Classification of Elements & Periodicity in properties

→ Need of classification?
↳ to ease the understanding of elements

Earlier attempts at classification

(i) Dobereiner's law of triads

e.g., Li Na K
7 23 39

atomic mass of middle element = avg. of first & last element

$$23 = \frac{7+39}{2}$$

triads had similar properties
→ did not work for all elements

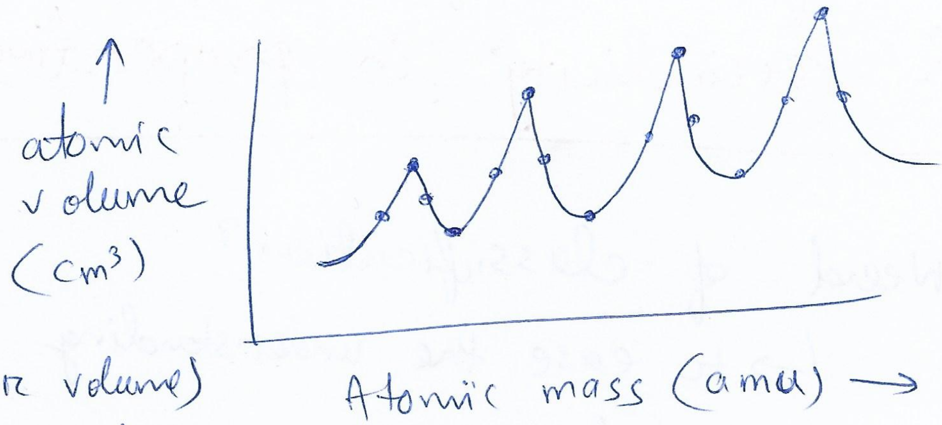
(ii) Newland's law of octaves

→ Element were arranged acc. to increasing atomic masses

Sa	Re	Ga	Ma	Pa	Dha	Ne
1	2	3	4	5	6	7
H	Li	Be	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K					

→ 8th element had similar properties as 1st

(iii) Lother Meyer's curve



(molar volume)
atomic volume

$= \frac{\text{atomic mass}}{\text{density}}$

(iv) Mendeleev's periodic table

→ arranged the elents ~~a~~ according to increasing atomic mass

Periodic law: "The properties of elemts are periodic function of their atomic masses"

→ Periods (horizontal rows)

→ groups (vertical colums)

→ had no group for noble gases

→ ^{127}I was placed ~~before~~ after $^{127.6}Te$

→ Eka-Aluminium (Galium), Eka-Silicon (Germanium)

Modern form of periodic table

→ modified by moseley

" Properties of elements are periodic function of their atomic numbers."

Groups I to VII < A, B (Sub groups)

zeroth group for noble gases

VIII th group was subdivided in to three

VIII

Fe Co Ni

Ru Rh Pd

⋮ ⋮ ⋮

I		II		— — —	VIII	0th
A	B	A	B		∣ ∣ ∣	

(i) Valency

Group	1	2	13	14	15	16	17
	IA	IIA	IIIA	IVA	VA	VIA	VIIA
valency (O = 2)	Na	Mg	Al	Si	P	S	Cl
oxides	N_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl_2O_7
valency w.r.t O	1	2	3	4	5	6	7

valency w.r.t. O = Group NO. (I A, II A, III A ---)

w.r.t. H	NaH	MgH_2	AlH_3	SiH_4	PH_3	H_2S	HCl
valency w.r.t. H	1	2	3	4	3	2	1

(11) Diagonal relationship

Group	I	II	III	IV
2nd period	Li	Be	B	C
3rd period	Na	Mg	Al	Si

$Li \to Mg$, $Be \to Al$, $B \to Si$

for example B & Si are metalloids

→ diagonal elements had similar properties

↓

their compounds had similar properties

Electronic configurations

	Z	spdf	KLMN
H	1	$1s^1$	1
He	2	$1s^2$	2
Li	3	$1s^2, 2s^1$	2, 1
Be	4	$1s^2, 2s^2$	2, 2

