General Chemistry Mid-term (11/07/'18)) Name ________________學號_____________(p.1)

1. Name the following in English: (a) Pb (b) Si (c) C (d) NaCl (e) K (f) Ag (g) Al (h) CO

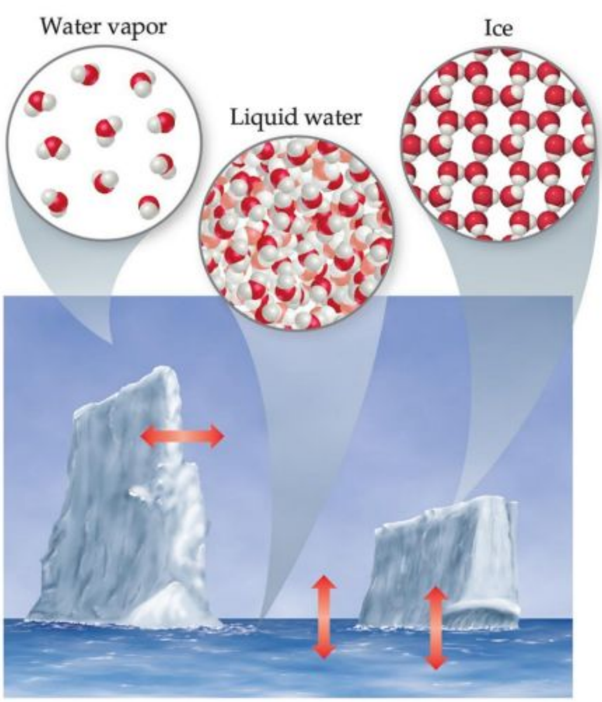
(a) Lead (b) silicon (c) carbon (d) sodium chloride

(e) Potassium (f) silver (g) aluminum (h) carbon monoxide

2. What are the three states for water? The heat of vaporization for water is 44.94 kJ/mol at 0 °C, 44.02 kJ/mol at 25 °C and 40.67 kJ/mol at 100 °C. Why would the heat of vaporization for water varies with temperature?

9/17 cont'd

**The three States of Matter:**
**gas, liquid, and solid**




Heat (enthalpy) of vaporization:

44.94 kJ/mol at 0 °C
44.02 kJ/mol at 25 °C
40.67 kJ/mol at 100 °C

**What is the 'heat' for?**

**Only in molecular compounds you would see such a distinct 'state change'.**

3. (a) Write electronic configuration for F, Cl, Ti, Cr and Co, respectively.
(b) Chlorine is considered the very chemical that holds for record for saving the most lives. Write the reaction for chlorine when it is added to water.
(c) What is the chemical formula of titanium tetrachloride? Why it is called the ink by skywriters?

(a) F [He] 2s^2 2p^5

Cl [Ne] 3s^2 3p^5

Ti [Ar] 3d^2 4s^2

Cr [Ar] 3d^5 4s^1

Co [Ar] 3d^7 4s^2

(b)

Chlorine is the most industrially useful of the halogens. It is produced by a process called electrolysis, where an electrical current is used to oxidize chloride anions to molecular chlorine, $Cl_2$. Unlike fluorine, chlorine reacts slowly with water to form relatively stable aqueous solutions of HCl and HOCl (hypochlorous acid):

$$Cl_2(g) + H_2O(l) \longrightarrow HCl(aq) + HOCl(aq) \quad [7.33]$$

Chlorine is often added to drinking water and swimming pools because the $HOCl(aq)$ that is generated serves as a disinfectant.

(c)

$$TiO_2 + 2\ Cl_2 + \text{carbon} \rightarrow TiCl_4 + CO_2$$

$$TiCl_4 + 2\ Mg \rightarrow 2\ MgCl_2 + Ti$$

Interestingly, titanium tetrachloride is the "ink" used by skywriters. When the pilot is ready to maneuver the airplane to spell out words, she releases a spray of $TiCl_4$, which reacts with atmospheric moisture to form visibly white titanium dioxide particles.

