1. **(5 points each)**

A) The Sun emits radiant energy at the rate of $3.9 \times 10^{26}\ J \cdot s^{-1}$. What is the rate of mass loss (in kilograms per second) of the Sun?

in 1 sec $\rightarrow 3.9 \times 10^{26}$ J

$E = mc^2$

$m = \frac{E}{c^2} = \frac{(3.9 \times 10^{26}\ J)}{(3 \times 10^8 \frac{m}{s})^2} = 4.3 \times 10^9\ kg$

mass loss: $4.3 \times 10^9 \frac{kg}{s}$

B) Write out the fusion mechanism that is responsible for 90% of the Sun's energy output.

Proton - Proton cycle

$${}^1_1H + {}^1_1H \rightarrow {}^2_1H + \beta^+ + \nu$$
$${}^2_1H + {}^1_1H \rightarrow {}^3_2He + \gamma$$ } twice

$${}^3_2He + {}^3_2He \rightarrow {}^4_2He + 2\,{}^1_1H$$

$$4\,{}^1_1H \longrightarrow {}^4_2He + 2\beta^+ + 2\nu + 2\gamma$$

C) Elements heavier than He but lighter than Fe are primarily produced by red giants. Write the most important nuclear reactions for producing $^{16}O$.

$${}^4_2He + {}^4_2He \rightarrow {}^8_4Be$$
$${}^8_4Be + {}^4_2He \rightarrow {}^{12}_6C$$
$${}^{12}_6C + {}^4_2He \rightarrow {}^{16}_8O$$

D) Write the nuclear reactions for producing $^{26}_{13}Al$ in a red giant.

Any reasonable scheme was acceptable (balanced nuclear reactions)

$$^{4}_{2}He \xrightarrow{\alpha} {}^{8}_{4}Be \xrightarrow{\alpha} {}^{12}_{6}C \xrightarrow{\alpha} {}^{16}_{8}O \xrightarrow{\alpha} {}^{20}_{10}Ne \xrightarrow{\alpha} {}^{24}_{12}Mg$$

$$^{24}_{12}Mg + {}^{1}_{0}n \rightarrow {}^{25}_{12}Mg \xrightarrow{{}^{1}_{0}n} {}^{26}_{12}Mg \xrightarrow{{}^{1}_{0}n} {}^{27}_{12}Mg$$

$$^{27}_{12}Mg \rightarrow {}^{27}_{13}Al + \beta^- \qquad {}^{27}_{13}Al \rightarrow {}^{26}_{13}Al + {}^{1}_{0}n$$

E) How is $^{235}U$ produced in nature?

Supernovae Explosions

**2. (5 points each)**

A) Calculate the longest wavelength of light (in nanometers) that can be absorbed by an electron confined in a quantum dot of diameter = 1.00 nm (use our 1-D model).

longest wavelength absorbed => smallest energy level difference

$\therefore$ $n = 1 \rightarrow n = 2$ transition

$$E_n = \frac{n^2 h^2}{8mL^2} \qquad \text{so, } \Delta E_{1\rightarrow 2} = \frac{(2^2 - 1^2)h^2}{8mL^2}$$

$$= \frac{(3)(6.626\times10^{-34}\,J\cdot s)^2}{(8)(9.11\times10^{-31}\,kg)(1.00\times10^{-9}\,L)^2}$$

$$= 1.807\times10^{-19}\,J$$

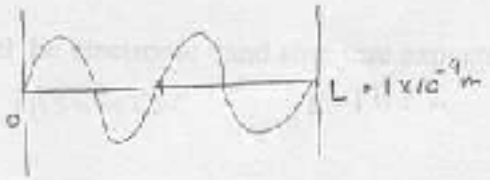
$$\lambda = \frac{hc}{E}$$

$$= \frac{(6.626\times10^{-34}\,J\cdot s)(3\times10^{8}\,\frac{m}{s})}{(1.807\times10^{-19}\,J)}$$