B 5 $1s^2, 2s^2, 2p^1$ 2,3

C 6 $1s^2, 2s^2, 2p^2$ 2,4

N 7 $1s^2, 2s^2, 2p^3$ 2,5

O 8 $1s^2, 2s^2, 2p^4$ 2,6

F 9 $1s^2, 2s^2, 2p^5$ 2,7

Ne 10 $1s^2, 2s^2, 2p^6$ 2,8

Na 11 $1s^2, 2s^2, 2p^6, 3s^1$ 2,8,1

Mg 12 $[Ne]\, 3s^2$ 2,8,2

Al 13 $[Ne]\, 3s^2, 3p^1$ 2,8,3

Si 14 $[Ne]\, 3s^2, 3p^2$ 2,8,4

P 15 $[Ne]\, 3s^2, 3p^3$ 2,8,5

S 16 $[Ne]\, 3s^2, 3p^4$ 2,8,6

Cl 17 $[Ne]\, 3s^2, 3p^5$ 2,8,7

Ar 18 $[Ne]\, 3s^2, 3p^6$ 2,8,8

K 19 $[Ar]\, 4s^1$ 2,8,8,1

Ca 20 $[Ar]\, 4s^2$ 2,8,8,2

Sc 21 $[Ar]\, 4s^2 3d^1$ 2,8,9,2

Ti 22 $[Ar]\, 4s^2 3d^2$ 2,8,10,2

V 23 $[Ar]\, 4s^2 3d^3$ 2,8,11,2

Cr 24 $[Ar]\, 4s^1 3d^5$ 2,8,12,2

Mn 25 $[Ar]\, 4s^2 3d^5$ 2,8,13,2

Fe 26 $[Ar]\, 4s^2 3d^6$ 2,8,14,2

Co 27 $[Ar]\, 4s^2 3d^7$ 2,8,15,2

Ni 28 $[Ar]\, 4s^2 3d^8$ 2,8,16,2

Cu 29 $[Ar]\, 4s^1 3d^{10}$ 2,8,17,2

Zn 30 $[Ar]\, 4s^2 3d^{10}$ 2,8,18,2

Ga 31 $[Ar]\, 4s^2 3d^{10} 4p^1$ 2,8,18,3

Ge 32 $[Ar]\, 4s^2 3d^{10} 4p^2$ 2,8,18,4

As 33 $[Ar]\, 4s^2 3d^{10} 4p^3$ 2,8,18,5

Se 34 $[Ar]\, 4s^2 3d^{10} 4p^4$ 2,8,18,6

Br 35 $[Ar]\, 4s^2 3d^{10} 4p^5$ 2,8,18,7

Kr 36 $[Ar]\, 4s^2 3d^{10} 4p^6$ 2,8,18,8

Rb 37 $[Kr]\, 5s^1$ 2,8,18,8,1

La 57 $[Xe]\, 6s^2 5d^1$

Ce 58 $[Xe]\, 4f^1 5d^1 6s^2$

Pr 59 $[Xe]\, 4f^3 5d^0 6s^2$

$4f^4$

Gd 64 $[Xe]\, 4f^7 5d^1 6s^2$

Lu 71 $[Xe]\, 4f^{14} 5d^1 6s^2$

Period No.	orbitals being filled	No. of elements
1	1s (2)	2 (very short)
2	2s, 2p (2) (6)	8 (short)
3	3s, 3p (2) (6)	8 (short)
4	4s 3d 4p (2) (10) (6)	18 (Long)
5	5s 4d 5p	18 (Long)
6	6s 4f 5d 6p (2) (14) (10) (6)	32 (very long)
7	7s 5f 6d 7p	32 (very long)

Classification of elements based on electronic configuration

Bohr's classification

(i) $ns^2, np^6 \rightarrow$ noble gases

(ii) ns^1 or ns^2 or $ns^2\ np^{1-5}$

Representative elements (s block & p block)

(Except Noble gas)

Group 1, 2, Group 13 – 17

(iii) Transition elemets

$(n-1)d^{1-10}\ ns^{0\ or\ 1\ or\ 2}$

(iv) Inner transition elemets

$(n-2)f^{0-14}\ (n-1)d^{0\ or\ 1\ or\ 2}\ ns^2$

(Lanthanides & actinides)

Differentiation based on the orbital containing the last e^-

(s-, p-, d-, f- blocks)

(i) s- Block

ns^1 or ns^2

→ last e^- goes into s orbitals

→ IA & II A or grp 1 & 2

IA: alkali metals; IIA: alkaline earth metals [Typical metals]

