Fall 2024

CHM2045 Exam 2 Review Solutions

1. $2C_6H_6(l) + 15O_2(g) \longrightarrow 12CO_2(g) + 6H_2O(g)$

$1.608\,g \cdot \frac{1\,mol\,C_6H_6}{78.11\,g} = 0.0206\,mol\,C_6H_6$

$q_{rxn} + q_{H_2O} + q_{cal} = 0$

$q_{H_2O} + q_{cal} = -q_{rxn}$

$q_{H_2O} = mC\Delta T$

$m = 2.45\,Kg \cdot \frac{1000\,g}{1\,Kg} = 2450\,g\,H_2O$

$C = 4.154\,J/g\,°C$

$\Delta T = T_f - T_i = 34.852 - 25.720 = 9.132\,°C$

$q_{H_2O} = 2450\,g\left(\frac{4.154\,J}{g\,°C}\right)(9.132\,°C) = 93410.31\,J$

$q_{cal} = C_{cal}\Delta T = \frac{923\,J}{°C}(9.132\,°C) = 8428.836\,J$

$-q_{rxn} = 93410.31 + 8428.836 = 102039.14\,J$

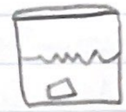
$q_{rxn} = -102039.14\,J \cdot \frac{1\,KJ}{1000\,J} = -102.04\,KJ$

$\Delta E = \Delta H + w$ ← 0 b/c bomb calorimeter has $\Delta V = 0$

$\Delta E = \Delta H = \frac{q_{rxn}}{mol\,H_2O} = \frac{-102.04\,KJ}{0.0206\,mol\,C_6H_6} = -4953.4\,KJ/mol$

$\boxed{\Delta E = -4953\,KJ/mol\,C_6H_6}$

2. $q_{Fe} + q_{H_2O} = 0$
$q_{Fe} = -q_{H_2O}$



$T_{f\,Fe} = T_{f\,H_2O}$
$\Delta T = T_f - T_i$

$q_{Fe} = m_F c_F(\Delta T) = 130g(0.450\ J/g°C)(\Delta T) = 58.5\ \Delta T$
$q_{H_2O} = m_H c_H(\Delta T) = 120g\ (4.184\ J/g°C)(\Delta T) = 502.08\Delta T$

$58.5\Delta T = -502.08\ \Delta T$
$58.5(T_f - 120) = -502.08(T_f - 22)$
$58.5\ T_f - 7020 = -502.08\ T_f + 11045.76$
$560.58\ T_f = 18065.76$
$T_f = 32.23\ °C$

3. $2NOCl\ (g) \longrightarrow N_2\ (g) + O_2\ (g) + Cl_2\ (g)$

$\frac{1}{2}N_2\ (g) + \frac{1}{2}O_2\ (g) \longrightarrow NO\ (g)$ $\Delta H = 90.3\ kJ$
flip: $NO\ (g) \longrightarrow \frac{1}{2}N_2\ (g) + \frac{1}{2}O_2\ (g)$ $\Delta H = -90.3\ kJ$
× 2: $2NO\ (g) \longrightarrow N_2\ (g) + O_2\ (g)$ $\Delta H = -180.6\ kJ$

$NO\ (g) + \frac{1}{2}Cl_2\ (g) \longrightarrow NOCl\ (g)$ $\Delta H = -38.6\ kJ$
flip $NOCl\ (g) \longrightarrow NO\ (g) + \frac{1}{2}Cl_2\ (g)$ $\Delta H = +38.6\ kJ$
× 2 $2NOCl(g) \longrightarrow 2NO\ (g) + Cl_2\ (g)$ $\Delta H = +77.2\ kJ$

add $2NO(g) \longrightarrow N_2\ (g) + O_2(g)$ $\Delta H = -180.6\ kJ$
$2NOCl\ (g) \longrightarrow 2NO(g) + Cl_2\ (g)$ $\Delta H = +72.2\ kJ$

$2NOCl\ (g) \longrightarrow N_2\ (g) + O_2\ (g) + Cl_2\ (g)$ $\Delta H = -108.4\ kJ$

$\Delta H_{rxn} = -108.4\ kJ$

4. $\Delta H^\circ_{rxn} = \Sigma \Delta H^\circ_f \text{ product} - \Sigma \Delta H^\circ_f \text{ reactants}$

$= [2(\Delta H^\circ_f H_2O) + 2(\Delta H^\circ_f SO_2)] - [2(\Delta H^\circ_f H_2S) + 3(\Delta H^\circ_f O_2)]$

(A) $= [2(-241.8 \text{ kJ/mol}) + 2(-296.8 \frac{kJ}{mol})] - [2(-20.2 \frac{kJ}{mol}) + 3(0 \frac{kJ}{mol})]$