4. Write Lewis dot structure for

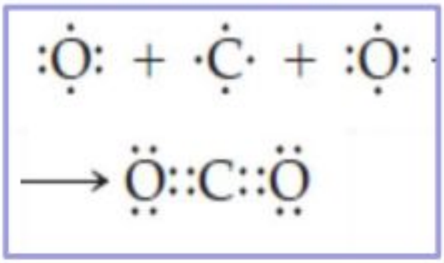
(a) $CO_2$ (b) $SO_3$ (c) NO (d) HCN, respectively.

(b) Draw MO diagram for (a) NO and (b) HF.

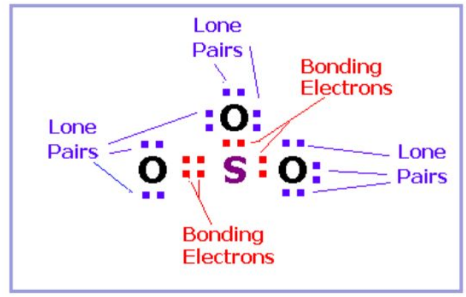
(c) Use MO model to predict the bond order and magnetism for (i) NO and (ii) $CN^-$?

(a)

**double bond**



(b)




(c)

The molecule has two possible **Lewis structures** can be drawn. The Lewis structure with the lower **formal charges** places the odd electron on the N atom:

(d)

The octet rule is satisfied for the C and N atoms, and the H atom has two electrons around it. This is a correct Lewis structure.

4. Write Lewis dot structure for

(a) $CO_2$ (b) $SO_3$ (c) NO (d) HCN, respectively.

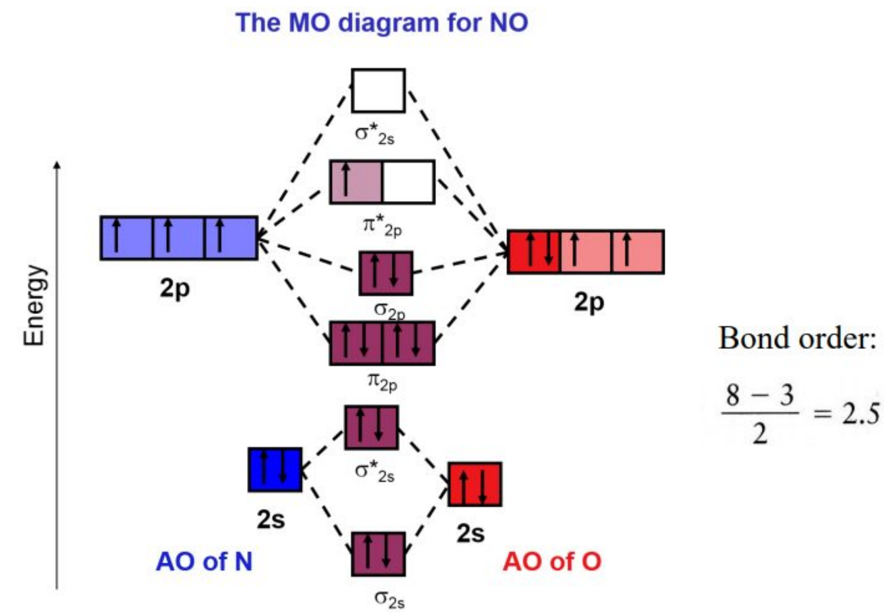
(b) Draw MO diagram for (a) NO and (b) HF.

(c) Use MO model to predict the bond order and magnetism for (i) NO and (ii) $CN^-$?