→ soft metals, low m.p. & B.P., good conducters of heat & electricity

→ electropositive, fixed valency (1)

→ form ionic compounds
(exception Li & Be)

→ Oxides & hydroxides
↓ ↓
Basic — Strong alkali
(e.g., Na_2O, MgO) — (e.g. NaOH, KOH)

→ M.p
Cs → 28.5°C
Fr → 27°C

$\boxed{\text{Fr, Ra} \rightarrow \text{Radioactive}}$

(ii) p- Block

→ last e^- enters a p orbital

configuration is $ns^2 np^{1-6}$

→ include metals, non-metals & metalloids
e.g. (Al) (O_2) (Si)

→ have acidic oxides (Generally)

→ have all the gases of periodic table

e.g., O_2, N_2, F_2, Cl_2,

Br_2 → liquid non-metal

metal ← Ga (M.p.) → 29.76 °C

(iii) <u>d - Block</u> (Transition series)

$(n-1)d^{1-10} \; ns^{0 \text{ or } 1 \text{ or } 2}$

$(n-1)d$ → (Penultimate shell @ 2nd last shell)

ns → outermost shell or valence shell

→ 3d, 4d, 5d, 6d Series

→ all are metals, high M.P. & B.P., hard, good conductors of heat & electricity, malleable & ductile, high tensile strength, high densities

→ only liquid metal is Hg (mercury)

→ Pt, Au, Hg → noble metals

→ Variable valencies

→ compounds are coloured, paramagnetism, catalysts

→ alloy formation

(iv) f - Block elements (Inner transition elements)

$(n-2)f^{0-14} \; (n-1)d^{0 \text{ or } 1 \text{ or } 2} \; ns^2$

→ belong to 3rd group (or III B)

(a) 4f series ^{57}La to ^{71}Lu → 15 elements
(Lanthanide series)

→ 5f Series (Actinides)

^{89}Ac to ^{103}Lr → 15 elents

Properties are similar to d block elemets

→ all are metals, variable valency, paramagnetic, coloured compounds

→ also known as <u>rare earth elements</u>
(difficult to separate from each other)

→ Actinides are radioactive

Periodic table is a graphical representation of aufbau principle.

Period no. = Principal q. No. of the valence shell

<u>7 periods</u>

<u>18 groups</u>

<u>Determination of Block, period & group no. of a given element</u>

(i) Block = the orbital in which last e^- enters

(ii) Period ✓

(iii) Group NO.

To determine group NO. e^- in the last shell and/or penultimate shell

---

(a) $(n-1)$ (n)

Penultimate shell ← $(n-1)$; (n) → outermost shell

$(n-1)$ → He → $(n-1)s^2$ or $(n-1)s^2p^6$

(n) → 1 or 2 e^-

Group NO. = no. of e^- in the valence shell

'S Block'

			Grup NO.
Li	3	$1s^2, 2s^1$	1
Be	4	$1s^2, 2s^2$	2
K	19	$[Ar]4s^1$	1
Sr	38	$[Kr]5s^2$	2

(b) If the last shell has 3 or more e^-

⇒ group NO. = no. of e^- in last orbit + 10 (P Block)

	Z		Group No.
S	16	$[Ne]\,3s^2\,3p^4$	$10+6=16$
Ge	32	$\underset{18}{[Ar]}\,3d^{10}\,4s^2 4p^2$	$10+4=14$
Xe	54	$[Kr]\,4d^{10}\,5s^2\,5p^6$	$10+8=18$
At	85	$[Xe]\,4f^{14}\,5d^{10}\,\underbrace{6s^2 6p^5}_{7e^-}$	$10+7=17$

(c) $\underset{\text{d orbitals}}{(n-1)}\; ns^{0 \text{ or } 1 \text{ or } 2}$ [d block]

Group No. = sum of e^- in nth shell & $(n-1)d$ orbital

			Group No.
Cr	24	$[Ar]\,3d^5\,4s^1$	6
Cu	29	$[Ar]\,\underline{3d}^{10}\,\underline{4s}^1$	11
Ru	44	$[Kr]\,4d^7\,5s^1$	8
Hf	72	$[Xe]\,4f^{14}\,\underline{5d}^2\,\underline{6s}^2$	4

