59. (Transition metal complexes, Le Châtelier's principle) The cobalt complexes participating in the equilibrium below comprise a humidity sensor. From Le Châtelier's principle, when the sensor is moist (excess H_2O), what color is the cobalt complex?

$$Co(H_2O)_6^{2+} + 4\ Cl^- \text{<---->}\ CoCl_4^{2-} + 6\ H_2O$$

pink blue

pink, blue

60. (Equilibrium, polarity) **Demonstration:** A solution of iodine dissolved in water is placed in a separatory funnel. An equal volume of CCl_4 is to be added to the funnel. Based on polarity,

most of the iodine will prefer to stay in the water layer, **most of the iodine will prefer to transfer into the CCl_4 layer**

Add the CCl_4 in such a way as to minimize mixing. Is the system at equilibrium?

yes, **no**

Shake several times to show that color changes eventually cease.

The equilibrium constant K for the reaction

$$I_2\ (\text{in water}) \text{<==>}\ I_2\ (\text{in } CCl_4)$$

has a value of ~100 near room temperature. If at some time the concentration of I_2 in water is 0.1 mM and of I_2 in CCl_4 is 1.0 mM, what will happen?

no net movement of I_2 between solvents, **I_2 in water will move into CCl_4**, I_2 in CCl_4 will move into water.

Once equilibrium for this partitioning experiment has been established, the amount of each solvent is to be doubled. What will then happen?

no net movement of I_2 between solvents, I_2 in water will move into hexane, I_2 in hexane will move into water.

Repeat the initial experiment in the reverse order: a solution of CCl_4 having the same total I_2 concentration is placed in a separatory funnel and an equal volume of water is to be added to it. Will the I_2 partition itself in the same way after shaking? (Compare the two separatory funnel color distributions)

yes, no

In water, I_2 can combine with I^- ion to form a complex, I_3^-, with a relatively large equilibrium constant of ~1000 M^{-1}. **Demonstration:** If KI is added to the water layer containing I_2 that had come to equilibrium with a layer of I_2 in CCl_4, what will happen?

no net movement of I_2 between solvents, I_2 in water will move into CCl_4, **I_2 in CCl_4 will move into water**

61. (Equilibrium) Consider the bonds that must be made or broken for the reaction

$$O_2N\text{-}NO_2\ (g) \text{<=>}\ 2\ NO_2\ (g)$$

The reaction will be

endothermic, exothermic

63. (Equilibrium, concentration, competition) A competition experiment involves O_2 and CO vying for hemoglobin (Hb) sites, defined by the equilibrium $Hb(O_2)_4$ + 4 CO <=> $Hb(CO)_4$ + $4O_2$. From Le Châtelier's principle, how is CO poisoning reversed?
   decrease O_2 pressure, **increase O_2 pressure**, remove Hb

64. (Equilibrium, Le Châtelier's principle; Ch. 5 & 9 "Companion") The body-centered cubic (bcc) phase of a metal has a 68% packing efficiency, while the face-centered cubic (fcc) phase of the same metal has a 74% packing efficiency. For the equilibrium

bcc metal<=>fcc metal

as pressure increases, the equilibrium
   shifts to the left, **shifts to the right**, is unaffected

66. (Enthalpy, equilibrium) N_2(g) + $3H_2$(g) <=> 2 NH_3(g) + reaction energy; Which are collectively stronger bonds?
   those in the reactants, **those in the products**

What effect will spraying H_2O into the system have if NH_3 is far more soluble in H_2O than N_2 and H_2?
   no effect, **increase product**, increase reactants

68. (pH scale) A solution with pH=5 is 100 times more acidic than a solution with a pH =?
   7, 3, 0.05

