CHM 2045 Fall 2023 Exam 2 Review Academic Resources

1. If 1000. g of boiling water (at 100 °C) was placed in an 1800. g cast iron skillet initially at 25°C, and the final equilibrium temperature of the water and the skillet was 88°C, estimate the specific heat capacity of the skillet. Assume this is a closed system and that the specific heat capacity of water is 4.184 J/°C•g.

$m_w = 1000g$ $m_c = 1800g$

$T_{i,w} = 100°C$ $T_{i_c} = 25°C$

$T_f = 88°C$

$C_w = 4.184 \frac{J}{°Cg}$ $C_c = ?$

$q = mc\Delta T$ $\Delta T = T_f - T_i$

$q_{water} + q_{skillet} = 0$

$-q_{water} = q_{skillet}$

$$+(1000\cancel{g} \cdot 4.184 \frac{J}{\cancel{°C}\cancel{g}} \cdot (\underbrace{88°C - 100°\cancel{C}}_{+12})) = 1800g \cdot x \cdot (\underbrace{88°C - 25°C}_{63°C})$$

$$\frac{50,208\,J}{113400°Cg} = \frac{11340 \cdot °C \cdot g \cdot x}{113400°Cg} = 0.4428\ J/°Cg$$

2. Which statement is incorrect regarding internal energy (U, E) and the first law of thermodynamics?

$\Delta E = q + w$

A) The first law of thermodynamics states that energy must be conserved. ✓

[✓ B)] When the system gains heat and performs work, then Δ{U, E} for the system must be positive.

$+q$ $-w$ by system on surrounding $\overset{+}{U} = q + \overset{-}{w}$ $+q\ -w \rightarrow ?$

C) The first law of thermodynamics does not imply that heat can't be converted to work.

D) When the system loses heat and performs work, then Δ{U, E} for the system must be negative. ✓

$-q$ $-w$ $-q - w = -E$

E) When its Δ{U,E} increases, then the system must gain heat or have work performed on it, or both.

$+E = +q\ +w$ $+q$ $+w$ by surrounding on system

3. Deterioration of buildings, bridges, and other structures through the rusting of iron costs millions of dollars a day. The enthalpy of formation of rust, Fe2O3(s), is −826.0 kJ/mol. How much heat is released (in kJ) when 0.500 kg of Fe reacts with 200. g of O2, forming Fe2O3(s)?

$2\,Fe(s) + \frac{3}{2}O_2(g) \longrightarrow Fe_2O_3(s)$ $\Delta H_f = -826\ kJ/mol$

$.5kg\ Fe \rightarrow 500g^{Fe} \cdot \frac{1\ mol\ Fe}{55.85\ g^{Fe}} \cdot \frac{1\ mol\ Fe_2O_3}{2\ mol\ Fe} = 4.476\ mol\ Fe_2O_3$

$200g\ O_2 \cdot \frac{1\ mol\ O_2}{32\ g} \cdot \frac{1\ mol\ Fe_2O_3}{\frac{3}{2}\ mol\ O_2} = \boxed{4.167\ mol\ Fe_2O_3}$

$\rightarrow \Delta H = \frac{q}{n}$ $\Delta H \cdot n = q$ $-826\ kJ/mol \cdot 4.167\ mol\ Fe_2O_3 = -3442\ kJ$

3442 kJ

→ .05L

4. When 50.0 ml of 0.200 M AgNO3 and 50.0 ml of 0.100 M CaCl2, both at 25.0°C are reacted in a coffee-cup calorimeter, the temperature of the reacting mixture increases to 26.0°C. Calculate ΔH in kJ per mole of AgCl produced. Assume the density of the solution is 1.05 g/ml and the specific heat capacity of the solution 4.20 J/g°C.. → C

$2AgNO_3(aq) + CaCl_2(aq) \rightarrow 2AgCl + Ca(NO_3)_2$

$\frac{.2 \text{ mol } AgNO_3}{1L} \cdot .05L \cdot \frac{2 \text{ mol } AgCl}{2 \text{ mol } AgNO_3} = .01 \text{ mol } AgCl$