[Xe] 6s 4f 5d 6p

54 2 14 10

$\underbrace{82 \quad 6s^2\ 4f^{14}\ 5d^{10}}_{80}\ 6p^2$ 10+2+2 = 14 grp

C	N	O	F
ns^2np^4	ns^2np^3	ns^2np^4	ns^2np^5
	3e⁻	(2)	(1)
(4)	(3)		

Properties of elements (

(i) Atomic properties (depend on individual atoms)

→ directly depend on e⁻ configuration.

examples atomic radii, ionic radii,

Ionisation energy or potential (IE or IP)

electrong gain enthalpy (ΔH_{eg}) or Electron affinite (EA), Electronegativity (EN)

(ii) Propenties ~~which~~ of group of atoms

→ M.P., B.P., ΔH_v (heat of vaporisation), ΔH_f (heat of fusion (melting)), density

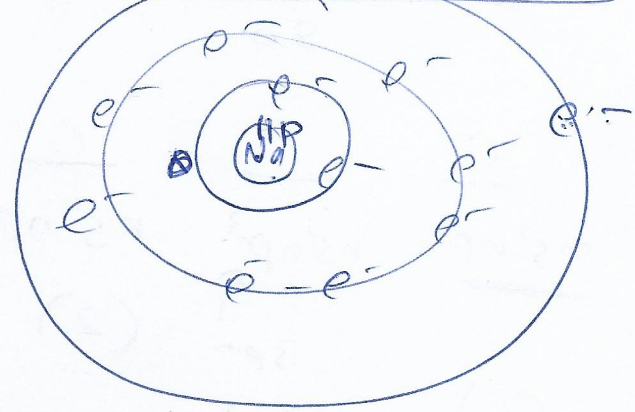
→ indirectly depend on e⁻ config.

(i) Properties of individual atoms

(i) Screening effect or shielding effect

Na 2, 8, 1

$11 p^+$



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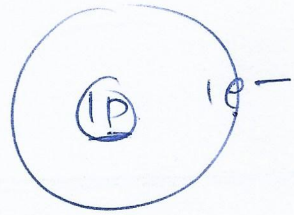


(1) measured by screening constant σ

σ increases in a ~~group~~ period from L to R

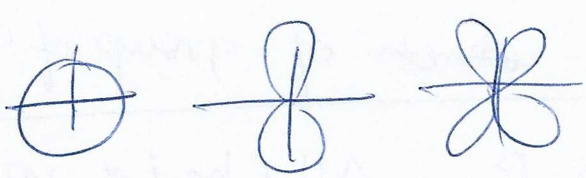
also increases in a group from top to bottom.

For orbitals the screening effect

s > p > d > f (for the same orbit or shell)

(s orbitals ~~has~~ e⁻ have highest screening effect)

closest to the nucleus.

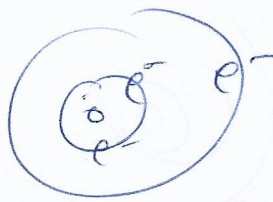
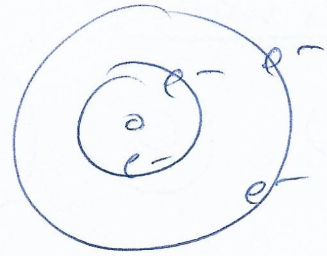


(ii) Effective nuclear charge Z^* or Z_{eff}

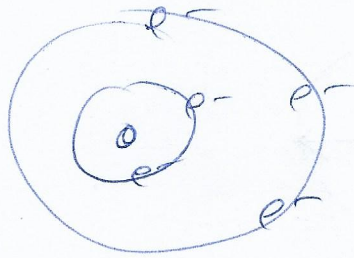
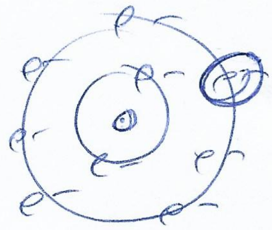
Z → atomic no.

$$\boxed{Z^* = Z - \sigma}$$

→ In a period Z^* increases from Left to right

Li  Be 

2,1 (3P) 2,2

B  - - - - F 

2,3 2,7 (9P)