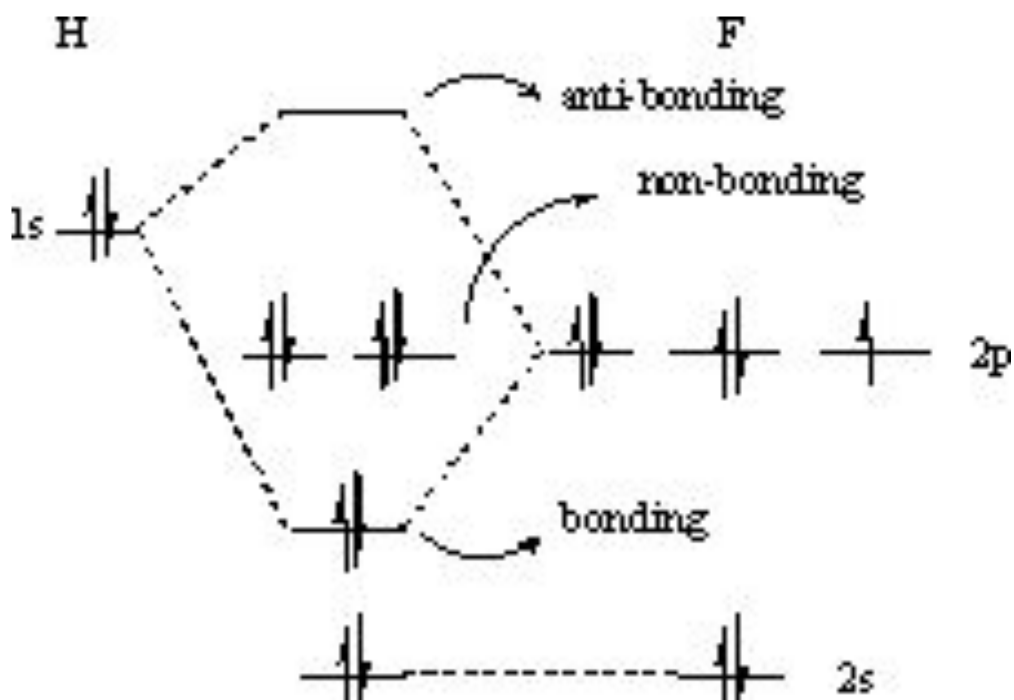
(a)

## Heteronuclear Diatomic Molecules

A special case (1) : when molecules containing **atoms adjacent to each other** in the periodic table; and MO diagram can be used for homonuclear molecules as atoms involved in such molecules are similar

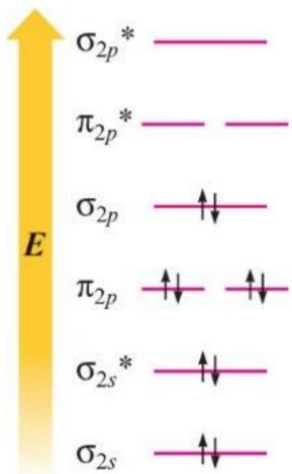



(b)



4. Write Lewis dot structure for
   (a) $CO_2$ (b) $SO_3$ (c) NO (d) HCN, respectively.
   (b) Draw MO diagram for (a) NO and (b) HF.
   (c) Use MO model to predict the bond order and magnetism for (i) NO and (ii) $CN^-$?

**Exercise: Use the molecular orbital model to predict the magnetism and bond order of the $NO^+$ and $CN^-$ ions.**



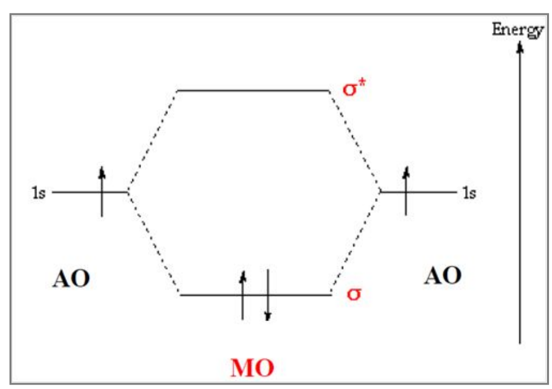

$NO^+$ ion has 10 valence electrons (5 + 6 – 1)

$CN^-$ ion also has 10 valence electrons (4 + 5 + 1)

Both ions are diamagnetic

$$\text{Bond order} = \frac{8 - 2}{2} = 3$$

**5**. The energy levels in a hydrogen molecule is shown below:
   (a) Define AO, MO, σ, and σ*.
   (b) If molecular hydrogen is irradiated by ultra-violet (UV) light and the molecule absorbs the energy, what will happen to the molecule?
   (c) A neutral hydrogen molecule would become anionic when it gains one electron, and become cationic when it loses one electron. What are the two ionic spcies? Which one is more stable? Why?