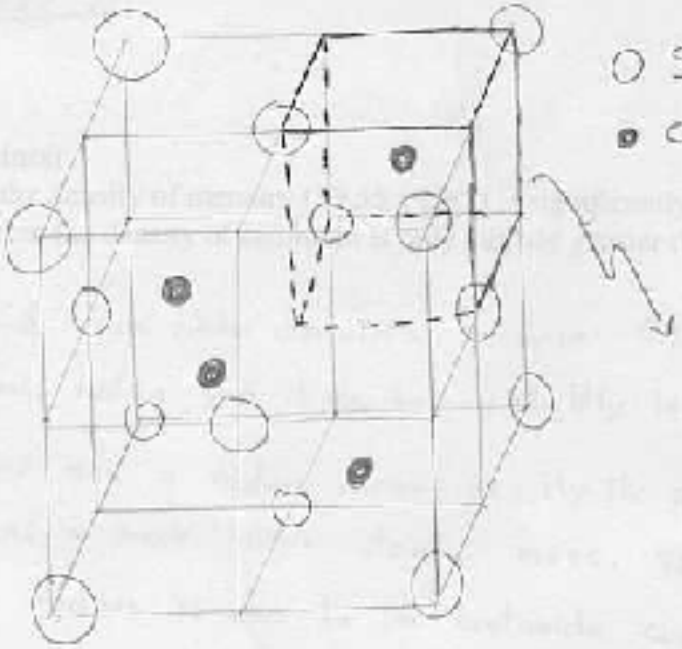
$$= 1.1\times10^{-6}\,m$$

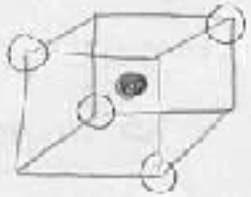
$\lambda = 1100\,nm$

B) Sketch the wavefunction for an electron in the n = 4 state of this quantum dot.




C) The CdS quantum dots that you made in lab were actually single crystals which have a diamond-like (zincblende) structure. Sketch the unit cell, labeling the atoms.

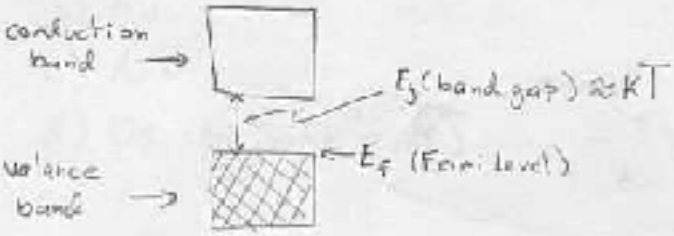


See Page 251
Figure 5.42 in textbook
($Cd^{2+}$ goes where $Zn^{2+}$ is)

D) Sketch and label the electronic band structure of CdS (show Fermi level).

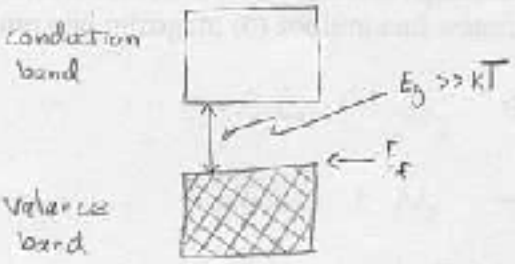
CdS - semiconductor (undoped)



E) As temperature increases, the electrical conductivity of CdS will increase.

F) Sketch and label the electronic band structure expected for quartz ($SiO_2$). Explain your answer.

$SiO_2$ - insulator




**3. (5+8+4+8 points)**

A) Explain why the density of mercury (13.55 g·cm$^{-3}$) is significantly higher than that of cadmium (8.65 g·cm$^{-3}$), whereas the density of cadmium is only slightly greater than that of zinc (7.14 g·cm$^{-3}$).

Zn and Cd have similar densities because Cd has a slightly larger atomic radius, but it also has a slightly larger atomic mass. Hg, however has a radius almost exactly the same as Cd, yet it has a much larger atomic mass. The similarity in atomic radius is due to the lanthanide contraction.

You must say something about both size and mass on this question

B) Identify the element with the larger atomic radius in each of the following pairs: (a) scandium and titanium; (b) copper and gold; (c) vanadium and niobium; (d) ruthenium and osmium.

a) Sc

b) Au

c) Nb

d) Os (or "same size")

C) The least reactive metals are gold and platinum.

The densest elements are osmium and iridium.

D) Write the balanced chemical equations for the reactions between (a) lithium and oxygen; (b) lithium and nitrogen; (c) sodium and water; (d) potassium superoxide and water.

a) $4Li + O_2 \rightarrow 2Li_2O$

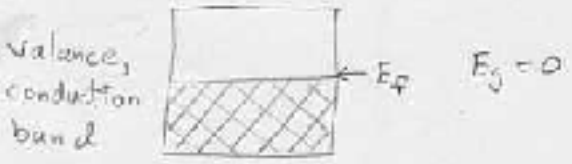
b) $6Li + N_2 \rightarrow 2Li_3N$

c) $2Na + 2H_2O \rightarrow 2NaOH + H_2$

d) $2KO_2 + H_2O \rightarrow 2KOH + \frac{3}{2}O_2$

**4. (5+10+5 points)** Silver is the best known conductor.

A) Sketch its energy band diagram, labeling the Fermi energy.



B) Calculate the atomic radius of silver given that its density is 10.5 g/cm$^3$ and that it forms an fcc crystal.

$$\text{FCC} \Rightarrow \quad d = \frac{4M}{8^{3/2} r^3 N_a}$$

$$r = \left(\frac{4M}{8^{3/2} N_a d}\right)^{1/3}$$

$$= \left[\frac{4\left(107.8 \frac{g}{mole}\right)}{8^{3/2}\left(6.02\times10^{23} mole^{-1}\right)\left(10.5 g/cm^3\right)}\right]^{1/3} = \boxed{1.4\times10^{-8} cm}$$

$$= 1.4\times10^{-10} m$$

$$= 140 pm$$

C) The coordination number of each atom in this crystal is 12.