Z 3 → 9

$Z^* \uparrow$

$$Z^* = Z - \sigma$$

↑

for one e^-

F $Z^* = 9 - \sigma$

↓

$Z \uparrow$ by one

→ Group Z^* almost remain same

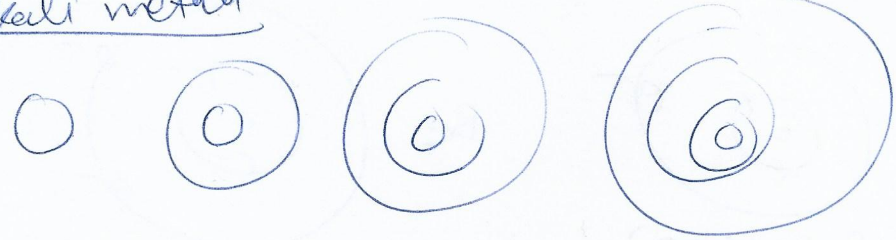
Atomic radius

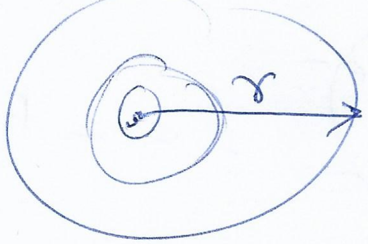
in a period (Left to right) Z^* increases ⇒ atomic radii decreases.

In a group Z^{*} remain same

- one shell is added $\Rightarrow$ size increases down the group.

alkali metals





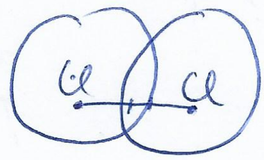
Types of atomic radii

(i) covalent radius (for non-metals)

$$r_{cov} = \frac{d}{2}$$

Cl_2

$Cl-Cl$



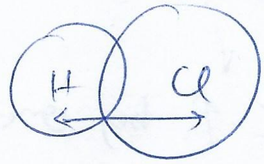
$\leftarrow d \rightarrow$

$\downarrow$

Homonuclear diatomic molecules (H_2, Br_2)

$H-Cl$

A B



d_{A-B}

$\downarrow$

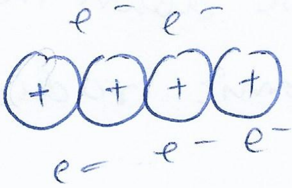
hetero nuclear diatomic molecules

$$r_A + r_B = d_{A-B}$$

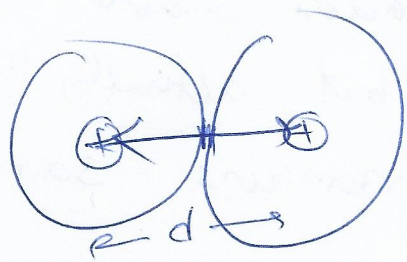
$$r_A = d_{A-B} - r_B$$

(ii) Crystal radius

(for metals & ionic compounds)



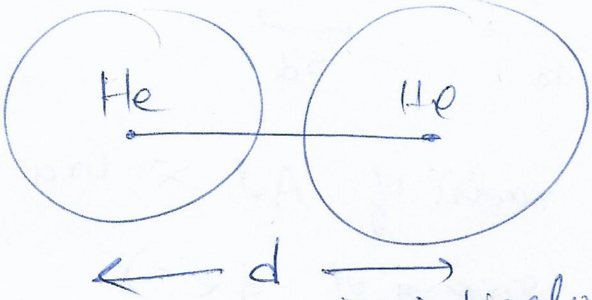
NaCl



$r = d/2$

(iii) Vander walls' radius

(Noble gases & non metals in solid state)



$\longleftarrow d \longrightarrow$ → ~~dis~~ closest distance between He atoms.

$r_{He} = d/2$

r_{Van}

Vander walls' radius > Crystal radius > covalent radius

4d series

^{39}Y ——— ^{48}Cd

5d series

^{71}Lu to ^{80}Hg

$4f$

Lanthanide contraction

as we go from 4d to 5d series the atomic raddi should increase down the group but actually the atomic radii almost remains same.