70. (Weak acids, Le Châtelier's principle) CH_3COOH<=>CH_3COO^- + H^+; pK_a=5

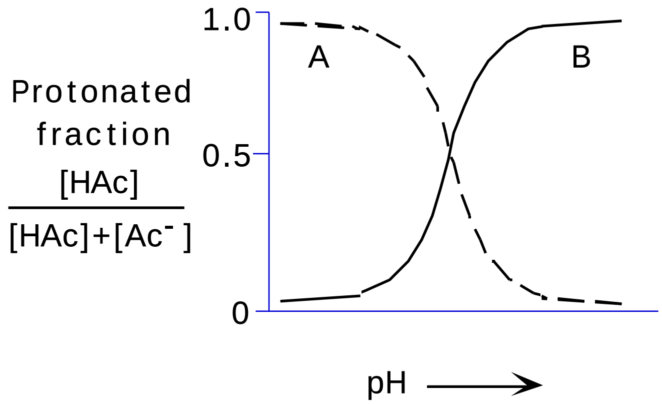
To make more CH_3COOH, add
   NaOH, **HCl**

To make more CH_3COO^-, add
   NaOH, HCl

At pH=2, what is the most prevalent species?
   CH_3COOH, CH_3COO^-, equal amounts of the acid and its conjugate base

At pH=5, what is the most prevalent species?
   CH_3COOH, CH_3COO^-, **equal amounts of the acid and its conjugate base**

Which plot shows the correct distribution of acetic acid as a function of pH?
   A, B



83. (Doping, semiconductors, periodic properties; Ch. 8 “Companion”) Which dopant will act as an acceptor for Si?
   B, Ge, As
   As a donor?
   B, Ge, **As**

84. (Equilibrium; Ch. 8 “Companion”) As a dopant in Si, Al is involved in the equilibrium
   Al<==>h^+ + Al^X. What is the charge on the aluminum in the product?
   -1, 0, +1

85. (Phase changes, Le Châtelier’s principle; Ch. 9 “Companion”) Nickel titanium memory metal has a symmetric cubic unit cell in its high temperature form and a less symmetric noncubic unit cell in its low temperature form. **Demonstration 9.6** “Companion”**:** By slightly changing the Ni to Ti ratio, a sample can have, at room temperature, one or the other of these phases. Two small rods, one in the symmetric structure, one in the less symmetric structure at room temperature are dropped on the floor. One produces a ringing sound, the other a soft thud. Which gives the ringing sound?
   the symmetric high temperature phase, the less symmetric low temperature phase

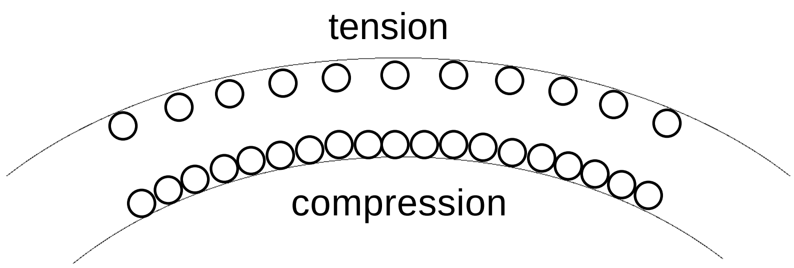
   To cause the ring-sounding sample to give a thudding sound,
   heat it, **cool it**
   Demonstration: cool the sample with liquid nitrogen, remove it and drop it to hear a thud. Rapid hand warming will eventually restore the ring during repeated drops.

   Which phase is more mechanically flexible?
   the symmetric high temperature phase, **the less symmetric low temperature phase**

   When nickel titanium memory metal interconverts between the symmetric high temperature form and the less symmetric low temperature form, which of the following changes?
   elemental analysis, **X-ray diffraction pattern**, **hardness**

When a sample of nickel-titanium in the high temperature phase is bent, as pictured, the atoms that are under compression and thus favored by Le Châtelier's principle to convert to the denser low-temperature phase are those

at the bottom of the bend, in the middle of the bend, at the top of the bend



Demonstration 9.5 “Companion”: Bend memory metal eyeglass frames and show that they return to their original shape. Then cool with liquid nitrogen to show that when the eyeglass frames are in the more flexible low temperature phase they stay bent until they return to room temperature, where they regain their original shape.

86. (Semiconductors, bands; Ch.8 “Companion”) Pictured below is an energy band diagram for silicon.