$\Delta H = \frac{q}{n ✓} = \frac{441J}{.01 \text{ mol}}$

$= 44,100 \text{ J/mol}$

$\frac{.1 \text{ mol } CaCl_2}{1L} \cdot .05L \cdot \frac{2 \text{ mol } AgCl}{1 \text{ mol } CaCl_2} = .01 \text{ mol } AgCl$

$q = mc\Delta T$

$m_s = 100 \text{ mL} \cdot \frac{1.05g}{mL} = 105g$

$\Delta T = 26°C - 25°C = 1°C$

$q = (105g) \cdot (4.20 \frac{J}{g°C})(1°C)$

$= 441 J$

-44.1 kJ/mol

5. A pure gold ring (C = 0.128 J/g°C) and pure silver ring (C = 0.235 J/g°C) have a total mass of 15.3g. The two rings are heated to 62.1°C and dropped into a 13.1mL of water (ρ = 1.00 g/mL and C = 4.184 J/g°C) at 20.9°C. When equilibrium is reached, the temperature of the water is 22.9°C. What was the mass of the gold ring?

$m_s + m_g = 15.3g$

$m_s = 15.3g - m_g$

$q_{silver} + q_{gold} + q_{water} = 0 \qquad q = mc\Delta T$

$\Delta T_m = 22.9°C - 62.1°C = \boxed{-39.2°C}$

$q_s + q_g = -q_w$

$\Delta T_w = 22.9°C - 20.9°C = 2°C$

$(m_s \cdot 0.235 \frac{J}{g°C} \cdot -39.2°C) + (m_g \cdot 0.128 \frac{J}{g°C} \cdot 39.2°C) = -(13.1g \cdot 4.184 \frac{J}{g°C} \cdot 2°C)$

$(15.3g - m_g) -9.212 \frac{J}{g} - m_g \cdot 5.0176 = -109.62 J$

$-140.94 + 9.212 \frac{J}{g} \cdot m_g - 5.012 m_g = -109.62$

$+140.94 \qquad\qquad +140.94$

$\frac{4.2 m_g}{4.2} = \frac{31.32 J}{4.2}$

$m_g = 7.46 g$

6. Find the heat of formation of gaseous HCl

(I) $\frac{1}{2}(N_2(g) + 3H_2(g) \leftarrow 2NH_3(g))$ ΔH = $\frac{1}{2}$(+91.8 kJ) $~~NH_3~~ \rightarrow ~~\frac{1}{2}N_2~~ + \frac{3}{2}H_2$ ✓

(II) $\frac{1}{2}(N_2(g) + 4H_2(g) + Cl_2(g) \rightarrow 2NH_4Cl(s))$ ΔH $\frac{1}{2}$(-628.8 kJ) $~~\frac{1}{2}N_2~~ + 2H_2 + \frac{1}{2}Cl_2 \rightarrow ~~NH_4Cl(s)~~$

★ (III) $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$ ΔH = +176.2 kJ $~~NH_4Cl(s)~~ \rightarrow ~~NH_3(g)~~ + HCl(g)$

$\Delta H_f = \frac{1}{2}(91.8 kJ) - \frac{1}{2}(628.8) + 176.2 \qquad \frac{1}{2}H_2(g) + \frac{1}{2}Cl_2(g) \rightarrow HCl(g)$

$= -92.3 kJ$

7. Consider the reaction

$C_{12}H_{22}O_{11}(s) + 12O_2(g) \rightarrow 12CO_2(g) + 11H_2O(l)$

in which 10.0 g of sucrose, $C_{12}H_{22}O_{11}$, was burned in a bomb calorimeter with a heat capacity of 7.50 kJ/∘C. The temperature increase inside the calorimeter was found to be 22.0°C. What is the heat of this reaction per mole of sucrose?