$= [-483.6 \text{ kJ} + -593.6 \text{ kJ}] - [-40.4 \text{ kJ} + 0]$

$= -1077.2 \text{ kJ} + 40.4 \text{ kJ}$

$\Delta H^\circ_{rxn} = -1036.8 \text{ kJ/mol}$

5. a) T: $\Delta E = q + w$

(A) b) F: $+\Delta T_{surrounding} = -\Delta T_{system}$ = exothermic

c) F: $W = -P\Delta V$

d F: $\Delta V = 0$ for BOMB calorimeter

6. $2CH_4(g) + 2O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(g)$

(D) $W = -P\Delta V$

$= -1 \text{atm}(3-2) = -1 \text{ L·atm}$

$-1 \text{ L·atm} \cdot \frac{101.3 \text{ J}}{1 \text{ L·atm}}$ $\boxed{= -101.3 \text{ J}}$

7. l from $0 \rightarrow n-1$

(C) m_l from $-l$ to l

m_s either $+\frac{1}{2}$ or $-1/2$

8. $q = m_{H_2O} C_{H_2O} \Delta T = 155 g (4.184 \frac{J}{g°C})(60°C)$

$q = 38911.2 \text{ J}$

(B) $E = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \text{ J/s} \, (3 \times 10^{8} \text{ m/s})}{0.22 \text{ m}} = \frac{9.035 \times 10^{-25} \text{ J}}{\text{photon}}$

$38911.2 \text{ J} \cdot \frac{1 \text{ photon}}{9.035 \times 10^{-25} \text{ J}} = \boxed{4.307 \times 10^{28} \text{ photons}}$

(D) 9. orbital = 1 box

f shell = 7 orbitals

(C) 10. Cu is exception [Ar] $4s^1 3d^{10}$

11. paramagnetic : unpaired electrons

(B) Kr = [Ar] $4s^2$ ~~$3d^{10}$~~ $4p^6$ all full

Ni = [Ar] $4s^2 3d^8$

↳ ↑↓ ↑↓ ↑↓ ↑ ↑ ← unpaired

Mg = [Ne] $4s^2$

Zn = [Ar] $4s^2 3d^{10}$

12. isoelectronic : same e⁻ configuration

a. V = [Ar] $4s^2 3d^3$ V^{3+} = [Ar] $3d^2$

Ca = [Ar] $4s^2$ ≠

(B) b. S = [Ne] $3s^2 3p^4$ S^{2-} = [Ne] $3s^2 3p^6$ = [Ar]

Ca = [Ar] $4s^2$ Ca^{2+} = [Ar] = ✓

c. Zn = [Ar] $4s^2 3d^{10}$ Zn^{2+} = [Ar] $3d^{10}$

Ni = [Ar] $4s^2 3d^8$ ≠

d. Ne = [He] $2s^2 2p^6$ ≠

Ar = [Ne] $3s^2 3p^6$

13. size inc L → R & down table b/c Zeff

cations smaller than neutral atoms b/c same proton & less electron

anions larger than neutral atom b/c more e⁻ & same protons, → neutral S < Cl < Ar < K < Ca

13 cont'd

anions

Ca^{2+} : [Ar]
K^+ : [Ar]
S^{2-} : [Ar]
Cl^- : [Ar]
Ar

} all have same e^- # so size base on # protons
(less protons, less Z_{eff}, (less pull to nucleus) bigger size)

$Ca^{2+} < K^+ < Ar < Cl^- < S^{2-}$ (B)

14. IE: energy need to remove 1 electron
makes huge jump when take from core shell
Ca 2 valence electrons
big jump when removing 3rd electron (A)

15. electron affinity: energy released to add electron
$X(gas) + e^- \longrightarrow X^-(gas)$ (A)

b) Solid Na need be gas
c) ionization energy (IE)
d) make no sense should be S^+ not S^- & then it would be IE

16. ΔH_{rxn} = Σ bond broken (reactant) − Σ bond form (product)

CH_4 (H–C(H)(H)–H) + 3 Cl–Cl ⟶ H–C(Cl)(Cl)–Cl + 3 H–Cl

$\Delta H_{rxn} = [4(C-H) + 3(Cl-Cl)] - [3(C-Cl) + C-H + 3(H-Cl)]$

$= [4(413\frac{kJ}{mol}) + 3(243\frac{kJ}{mol})] - [3(-339\frac{kJ}{mol}) + 413\frac{kJ}{mol} + 3(-472)]$

$= 2381\frac{kJ}{mol} - -2020 =$ **4401 kJ/mol** (C)

17. single bond longest
triple shortest (A)

18. H is smallest ion
size ↑ as you go down column, bigger size, longer bond
$H < F < Cl < I$
$H-H < H-F < H-Cl < H-I$ (C)

19. lattice energy base on Columb Law $\propto \frac{|cation| \cdot |anion|}{r^2 \text{ (distance)}}$

charge product more important than size

charge
$CaCl_2$ $|(+2)||(-1)| = 2$
$NaCl$ $|(+1)||(-1)| = 1$
KCl $|1| |-1| = 1$
$BaCl_2$ $|+2| |-1| = 2$

$CaCl_2$ vs $BaCl_2$
base on size
smaller ion, more lattice energy
$BaCl_2 < CaCl_2$

$NaCl$ vs KCl
$KCl < NaCl$
bigger
~~less LE~~

$KCl < NaCl < BaCl_2 < CaCl_2$ (D)