When doped into Si, Al is a(n)

donor, **acceptor**

When doped into Si, P is a(n)

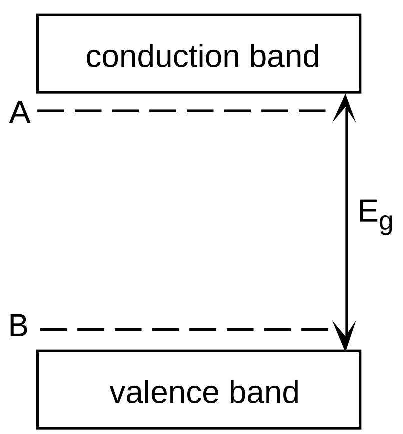
donor, acceptor

Which energy level corresponds to Al?

A, **B**

Which energy level corresponds to P?

A, B



Al <=> Al^- + h^+

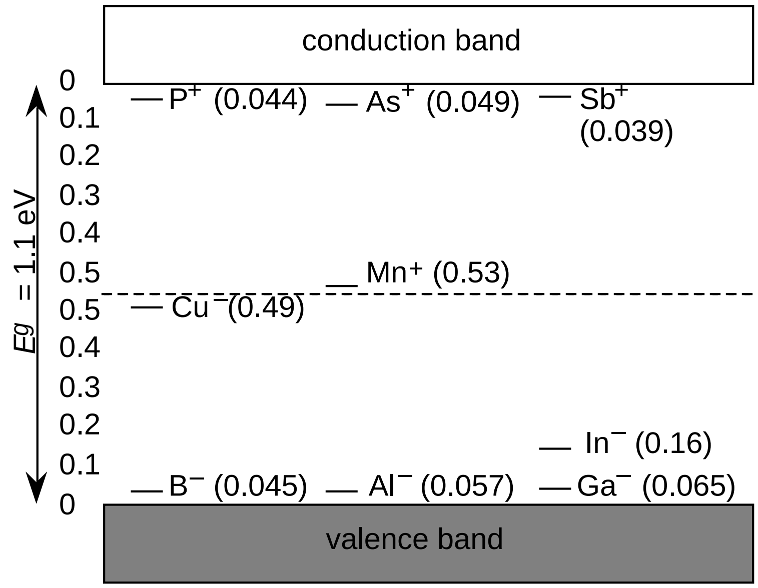
P <=> P^+ + e^-

87. (Semiconductors, doping; Ch 8 “Companion”) Which is a weaker acceptor (analogous to weaker acid)

In, **Cu**

Which is a weaker donor (analogous to weaker base)?

As, **Mn**



98. (Equilibrium) $K_{eq} = [NO_2]^2/[N_2O_4]$; heat + N_2O_4 <=> 2 NO_2
As temperature increases, the equilibrium constant, K
increases, decreases, remains constant

99. (Autoionization, equilibrium; Ch. 8 "Companion") If the product of n and p in a semiconductor is a constant, the two are
directly related, **inversely related**

100. (pH scale) **Demonstration:** Predict a pH value for 0.1 M NaOH.
1, 7, **13**

102. (Doping, equilibrium, autoionization; Ch. 8 "Companion") $K_{Si}=[h^+]x[e^-]=pxn \approx 10^{20}$ cm^{-6} For this endothermic autoionization reaction, as temperature increases, K_{Si}
increases, decreases, remains constant

116. (Equilibrium) If K = 100 = [I_2 in CCl_4] / [I_2 in water] for the equilibrium
I_2 in water <==> I_2 in CCl_4
What is K for the reverse reaction, I_2 in CCl_4 <==> I_2 in H_2O?
100, 1, **0.01**

121. (Coordination chemistry, equilibrium) **Demonstration:** A green solution of $Ni(H_2O)_6^{2+}$ has added to it a small quantity of ammonia, which turns the solution blue through formation of $Ni(NH_3)_6^{2+}$; the value of K for this reaction is ~10^9. To this blue solution is added about the same number of moles of the chelating ligand ethylenediamine (en), turning the solution violet through formation of $Ni(en)_3^{2+}$; the value of K for this reaction is also ~10^9. Using these same quantities, what happens if en is added first, then the ammonia is added?
the violet solution turns blue; **the violet solution stays violet**