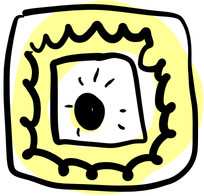
$\Delta T = 22^\circ C$

$\Delta H = \frac{q}{n}$

C

$q = \cancel{m}c \cdot \Delta T$

$= \frac{7500 J}{^\circ C} \cdot 22^\circ \cancel{C} = 165{,}000 J = 165 kJ$



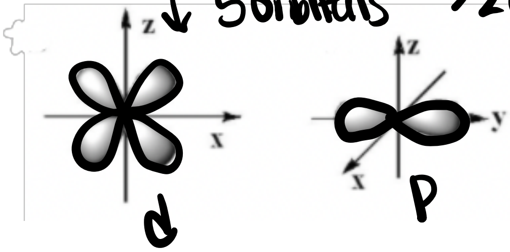
$10 g\, C_{12}H_{22}O_{11} \cdot \frac{1 mol\, C_{12}H_{22}O_{11}}{342.3 g\, C_{12}H_{22}O_{11}} = 0.0292 mol$ sucrose

$\frac{165 kJ}{.0292 mol} = -5650 kJ/mol$

$-q_{sample} = q_{water} + q_{cal}$

8. For each of the following orbital shapes below, give the maximum number of electrons that can be accommodated in the orbitals that share the same principal quantum number, *n*, and angular quantum number, *l*.

5 orbitals → 2e⁻ per orbital = 10e⁻



A) 4, 2 B) 6, 2 C) 5, 3 D) 10, 6 E) 14, 10

3 orbitals → 2e⁻ per orbital = 6e⁻

SO

d: row # -1
n → f: row # -2
s: row # = n
l → s=0; p=1; d=2; f=3
m_ℓ → +l → -l
m_s 0; -1,0,1; -2,-1,0,+1,+2
3 5
$+\frac{1}{2}, -\frac{1}{2}$