4d $\qquad$ 5d $\qquad$ s > p > d > f

$4f^{14}$

f e^- are very poor shielding.

atomic radii of $\underbrace{Zr}_{4d} \approx \underbrace{Hf}_{5d}$

→ ~~Al~~ atomic radii of Al ≈ Ga
(poor screeng of d e⁻)

→ In d block elemets atomic radius from left to right decreases initially but the decrease in not as much as expected, or

e.g. atomic radii of Fe

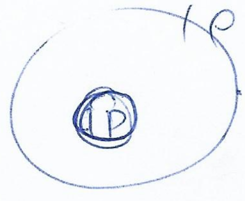
Sc Ti V Cr Mn $\underbrace{\text{Fe Co Ni Cu}}$ Zn

$3d^{1-10}$ $4s^2$

$\boxed{Fe \approx Co \approx Ni \approx Cu}$

Z^* remin same

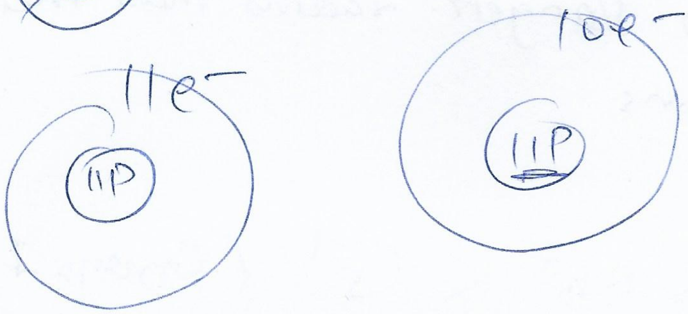
$3p^1 \quad 3p^2 \quad - - \quad 3p^7$



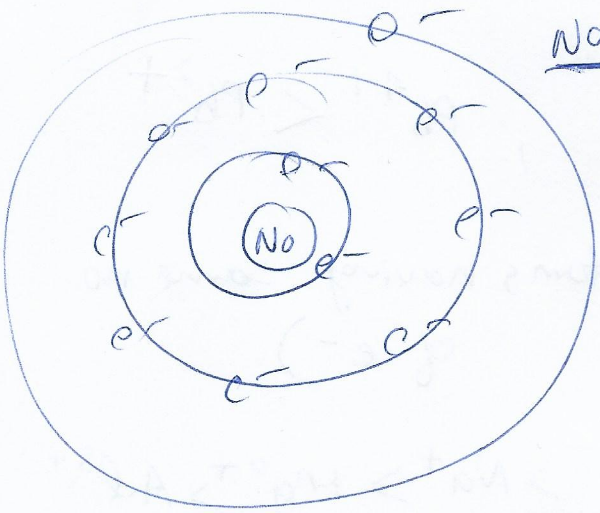
Ionic radius

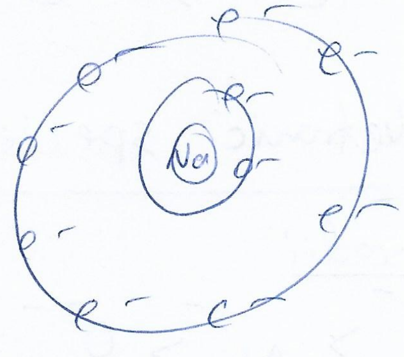
Na v/s Na^+ $\quad Z = 11$

2,8,1 $\quad$ 2,8



Na $\qquad$ Na^+





11P 11e⁻ $\qquad$ 11P 10e⁻

each e^- faces more nuclear charge

Z^* increases

$r_{Na} > r_{Na^+}$

→ cations have smaller ~~atom~~ ionic raddi then neutral atoms.

~~F^{3-}~~

F $\qquad$ F^-

2, 7 $\qquad$ 2, 8

9P, 9e^- $\qquad$ 9P, 10e^- → each e^- faces less nuclear charge Z_{eff} decreases hence atomic radii increases

$r_F < r_{F^-}$

→ anions have larger radius than their neutral atoms

ionic radii

$Li^+ < Na^+ < K^+ < Rb^+ < Cs^+$ (Group I)

→ $Fe^{2+} > Fe^{3+}$, $Pb^{4+} < Pb^{2+}$

isoelectronic species (atoms having same no. of e^-)

ionic radii

$C^{4-} > N^{3-} > O^{2-} > F^- > Na^+ > Mg^{2+} > Al^{3+}$

(each has 10e^-)

6P + 10e^- $\qquad$ 7P + 10e^- → more attraction