Example: Defects in gold

(Q): You have a single crystal of 100% pure gold. Identify which of the following defects you would expect to be present at room temperature.

(A): X | Free surface
| Grain bondaries
X | Vacancies
| Inclusions
| Substitutional impurity atoms
| Interstitial impurity atoms

Example: Glass transition temperature

(Q): Which of these processes will lower the glass transition temperature of glass?

(A):
- Increase the cooling rate
- Decrease the cooling rate
- X Increase amount of network modifier
- Decrease amount of network modifier
- Quench the glass to cool the surfaces quickly.
- X Decrease the number of defects

Example: Physical Properties

(Q): Please mark ~~all of the~~ below all of the statements that correctly describe the physical properties of glass.

(A):
- X | Glasses do not have slip systems
- X | Glasses consist of both covalent and ionic bonding
- | Glasses are brittle at room temperature
- X | Glasse are amorphous and have no long range symmetry
- | The volume of a sample of glass depends on its cooling rate
- | Glasses must consist of network ~~modifiers~~ formers and modifiers.

Example: Metal yield strength and defects

(Q): Metals yield at a stress much lower than those calculated on the basis of their bond strength alone. This is explained by the presence of defects. Identify the principal defects responsible for this observation.

(A):

- Grain boundaries
- Interstitial Metal Atoms
- Vacancies
- X Dislocations

Example: Aluminum Vacancies

(Q): At 10°C, below the melting point of aluminum, 0.08% of the atom sites are vacant. At 484°C, only 0.01% are vacant. Given this information, determine the energy of vacancy formation (ΔH_v) for aluminum.

(A): Recall the equation

$$\ln\left(\frac{n_{v1}}{n_{v2}}\right) = \frac{-\Delta H_v}{k}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

Solving for ΔH_v, see that

$$\Delta H_v = \frac{-k \ln\left(\frac{n_{v1}}{n_{v2}}\right)}{\left(\frac{1}{T_1} - \frac{1}{T_2}\right)}$$

Then by plugging in,

$$\Delta H_v = \frac{-(1.381 \cdot 10^{-23}) \ln\left(\frac{0.08}{0.01}\right)}{\frac{1}{923} - \frac{1}{757}}$$

$$= \boxed{1.21 \cdot 10^{-19} \text{ J/vacancy}}$$

Example: Largest Impurity

(Q): Determine the radius of the largest atom that can be accommodated in the interstices of BCC Fe without stress. (Hint: The center of the largest site is at 1/2, 1/4, 0; draw a unit cell, it helps.)

(A): We see that due to gaps in the BCC structure, impurities up to 3.61×10^{-9} cm are able to be put in without stress.

Example: Temperature dependence of vacancies

(Q): An activation energy of 2.0 eV is required for form a vacancy in a metal. At 800°C there is 1 vacancy for every 10^4 atoms. At what temperature will there be one vacancy for every 1000 atoms?

(A): Recall the equation

$$\ln\left(\frac{n_{v1}}{n_{v2}}\right) = \left(\frac{1}{T_1} - \frac{1}{T_2}\right)\frac{-\Delta H_v}{k}$$

Then by plugging in, see that

$$\ln\left(\frac{10^4}{10^3}\right) = \frac{-(2\,eV)(1.602\cdot 10^{-19})}{1.381\cdot 10^{-23}}\left(\frac{1}{T} - \frac{1}{1073}\right)$$

Solve for T; then

$$\boxed{T = 1201 \text{ Kelvin}}$$