9. Which of the following full sets of quantum numbers is incorrect?

a) The e⁻ gained from Br → Br⁻; n=4, l=1, m_l=+1, m_s=-1⁄2 ✓ row4 n=4

b) The outermost e- in Rb; n=5, l=0, m_l=0, m_s=+1⁄2 ✓

[✓ c)] The 6th e⁻ in O; n=2, l=0 (S), m_l=0, m_s=+1⁄2 ✗

d) The 3rd e⁻ in F; n=2, l=0, m_l=0, m_s=+1⁄2 ✓

e) The 8th e⁻ in O; n=2, l=1, m_l=-1, m_s=-1⁄2 ✓

n=2 l=1
m_ℓ=-1 m_s=-1/2

Br⁻: ↑↓ ↑↓ ↑↓
-1 0 +1
n=4 m_ℓ=+1
l=1 m_s=-1/2

O: ↑↓ ↑↓ ↑↓ ↑ ↑
1s 2s 2p
-1 0 +1
n=2 m_ℓ=0
l=1 m_s=+1/2

F: ↑↓ ↑↓ ↑↓ ↑↓ ↑
1s 2s 2p
n=2 m_ℓ=0
l=0 m_s=+1/2

Rb: n=5 l=0 5s ↑
m_ℓ=0 m_s=+1/2

+l → -l

10. Which of the following electron configurations are correct?

I. Hg: [Xe] $6s^2 4f^{14} 5d^{10}$ ✓ II. Mo: [Kr] $5s^1 4d^5$ ✓ III. Cr: [Ar] $4s^2 3d^4$ X

IV. Au: [Xe] $6s^2 4f^{14} 5d^9$ X V. Cu: [Ar] $4s^1 3d^{10}$ ✓

a) I, III, V

b) II, IV

c) I, II, V

d) None

e) All

Au: [Xe] $6s^2 4f^{14} 5d^9$ *

[Xe] $6s^1 4f^{14} 5d^{10}$

Cu: [Ar] $4s^2 3d^9$ *

[Ar] $4s^1 3d^{10}$

Hg: [Xe] $6s^2 4f^{14} 5d^{10}$

Mo: [Kr] $5s^2 4d^4$ *

[Kr] $5s^1 4d^5$

Cr: [Ar] $4s^2 3d^4$ *

[Ar] $4s^1 3d^5$

11. Which of the following electron configurations for these ions are correct?

I. Ca^{2+}: [Ar] $4s^2$ X II. V^{3+}: [Ar] $3d^2$ ✓ III. S^{2-}: [Ne] $3s^2 3p^6$ ✓ IV. Cr^{3+}: [Ar] $3d^3$ ✓ V. Br^-: [Ar] $5s^2 4d^{10} 5p^6$ X

a) All

b) I, V

c) II, IV, V

d) III, V

e) II, III, IV

Ca^{+2}: [Ar] $4s^{\cancel{2}}$

→ [Ar]