| Molecular species | e-config. | Bond order | bond length (pm) |
|---|---|---|---|
| $H_2^+$ | 1s (1s¹) | ½ | 106 |
| $H_2$, $He_2^{2+}$ | $1s^2$ | 1 | ~75 |
| $H_2^-$, $He_2^+$ | $1s^2\,1s^*$ | ½ | ~106, 108 |
| $H_2^{2-}$, $He_2$ | $1s^2\,1s^{*2}$ | 0 | not formed |

6. MO of homodiatomic species:

(a) Is diatomic molecule of helium a stable species? Why? (1分)

(b) Can the species of $He_2^{2+}$ exist? Why? How does it compare with hydrogen molecule? (1分)

(c) Draw MO energy level diagram for nitrogen molecule and oxygen molecule, respectively. (3,3分)

(d) In the following pair, which has a stronger bond? (i) $B_2$ and $N_2$ (ii) $N_2^+$ and $N_2^-$, (iii) $O_2^-$ and $O_2^+$. (1,1,1分)

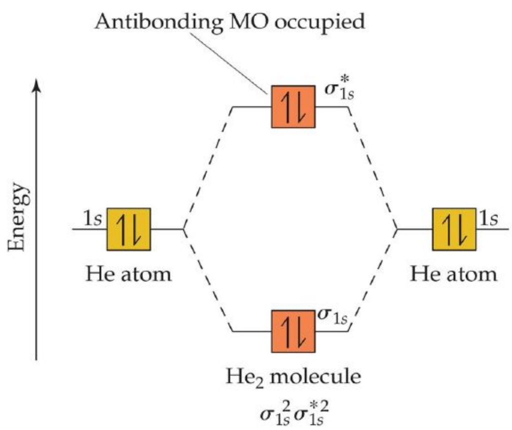
(e) Describe the magnetic property for $N_2$ and $O_2$. (2分)

(a) No.

The bond order is 0 for $He_2$.

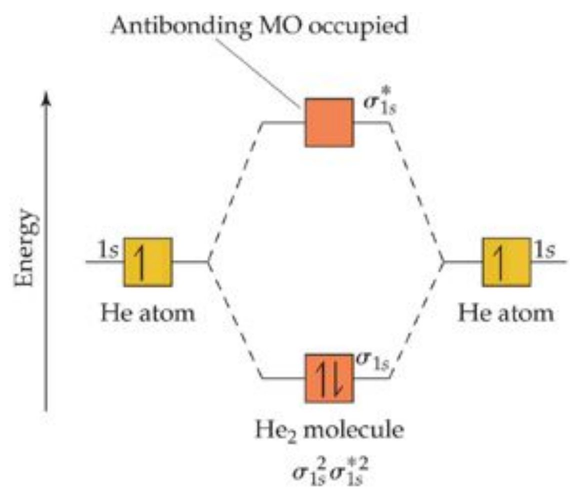
(b) Yes. The bond order = 1 in $He_2^{2+}$.

The bond order of $H_2$ and $He_2^{2+}$ are almost equal.




Bond order = ½(2 – 2) = 0 bonds

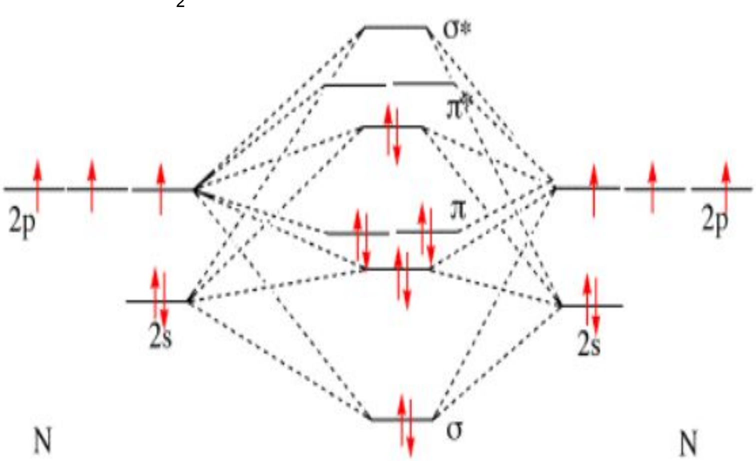
$He_2$ does *not* exist.



