
D
B
P
A
S
R
dp
db
da
ds



Physiological ionic strength
Repulsion
Attraction
Electrostatic force
van der Waal's force
5nm
Primary attraction



Two main mechanisms are shown here: **a**, coalescence sintering, and **b**, Ostwald ripening sintering. Coalescence sintering occurs when two clusters touch or collide and merge to form one bigger cluster. In contrast, Ostwald ripening sintering occurs by evaporation of atoms from one cluster, which then transfer to another. This is a dynamic process — both clusters exchange atoms, but the rate of loss from the smaller cluster is higher, because of the lower average coordination of atoms at the surface and their relative ease of removal. Thus big clusters get bigger at the expense of smaller clusters, which shrink and eventually disappear. The latter process is the usual form of sintering for metal clusters on a supported surface that are well spaced apart, although coalescence can occur for a high density of clusters. In general, the presence of the surface results in SMORS (surface-mediated Ostwald ripening sintering) in which material is transferred from one cluster to another by diffusion across the surface, and not through the gas phase.