V^{3+}: [Ar] $4s^{\cancel{2}} 3d^{\cancel{3}}$

[Ar] $3d^2$

S^{2-}: [Ne] $3s^2 4p^{6}$

Cr^{3+}: [Ar] $4s^{\cancel{1}} 3d^{\cancel{5}}$

[Ar] $3d^3$

Br^-: [Ar] $4s^2 3d^{10} 4p^{\cancel{5}6}$

12. Which of these are in the correct increasing atomic size order?

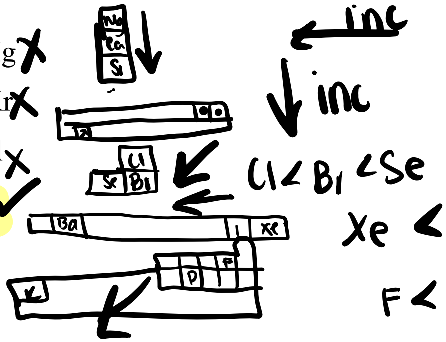
a) Sr < Ca < Mg X

b) Rb < Br < Kr X

c) Se < Br < Cl X

d) Xe < I < Ba ✓

e) K < P < F



Mg < Ca < Sr

Kr < Br < Rb

Cl < Br < Se

Xe < I < Ba

F < P < K

13. Which of these are in the correct order for increasing IE_1. ionization energy

noble gas

a) Cs < Xe < I X

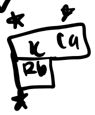
b) Kr < Ar < He ✓

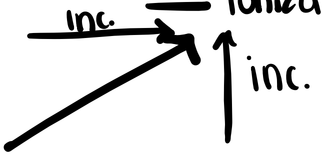
c) Rb < Ca < K X

d) Sn < Sb < I ✓

e) A and C

f) B and D





Rb < K < Ca

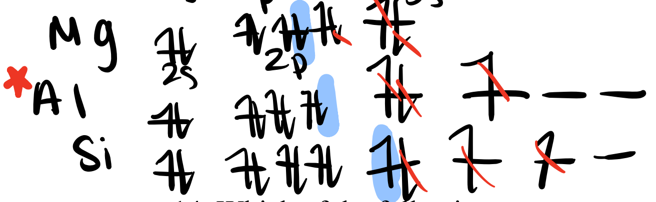
Sn < Sb < I

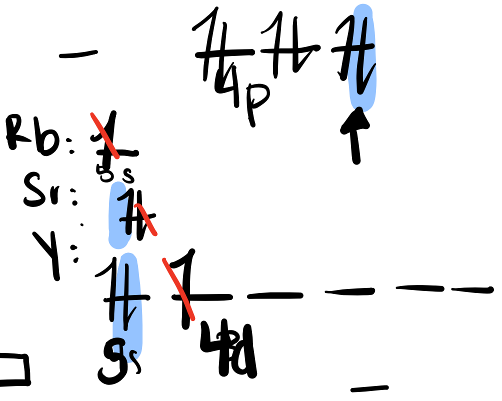
Sn	Sb	x	I

Mg

Al

Si





14. Which of the following statements on successive IE is true?

second

a) Between Rb, Sr, and Y, Rb has the highest IE_2 ✓

b) Between Rb, Sr, and Y, Sr has the highest IE_2 ✗

c) Between Na, Mg, Al, and Si, Al has the highest IE_4 ✓

d) Between Na, Mg, Al, and Si, Si has the highest IE_4 ✗

e) A and C

f) B and D

Rb	Sr	Y

Rb^+ Sr^+ Y^+

Na	Mg	Al	Si

Al^{3+} Si^{4+}

Al^{4+}

unpaired electrons

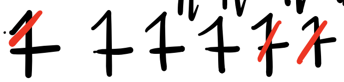
all paired electrons
full orbitals

15. Label the following ions paramagnetic or diamagnetic.

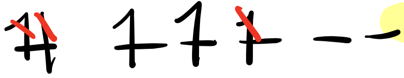
I. Co^{3+} : [Ar] $4s^2$ $3d^7$: paramagnetic

II. Hg^{2+} [Xe] $6s^2 4f^{14} 3d^{10}$ diamagnetic

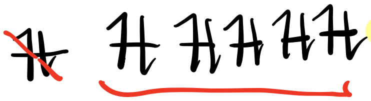
III. Cr^{3+}: [Ar] $4s^1$ $3d^5$ paramagnetic



IV. V^{3+} [Ar] $4s^2$ $3d^3$ paramagnetic



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



16. Which ions are ranked correctly by decreasing size?

cations & anions when isoelectronic

I. $Sr^{2+} > Ca^{2+} > Mg^{2+}$ ✓ II. $S^{2-} > Cl^- > K^+$ ✓ III. $Mg^{2+} > Na^+ > F^-$ ✗ cation IV. $Ba^{2+} > Cs^+ > I^-$ ✗ V. $P^{3-} > S^{2-} > Cl^-$ ✓

Mg
Ca
Sr

$18e^-$ $18e^-$ $18e^-$

cations & anions

a) I, III, V

b) II, IV

c) I, II, V

d) I, IV, V

e) II, III, IV, V

17. Which of the following is the correct order for increasing bond length?

C-C, C=C, C≡C

C≡C < C=C < C-C

a) C≡C < C=C < C-C

b) C=C < C≡C < C-C

c) C-C < C=C < C≡C

d) C≡C < C-C < C=C

18. How are bond length and bond strength related?

[✓ a) Inversely related]

b) Directly related

c) Length = 1⁄2 Strength

d) Strength = 1⁄2 Length

as bond length ↑ bond strength ↓

19. Calculate the enthalpy of the reaction:

$$C_2H_{4(g)} + Cl_{2(g)} \rightleftharpoons C_2H_4Cl_{2(g)}$$

Given the following bond energies:

C-C 347 kJ/mol
C=C 614 kJ/mol
C≡C 839 kJ/mol

C-H 413 kJ/mol
C-Cl 339 kJ/mol
Cl-Cl 243 kJ/mol

H-H 432 kJ/mol
H-Cl 427 kJ/mol

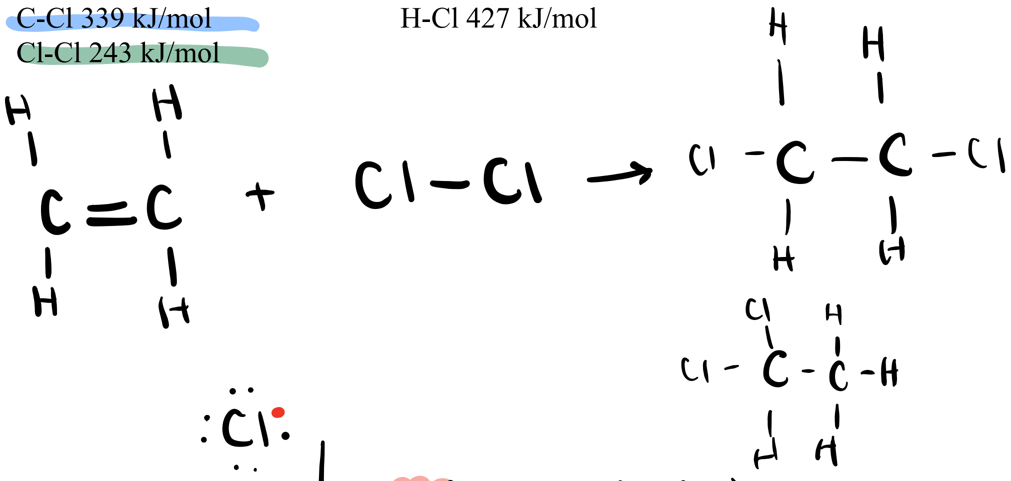
a) -1078 kJ

b) +168 kJ

[✓ c) -168 kJ]

d) +563 kJ

e) -563 kJ



4(C-H) 1(C=C) 1Cl-Cl | 4(C-H) 2(C-Cl) 1(C-C)

4(C-H) 2(C-Cl)

bonds broken - bonds formed
reactants - products

$$(4\cdot 413 + 1\cdot 614 + 1\cdot 243) - [4\cdot 413 + 2\cdot 339 + 1\cdot 347)$$

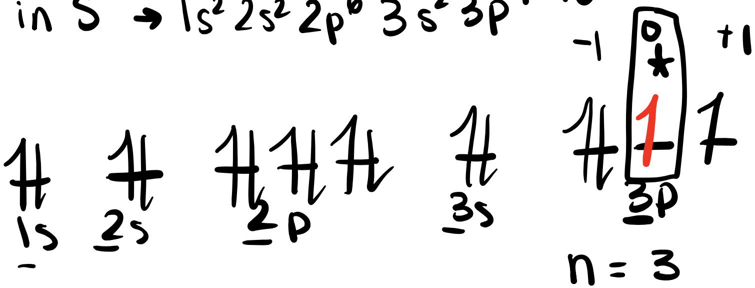
$$= -168\text{KJ}$$

n	ℓ	m_ℓ	m_s
# row	shape	specific orbital within a certain n/ℓ	spin
d: # row −1	s = 0	−ℓ → +ℓ	+1/2 , −1/2
f # row − 2	p = 1	s: 0	
	d = 2	p: −1 0 +1	
	f = 3		

d: −2 −1 0 +1 +2

f = −3 −2 −1 0 +1 +2 +3

14th e⁻ in S → $1s^2 2s^2 2p^6 3s^2 3p^4$ 16e⁻



$n = 3$

$\ell = 1$

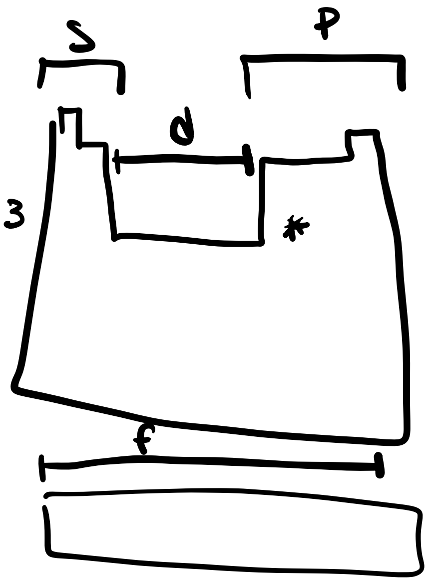
+1, 0, −1 $m_\ell = 0$

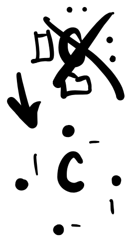
$m_s = +1/2$

s $\ell = 0$

p $\ell = 1$

d $\ell = 2$

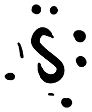




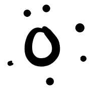
4 bonds

H· 1 bond

1 bond



2 bonds



2 bonds