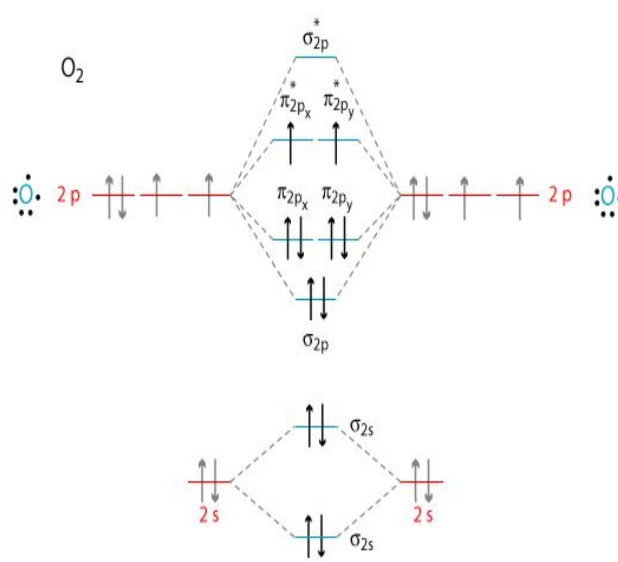

Bond order = 1

(c)

$N_2$

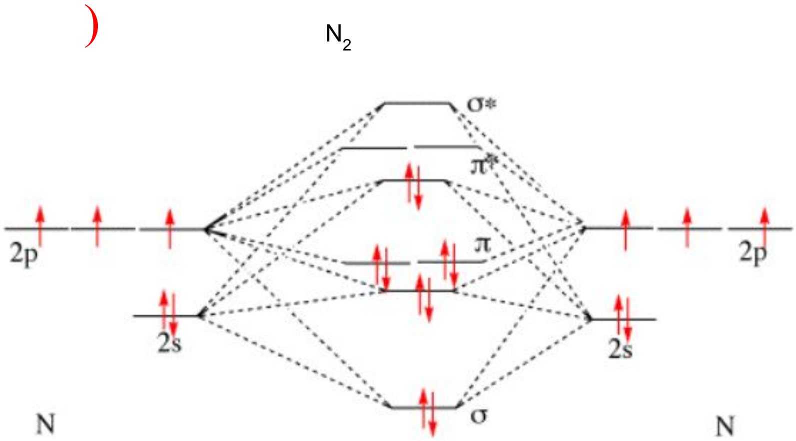


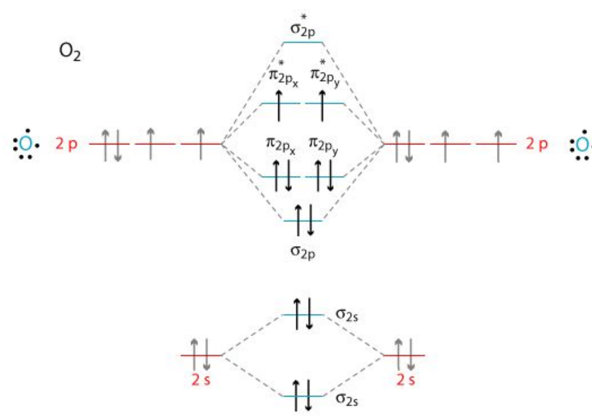

$O_2$



6. MO of homodiatomic species:
(a) Is diatomic molecule of helium a stable species? Why? (1分)
(b) Can the species of $He_2^{2+}$ exist? Why? How does it compare with hydrogen molecule? (1分)
(c) Draw MO energy level diagram for nitrogen molecule and oxygen molecule, respectively. (3,3分)
(d) In the following pair, which has a stronger bond? (i) $B_2$ and $N_2$ (ii) $N_2^+$ and $N_2^-$, (iii) $O_2^-$ and $O_2^+$. (1,1,1分)
(e) Describe the magnetic property for $N_2$ and $O_2$. (2分)

(c)




(d) (i)Bond order = 1 for $B_2$ and bond order = 3 for $N_2$, therefore the stronger bonds for **$N_2$**

(ii)Bond order = 2.5 for $N_2^+$ and $N_2^-$, therefore the **same**.