122. (Vapor pressure, equilibrium) **Demonstration:** The same amount of solid iodine is added to two identical glass tubes, which are then stoppered and heated to the same temperature. The color in the two tubes is seen to be the same and solid iodine is still present in the bottom of the tubes. When a lot of additional iodine crystals are added to one of the tubes

the color of the vapor in that tube will become darker, **there is no change in the color of the vapor**, the color of the vapor in that tube will become lighter

124. (Equilibrium, semiconductors, doping; Ch. 8 “Companion;” LeChâtelier's principle) When doped into Si, Cu is a weak acceptor, Cu <==> Cu^- + h^+.
To convert most of the copper to Cu^-, dope with

a strong acceptor like aluminum, **a strong donor like phosphorus**

126. (Chromatography, equilibrium) The chromatographic equilibrium for a species A can be described as A in mobile phase <==> A in stationary phase
A mixture of two volatile compounds is injected onto a column with air, which doesn't interact with the column. Which of the three peaks below is air?

1, 2, 3

Which of the other two peaks corresponds to the larger equilibrium constant K?

1, 2, **3**

```
        1          2     3
  |_____|________|___|________________
inject                  retention time -->
t = 0
```

139. (Semiconductors, equilibrium, Ch. 8 “Companion”) When a semiconductor having autoionization equilibrium constant K is irradiated with light above its band gap energy

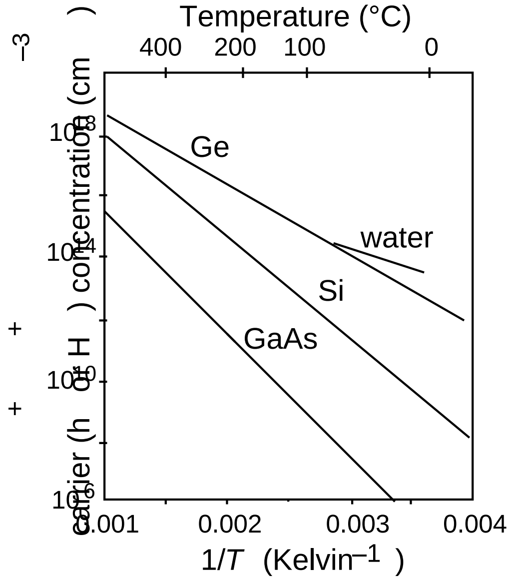
n x p = K, **n x p > K**, n x p < K

147. (Semiconductors, equilibrium; Ch. 8 “Companion”) Given that the band gap energy for Ge is less than that for Si, at room temperature what will be true of the equilibrium constants for autoionization of the two solids?

$K_{Si} > K_{Ge}$, $K_{Si} = K_{Ge}$, **$K_{Si} < K_{Ge}$**

148. (Semiconductors, equilibrium; Ch. 8 “Companion”) Compare the number of carriers per cm^3 in silicon and water at room temperature from the graph below?

10^4 times more in silicon, equal numbers, **10^4 times more in water**



150. (Semiconductors; Ch. 8 “Companion”) Conductivity reflects the concentration of electrons, n, and holes, p; and n x p = K. In pure Si, K = 10^{20} cm^{-6}. There are approximately how many charge carriers per cm^3?

10^{20}, **10^{10}**, 10

When Si is doped with Al to make p = 10^{17}, there are now approximately how many charge carriers per cm^3?

