CHM 139
April 2012 Exam
Solutions

① Assuming 100g of compound:

Cr:

$$n = \frac{73.52\text{g}}{52\text{g/mol}} = 1.414 \text{ mol}$$

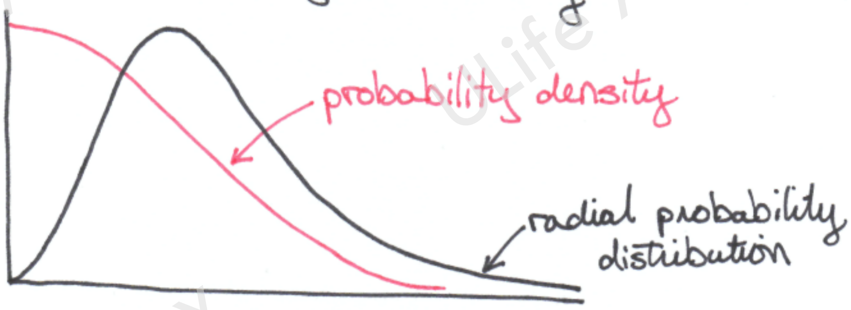
Si:

$$n = \frac{26.48\text{g}}{28.1\text{g/mol}} = 0.942 \text{ mol}$$

$$Cr_{\frac{1.414}{0.942}} Si_{\frac{0.942}{0.942}} \rightarrow Cr_{1.5}Si \rightarrow Cr_3Si_2$$

Ⓓ

② Ⓓ The radial probability curves take the surface area of a sphere into consideration when calculating probability distribution



③

$$E_{light} = (75\,J)(0.05)(0.1)$$

$$= 0.375\,J \text{ every second}$$

$$E_{photon} = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34})(3\times10^{8})}{550\times10^{-9}}$$

$$= 3.614\times10^{-19}\,J$$

$$\#\text{ photons} = \frac{E_{light}}{E_{photon}} = 1.04\times10^{18}\text{ photons}$$

Ⓑ

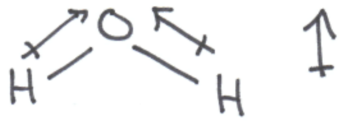
④ Ⓔ from the graph $\frac{V}{V-b} - \frac{a}{VRT} > 0$

for ALL P $\therefore \frac{V}{V-b} > \frac{a}{VRT}$

⑤ Generally the magnitude of election affinity increases going to the right and going up on the periodic table.

Ⓓ

⑥ H_2O is bent and O is more electronegative than H



Ⓓ

⑦ Need mol fractions:

H_2O

$m = (500\,mL)(0.988\,g/mL)$

$= 494\,g$

$n = \frac{494\,g}{18\,g/mol}$

$= 27.44\,mol$

$X_{H_2O} = \frac{27.44}{27.44+0.137}$

$= 0.995$

Glycerol

$m = (10\,mL)(1.26\,g/mL)$

$= 12.6\,g$

$n = \frac{12.6\,g}{92\,g/mol}$

$= 0.137\,mol.$

$X_{glycerol} = 0.005$

$P = P_{H_2O} X_{H_2O} = (92.5)(0.995)$

$= 92.04$ torr

$\Delta P = 92.5 - 92.04$

$= 0.46$ torr

Ⓑ

⑧ Using $\Delta T_b = K_b m$ the solution with the highest molality will have the highest b.p.

Ⓒ $$CuCl_2 \longrightarrow \underbrace{Cu^{2+} + 2Cl^-}_{2.25\ m}$$

⑨ Ⓒ For zeroth order reactions rate does not depend on concentration.

⑩ Reaction is 2nd order.

$$\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$$

$$\frac{1}{(0.041)} = k(67) + \frac{1}{(0.125)}$$

$$k = 0.245\ M^{-1}s^{-1}$$

Ⓒ

⑪

$$\begin{array}{lccc} & NH_4HS_{(s)} \rightleftharpoons & H_2S & + NH_3 \\ I & & 0 & 0 \\ C & & +x & +x \\ E & & x & x \end{array}$$

$P_T = 2x$

$= 0.66\ atm$

Ⓓ

$K_p = (P_{H_2S})(P_{NH_3}) = x^2 = 0.11$

$x = 0.33\ atm$

⑫

$n = \frac{20g}{74.45g/mol}$

$= 0.269\ mol$

$[NaClO] = \frac{0.269\ mol}{20\ L}$

$= 0.01343\ M$

$K_b = \frac{K_w}{K_a} = \frac{10^{-14}}{2.9\times10^{-8}} = 3.45\times10^{-7}$

	ClO^- +	H_2O $\rightleftharpoons$	$HClO$ +	OH^-
I	0.01343		0	0
C	$-x$		$+x$	$+x$
E	0.01343		x	x