(iii)Bond order = 1.5 for $O_2^-$ and bond order = 2.5 for $O_2^+$, therefore the stronger bonds for **$O_2^+$**

(e) $N_2$ is diamagnetic, $O_2$ is paramagnetic.

7. Write the atomic symbol and electronic configuration for **five** of the following metals: titanium, vanadium, chromium, manganese, Iron, cobalt, nickel, copper and zinc.

(10分)

Ti: [Ar] $3d^2 4s^2$ V: [Ar] $3d^3 4s^2$ Cr: [Ar] $3d^5 4s^1$ Mn: [Ar] $3d^5 4s^2$
Fe:[Ar] $3d^6 4s^2$ Co: [Ar] $3d^7 4s^2$ Ni: [Ar] $3d^8 4s^2$ Cu:[Ar] $3d^{10} 4s^1$
Zn: [Ar] $3d^{10} 4s^2$

**8**. For the coordination compounds, $Pt(NH_3)_2Cl_2$ and $[CoCl(NH_3)_5]Cl_2$

(a) Do the central metal ions in the above two coordination compounds have the same oxidation states? Why? (2分)

(b) What is the coordination geometry for the central metal ion of Pt and Co, respectively? (2,2分)

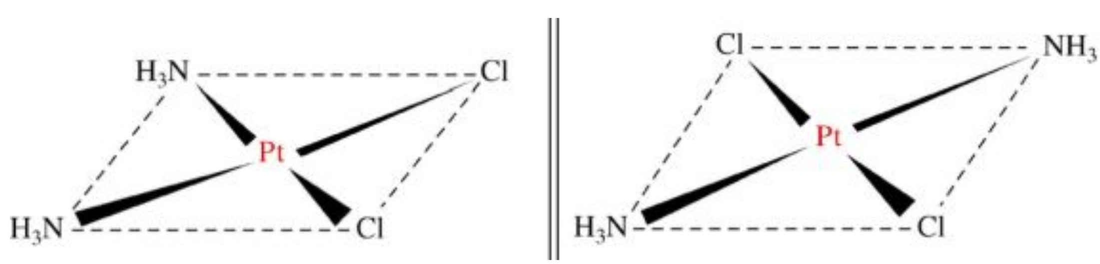
(c) Which compound has isomers? Depict them. (4分)

(a) No, Pt is 2+ to balance the two negative charges from Cl ligands and Co is 3+ to balance the negative charges from three $Cl^-$.

(b) square-planar for $Pt^{2+}$ and octahedral for $Co^{3+}$.

.

(c) The Pt compound. It has *cis*- and *trans*- isomers



**9**. For the two complex ions $[CoF_6]^{3-}$ and $[Co(NH_3)_6]^{3+}$

(a) Why one is anionic whereas the other is cationic? **(1分)**

(b) Draw the split 3*d* orbital for the central Co ion. **(1,1分)**

(c) Do these two ions show different magnetic properties? Explain. **(1分)**

(d) Which one is a high-spin case like $[Co(H_2O)_6]^{2+}$?

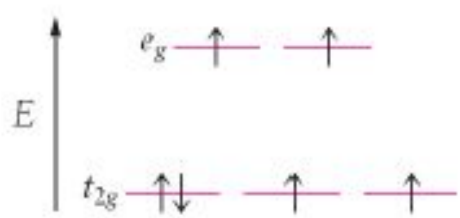
Does it contain the same number of unpaired electrons as $[Co(H_2O)_6]^{2+}$? Why? **(1,1分)**

(a) The charge of F = -1 ,$NH_3$ =0,and Co= +3.$[CoF_6]^{3-}$ = +3+(-1)*6= -3, so it is an anionic complex ion ,and $[Co(NH_3)_6]^{3+}$ = +3+(0)*6= +3, it is cationic.