10^3,10^{10}, **10^{17}**

156. (Equilibrium) I_2 in water <==> I_2 in oil K_1 = [I_2 in oil] / [I_2 in water]

I_2 in oil <==> I_2 in ether K_2 = [I_2 in ether] / [I_2 in oil]

What is K_3 for the summed reaction, I_2 in water <==> I_2 in ether K_3 = [I_2 in ether] / [I_2 in water]

$K_3 = K_1 + K_2$, **$K_3 = K_1 \times K_2$** , $K_3 = K_1 / K_2$, $K_3 = K_2 / K_1$

157. (Chirality) Chiral molecules rotate the plane of polarized light because the left- and right-hand circularly polarized components of the light (which trace out chiral opposite-handed helices) experience different refractive indices in their interactions with a chiral molecule and travel at different velocities (c/n), causing a net rotation of the plane-polarized light. If RHCPL travels faster through a solution of the *d* isomer of a chiral molecule, causing a clockwise rotation, which other combination causes the light to travel at this same velocity?

d isomer with LHCPL, ***l* isomer with LHCPL**, *l* isomer with RHCPL

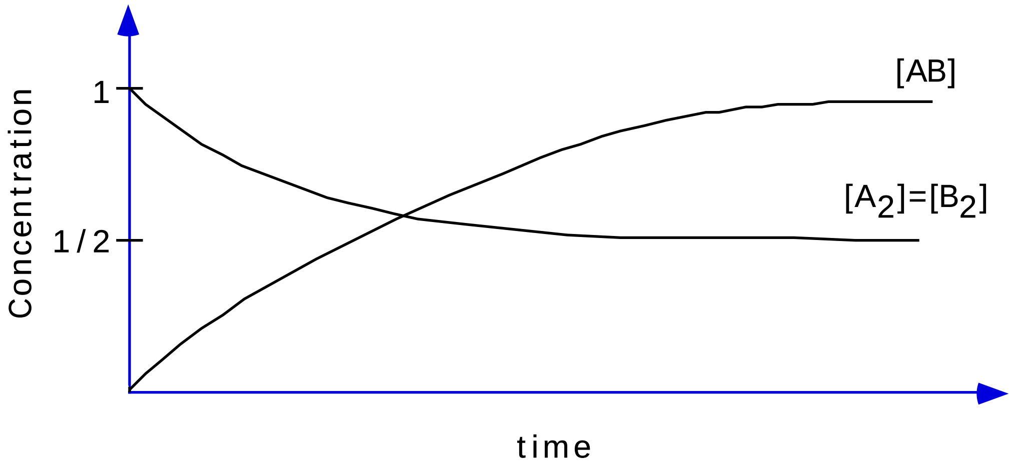
Is the plane of polarized light rotated in the same direction in both of these experiments?

yes, **no**

166. For the reaction:

$$A_2 + B_2 \longrightarrow 2AB$$

The concentration-time graph is as follows:



What is the value of the equilibrium constant?

1, 2, **4**

167. The equilibrium constant expression

$$\frac{[N_2][H_2O]^2}{[NO]^2[H_2]^2} = K_c$$

corresponds to which of the following balanced chemical reactions?

A. $N_2(g) + 2H_2O(g) \longleftrightarrow 2NO(g) + H_2(g)$

B. $2H_2(g) + 2NO(g) \longleftrightarrow 2H_2O(g) + N_2(g)$

A, **B**

168. For the reaction

$$N_2(g) + 3H_2(g) \longleftrightarrow 2NH_3(g)$$

The relationship between K_c and K_p is

A. $K_p = K_c(RT)^2$

B. $K_p = K_c(RT)^{-2}$

A, **B**

169. For the reaction

$$N_2(g) + 3H_2(g) \longleftrightarrow 2NH_3(g)$$

$$Kc = \frac{[NH_3]^2}{[N_2][H_2]^3} = 0.500 \text{ at } 400^oC$$

Suppose we make a mixture with the following concentrations:

$$[NH_3] = 1.0M, [N_2] = 1.0M, [H_2] = 1.0M$$

In which direction will the reaction go?

A. Reactants $\longrightarrow$ Products

B. Products $\longrightarrow$ Reactants

A, **B**

170. In the equilibrium

$$2NOCl(g) \longleftrightarrow 2NO(g) + Cl_2(g)$$

The initial conditions are:
$[NOCl]_o$ = 1.0 M
[NO] = 0.0 M
[Cl2] = 0.0 M

Which is the correct expression for the equilbrium concentrations?