$K_b = \frac{[HClO][OH^-]}{[ClO^-]}$

$3.45\times10^{-7} = \frac{x^2}{0.01343-x}$

$x = 6.8\times10^{-5} = [OH^-]$

$pOH = -\log 6.8\times10^{-5} = 4.17$

$pH = 14 - 4.17 = 9.83$

Ⓔ

⑬ $\underset{\uparrow}{\mathrm{AcOH}} + \mathrm{H_2O} \rightleftharpoons \underset{\uparrow}{\mathrm{AcO^-}} + \underset{\uparrow}{\mathrm{H_3O^+}}$

decreasing volume increases ALL concentrations

$K_a = \frac{[\mathrm{AcO^-}][\mathrm{H_3O^+}]}{[\mathrm{AcOH}]}$ ← numerator increases the most so $Q_c > K_a$ ∴ equilibrium shifts left.

Ⓐ

⑭ $\Delta G° = \underset{-}{\Delta H°} - T\underset{+}{\Delta S°}$ ↙ $\Delta G°$ will always be negative

Ⓐ

⑮
$$\begin{aligned}\Delta G &= \Delta G° + RT \ln Q \\ &= -RT \ln K_e + RT \ln Q \\ &= RT(\ln Q - \ln K) \\ &= (8.314)(298)\left(\ln\left(\frac{(0.122)^2}{0.453}\right) - \ln 0.113\right) \\ &= -3060\ \mathrm{J}\end{aligned}$$

Ⓒ

⑯

$$q = m C_p \Delta T$$
$$= (22\text{g})\left(4.18\tfrac{\text{J}}{\text{g}^\circ\text{C}}\right)(75^\circ\text{C})$$
$$= 6\,897\ \text{J}$$

Ⓐ

⑰ $Hg_{(l)} \rightarrow Hg_{(g)}$ find when the reaction becomes spontaneous

$$\Delta G = \Delta H - T\Delta S$$
$$0 = (60\,780\text{J}) - T(174.7 - 77.4)$$
$$T = 624\ \text{K}$$

Ⓓ

⑱ Anode (oxidation is on the left)

$$Cu \mid Cu^{2+} \parallel Fe^{2+}, Fe^{3+} \mid Pt_{(s)}$$

Ⓓ

⑲ Ⓓ (there is a table of E° values at the end of the test)

⑳

$$H_{2(g)} + Hg_2Cl_{2(s)} \longrightarrow 2\,H^+_{(aq)} + 2Cl^-_{(aq)} + 2\,Hg_{(l)}$$

decreasing $[H^+]$ shifts eq. to the right

Ⓓ

㉑

Anode : Al (oxidation) Anions $(NO_3^-) \rightarrow A$

Cathode : Co (reduction) Cations $(Na^+) \rightarrow B$

Ⓑ

㉒

$$E = E^\circ - \frac{0.0592}{n} \log \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

$$= 1.10 - \frac{0.0592}{2} \log\left(\frac{1}{0.2}\right)$$

$$= 1.08V$$

$Zn \longrightarrow Zn^{2+} + 2e^-$ $E^\circ = +0.76$

$Cu^{2+} + 2e^- \longrightarrow Cu$ $E^\circ = +0.34$

$E = 1.10$

Ⓑ

㉓

$$E = E^\circ - \frac{0.0592}{n}\log Q$$

$$= 0 - \frac{0.0592}{1}\log\frac{5\times10^{-3}}{0.15}$$

$$= 0.087\ V$$

$$\Delta G = -nFE$$

$$= -1\,(96\ 500)(0.087)$$

$$= -8\ 438\ J$$

Ⓐ Work done will be positive (on the surroundings) But actual work done will depend on the volume of the solution. Ⓐ is the best answer.