(b)

$[CoF_6]^{3-}$

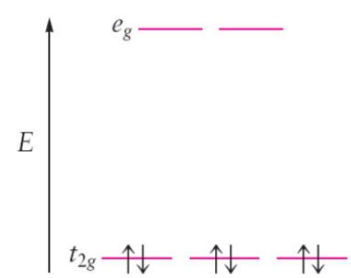
$F^-$ is weak- field ligand




High-spin complex

$[Co(NH_3)_6]^{3+}$

$NH_3$ is strong- field ligand




Low-spin complex

(c) Yes. $[CoF_6]^{3-}$ is paramagnetic

$[Co(NH_3)_6]^{3+}$ is diamagnetic.

(d) $[CoF_6]^{3-}$ is a high-spin case.

**No.** It contains 4 unpaired electrons ( a $d^6$ system)

$[Co(H_2O)_6]^{2+}$ contains 3 unpaired electrons ( $d^7$ system)

10. Fill in the following blanks:

| Process | Change in $A$ | Change in $Z$ |
|---|---|---|
| $\beta$-Particle (electron) production | 0 | +1 |
| Positron production | 0 | −1 |
| Electron capture | 0 | −1 |
| $\alpha$-Particle production | −4 | −2 |
| $\gamma$-Ray production | 0 | 0 |

| | |
|---|---|
| Beta emission | ${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$ |
| Positron emission | ${}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e$ |
| Electron capture* | ${}^{A}_{Z}X + {}^{0}_{-1}e \longrightarrow {}^{A}_{Z-1}Y$ |
| Alpha emission | ${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$ |

11. (a) Define atom and isotope and nuclide.

(b) Neutron is unstable and would decay into proton. Write the radioactive decay reaction.

(c) Why nuclear reactors (or bombs) do not use the naturally abundant uranium source of U-238 instead of the much less abundant U-235 for fission?

(d) Write the balanced equation for nitrogen atom that captures a neutron to become an isotope of carbon.

(e) Write the nuclear reaction for the transformation reaction from the radioactive iodine-131 (Z = 53) to xenone-131 (Z = 54).

(f) Write the nuclear reaction for the alpha decay of U-238 (Z = 92).

(g) Write the reactions for (i) ${}^{14}{}_{7}N$ captures a neutron (ii) ${}^{14}{}_{6}C$ produces a beta particle.

(a) Atom:由電子與原子核組成的基本粒子

Isotope:原子序相同原子量不同的元素

Nuclide:質子與中子組成的原子核

(The nucleus of an isotope is called a nuclide.)

(b) $\mathbf{n} \longrightarrow \mathbf{p} + \mathbf{e}^{-}$

(c) The U-238 typically does not undergo fission. So any chain reaction is snuffed out by the neutron absorbing U-238

(d) ${}^{14}_{7}\mathrm{N} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{14}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{H} \quad ({}^{1}_{1}\mathrm{P})$

(e) ${}^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\mathrm{e}$

(f) ${}^{238}_{92}\mathrm{U} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{234}_{90}\mathrm{Th}$

(g) ${}^{14}_{7}\mathrm{N} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{14}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{H} \quad ({}^{1}_{1}\mathrm{P})$

${}^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}\mathrm{e}$

12.

(a) Where does the energy from fission come from?

(b) Iron-56 with atomic mass 55.935 amu is the most common and stable isotope of iron. The nuclide contains 26 protons and 30 neutrons. Calculate the binding energy per nucleon for Fe-56, giving that the mass of a neutron 1.0087 u and the mass of proton 1.0078 u. (Hint: 1 amu of mass defect = 931.5 MeV)

a) Mass Defect ; $E = \Delta mc^2$

(b) $\Delta m$ = (mass products – mass reactants)

$= (26*1.0078+30*1.0087-55.935) = 0.5288$

$E = 0.5288*931.5 = 492.5772$ (MeV)

$E = \Delta mc^2 = 0.5288 * 1.66*10^{-24}*10^{-3} *(3*10^8)^2$

$= 7.9* 10^{-11}$ (J)

($1eV=1.6*10^{-19}$ J )

13. Did you read the article 'Toxic Wastes and the Superfund Act"? What is it all about? What would you do if you discovered that your neighborhood was built upon a leaking toxic waste dump? What would you do if governmental agencies told you that there was no proof that the toxic wastes were causing you harm?