A. [NOCl] = 1.0-x, [NO] = x, $[Cl_2]$ = x

B. [NOCl] = 1.0-2x, [NO] = 2x, $[Cl_2]$ = x

A, **B**

171. Which of the following equilibria will move left (products ---> reactants) when the volume of the reaction vessel is increased?

A. $N_2(g) + 3H_2(g) \longleftrightarrow 2NH_3(g)$

B. $H_2(g) + I_2(g) \longleftrightarrow 2HI(g)$

C. $2H_2S(g) \longleftrightarrow 2H_2(g) + S_2(g)$

A, B, C

172. The equilibrium constant for the reaction

$$CO(g) + 2H_2(g) \longleftrightarrow CH_3OH(g)$$

is 4.3 at 250^{o}C and 1.8 at 275^{o}C.

The reaction is

exothermic, endothermic

190. If the density of graphite is about 2 g/mL and that of buckyball is about 1.5 g/mL, in which direction would the application of high pressure drive the equilibrium?

toward formation of graphite, toward formation of buckyball, neither would be formed preferentially

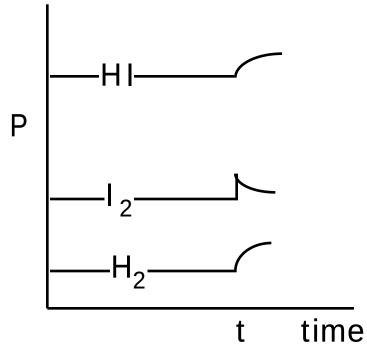
209. The equilibrium constant for autoionization of silicon at 298 K is about 10^20 cm^-6. If the silicon is doped with phosphorus to give an electron concentration, n, of 10^15cm^-3, the concentration of valence band holes, p, is:

10^20 cm^-3
10^15 cm^-3
10^10 cm^-3
10^5 cm^-3

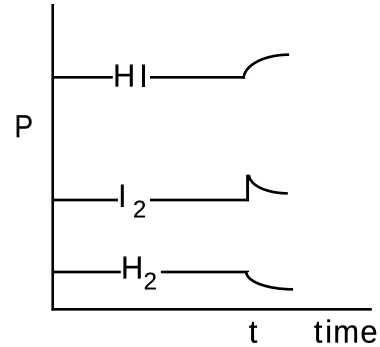
211. The element Bi melts at 271 degrees C and has a density of 9.73 g/ml as a solid and 10.05 g/ml as a liquid at this temperature. For the equilibrium, Bi(s) <==> Bi(l), melting is favored in this endothermic reaction by

decreasing either temperature or pressure
increasing temperature or decreasing pressure
increasing either temperature or pressure
decreasing temperature or increasing pressure

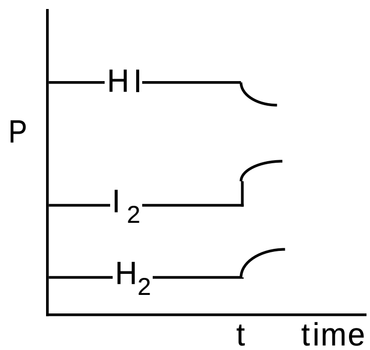
217. Consider the gaseous equilibrium of H_2 (g) + I_2 (g) <==> 2 HI (g). As sketched below, the pressures, P, of these three gases are at equilibrium in a container. At some time, t, extra I_2 is added, as shown. Which of the sets of curves shows how the system will respond to this situation?



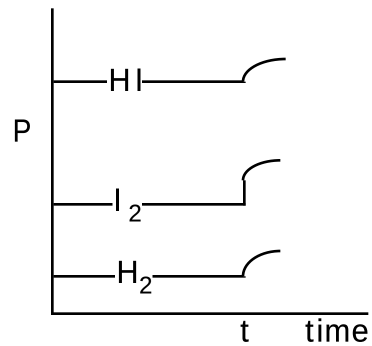
A



B



C



D

A, **B**, C, D