㉔ $Ca^{2+} + 2e^- \rightarrow Ca$

$$q = I\cdot t = (1.12\ A)(3h \times 3600\ s/h)$$

$$= 12\ 096\ C$$

$$n_{e^-} = \frac{12\ 096\ C}{96\ 500\ C/mol} = 0.125\ mol$$

$$n_{Ca} = \frac{n_{e^-}}{2} = 0.0627\ mol$$

$$m_{Ca} = 0.0627\ mol\cdot 40\ g/mol = 2.51\ g$$

Ⓒ

Short Answer:

① a) Solid A

1 A (8 on corners)
1 X (1 in middle)

Solid B

4 A (4 in middle)
4 X (8 on corner, 6 of faces)

Solid C

4 A (8 on corners, 6 on faces)
4 X (1 in middle, 12 on edges)

b)

$$\frac{2.10\,g}{(1\ cm)^3} = \frac{X}{(0.57\,nm)^3}$$

$$\frac{2.10\,g}{(0.01\,m)^3} = \frac{X}{(0.57\times10^{-9}\,m)^3}$$

need to make sure units match.

$$X = 3.89\times10^{-22}\,g$$

c) AX has MW = 58.5 g/mol

$$n = \frac{3.89\times10^{-22}\,g}{58.5\,g/mol} = 6.65\times10^{-24}\,mol$$

$$N = \frac{6.65\times10^{-24}}{\cancel{\quad}} \times N_A = 4$$

$\therefore$ there are 4 A's and 4 X's in the unit cell

d) Solid B and C both have the correct unit formula.

② a)

$$\ln\left(\frac{K_2}{K_1}\right) = -\frac{\Delta H}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$\ln\left(\frac{K_2}{1.28\times10^4}\right) = -\frac{(-98900)}{8.314}\left(\frac{1}{222} - \frac{1}{852}\right)$$

$$K_2 = 2.06\times10^{21}$$

b)

$$\text{Sol.} = K_H \cdot P$$

$$= (1.242)(1\times10^{-3})$$

$$= 1.242\times10^{-3}\ \text{M}$$

c)

	H_2SO_3 + H_2O →	HSO_3^- +	H_3O^+
I	1.242×10^{-3}	0	0
C	$-x$	$+x$	$+x$
E	$1.242\times10^{-3}-x$	x	x

Assume that all of the acid results from the first deprotonation.

$$K_{a1} = \frac{x^2}{1.242\times10^{-3}-x} = 1.32\times10^{-2}$$

$$x^2 + 1.32\times10^{-2}x - 1.64\times10^{-5} = 0$$

$$x = 0.00114\ \text{M} = [H_3O^+]$$

$$\text{pH} = -\log x = 2.94$$

③ a) Rearranging the given equations :

$$\Delta G = \Delta H - T\Delta S$$

$$-RT\ln K = \Delta H - T\Delta S$$

$$\underset{\underset{y}{\uparrow}}{\ln K} = \underset{\underset{m}{\uparrow}}{-\left(\frac{\Delta H}{R}\right)} \underset{\underset{x}{\uparrow}}{\frac{1}{T}} + \underset{\underset{b}{\uparrow}}{\frac{\Delta S}{R}}$$

$$y = m x + b$$

$\therefore \frac{\Delta S}{R} = 40$

$\Delta S = 333\ \text{J/K mol}$

$-\frac{\Delta H}{R} = \frac{-40}{0.003}$

$\Delta H = +111\ \text{kJ/mol}$

b) An exothermic process would have a positive slope, while an endothermic process has a negative slope.

c) $\Delta G = \Delta H - T\Delta S$

$= 111\,000 - (773)(333)$

$= -146\ \text{kJ}$

Yes, because $\Delta G°$ is negative.

④ a)

$$\Delta G = -nFE$$
$$= -(4)(96\,500)(-1.23)$$
$$= 475 \text{ kJ}$$

b) Use Hess's Law:

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)} \quad \Delta G^\circ = -475\text{kJ}$$
$$2H_2O_{(l)} \rightarrow 2H_2O_{(g)} \quad \Delta G^\circ = 2(8.6)\text{kJ}$$
$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)} \quad \Delta G^\circ = -457.8\text{kJ}$$

c)

$$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$$
$$\Delta G = (\Delta G_f)_{prod.} - (\Delta G_f)_{react.}$$
$$= 3(-394) + 4(-229) - (-24.5)$$
$$= -2\,073.5 \text{ kJ/mol}$$

$$n = \frac{700g}{44g/mol} = 15.9 \text{ mol}$$

$$\text{Work} = n(-\Delta G)$$
$$= (15.9)(2073.5)$$
$$= 33\,000 \text{ kJ}$$

d) 2 mol of H_2 creates 457.8 kJ (part b)

or 228.9 kJ/mol.

$$n = \frac{33000 \text{ kJ}}{228.9 \text{ kJ/mol}} = 144 \text{ mol}$$

$$m = n \cdot MW = (144)(2.016) = 290 \text{ g}$$

H_2 produces more energy per gram.