THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

DEPARTMENT OF CHEMISTRY

2016/17 ACADEMIC YEAR

CHEMISTRY (CH 11O/FO 130*)* TEST TWO MARKING GUIDE

TIME ALLOWED: Two (2) Hours.

DATE: 17 / 03/ 2017

INSTRUCTIONS:

(i) Attempt all the three questions that carry specified marks.
(ii) All calculated quantities must have units and reported to the correct number of significant figures.
(iii) Do not open till instructed to do so.

IMPORTANT DATA:

Physical Constants		
Constant	**Symbol**	**Value**
Planck's constant	h	6.626×10^{-34} J s
Speed of light (vacuum)	c	2.998×10^{8} m s^{-1}
Rydberg constant	R_H	$1.097 \times 10^{7} m^{-1}$
Rydberg energy	R_E	2.179×10^{-18} J
Atomic mass unit	*Amu*	1.660554×10^{-27}kg
Avogadro's number	N_A	6.02214 x $10^{23} mol^{-1}$
Gas constant	R	8.31451 J $K^{-1} mol^{-1}$
		0.08206 L atm $K^{-1} mol^{-1}$
1 atm = 760mmHg = 1.0132×10^{5} Nm^{-2} = 1.0132 x 10^{5}Pa		

QUESTION ONE (THERMOCHEMISTRY) **[33 marks]**

a) Indicate whether the following statements are true or false; the internal energy can be increased by

(i) transferring heat from the surroundings to the system
(ii) transferring heat from the system to the surroundings
(iii) doing work on the system [3]

ANSWER (i) True [1] (ii) False [1] (iii) True [1]

b) Indicate whether the following process is endothermic or exothermic

(i) ice melting (ii) boiling soup (iii) condensation of water vapor [3]

ANSWER (i) endothermic [1] (ii) endothermic [1] (iii) exothermic [1]

c) An 8.29 g sample of calcium carbonate [$CaCO_3$ (s)] absorbs 50.3 J of heat, upon which the temperature of the sample increases from 21.1 °C to 28.5 °C. What is the specific heat of calcium carbonate? [4]

ANSWER

Using $q = m \times C_s \times \Delta T$ [1]

$C_s = \frac{q}{m \times \Delta T} = \frac{50.3\ J}{8.29\ g \times (28.5-21.1)^{o}C}$ [2]

$= 0.82\ J\ g^{-1}\ ^{o}C^{-1}$ [1]

d) Write a thermochemical equation for each of the following processes:

(i) The enthalpy of combustion of liquid benzene (C_6H_6) is -3268 kJ/mol.
(ii) When solid boron reacts with oxygen gas to form one mole of solid diboron trioxide 1274 kJ heat is released.
(iii) The enthalpy of formation of liquid methanol (CH_3OH) is -239 kJ/mol. [6]

ANSWER

(i) $C_6H_6(l) + \frac{9}{2}O_2(g) \rightarrow 6\ CO_2(g) + 3\ H_2O(l)$ $\Delta H = -3268$ kJ [2]

(ii) $2\ B(s) + \frac{3}{2}O_2(g) \rightarrow B_2O_3(s)$ $\Delta H = -1274$ kJ [2]

(iii) $C(graphite) + O_2(g) + H_2(g) \rightarrow CH_3OH(l)$ $\Delta H = -239$ kJ [2]

subtract marks for not correctly balancing eqn (−1), wrong sign of ΔH(−½) and or not including ΔH(− 1)

e) For the reaction: $HgO(s) \rightarrow Hg(l) + ½O_2$ $\Delta H = +90.7$ kJ

(i) What quantity of heat is required to produce 3moles of mercury by this reaction?
(ii) What quantity of heat is required to produce 1 mol of oxygen gas by this reaction?
(iii) What quantity of heat would be released in the following reaction as written?
$2\ Hg(l) + O_2(g) \rightarrow 2HgO(s)$ [6]

ANSWER

(i) $1\ mol\ Hg \equiv +90.7\ kJ$

$q = +90.7\ kJ \times \frac{3\ mol\ Hg}{1\ mol\ Hg} = +272\ kJ$ [2]

(ii) $½\ mol\ O_2 \equiv +90.7\ kJ$

$q = +90.7\ kJ \times \frac{1\ mol\ O_2}{½\ mol\ O_2} = 181\ kJ$ [2]

(iii) Reaction is 2 x reverse of given reaction

q= $-2 \times 90.7 = -181$ kJ [2]

f) Given the following data

$2ClF(g) + O_2(g) \rightarrow Cl_2O(g) + F_2O(g)$ $\Delta H = -447$ kJ

$2ClF_3(g) + 2\ O_2(g) \rightarrow Cl_2O(g) + 3F_2O(g)$ $\Delta H = 341.4$ kJ

$2\ F_2(g) + O_2(g) \rightarrow 3F_2O(g)$ $\Delta H = -43.4$ kJ

Calculate ΔH for the reaction

$ClF(g) + F_2(g) \rightarrow ClF_3(g)$ [6]

ANSWER

To get ClF in target eqn divide (1) by 2 [0.5]

Reverse (2) and divide it by 2 to ClF_3 on product side [0.5]

Divide (3) by 2 to get F_2 on reactant side [0.5]

Add the resulting eqns [0.5]

$ClF(g) + ½O_2(g) \rightarrow ½Cl_2O(g) + ½F_2O(g)$ $\Delta H = -223.5$ kJ [1]

$½Cl_2O(g) + 3/2F_2O(g) \rightarrow ClF_3(g) + O_2(g)$ $\Delta H = -170.7$ kJ [1]

$F_2(g) + ½O_2(g) \rightarrow 3/2F_2O(g)$ $\Delta H = -21.7$ kJ [1]

Add ----------

$ClF(g) + F_2(g) \rightarrow ClF_3(g)$ $\Delta H = -223.5$ kJ -170.7kJ -21.7 kJ $= -416$ kJ [1]

g) A meal containing a burger, chips, and a milkshake contains 53.0 grams of fat, 38.0 grams of protein, and 152 grams of carbohydrate. The respective fuel values for protein, fat, and carbohydrate are 17, 38, and 16 kJ/g, respectively. If swimming typically burns 1100.0 kJ/hour how many minutes of swimming are required to completely burn off the meal. [5]

ANSWER

Total energy in meal $= 53.0\ g \times 38\frac{kJ}{g} + 38.0\ g \times 17\frac{kJ}{g} + 152\ g \times 16\frac{kJ}{g} = 5092$kJ [2]

Given $1\ hr \equiv 1100.0\ kJ$

Hence time needed is $t = 5092\ kJ \times \frac{1\ hr}{1100.0\ kJ} \times \frac{60\ min}{1\ hr} = 278\ min$ [3]

QUESTION TWO (ATOMIC STRUCTURE AND PERIODICITY) **[33 marks]**

a). The green light has a wavelength of 535 nm. Calculate the energy of a photon of green light. [3]

ANSWER

$E = h\nu$, $\nu = c/\lambda$ **[1]**

$\nu = 2.998 \times 10^{8}\ ms^{-1}/(535nm \times 10^{-9}m) = \mathbf{5.60 \times 10^{14}\ Hz}$ **[1]**

$E = 6.626 \times 10^{-34} J.s \times 5.60 \times 10^{14}\ Hz = \mathbf{3.71 \times 10^{-19}\ J}$ **[1]**

b) Calculate the wavelength of an infrared transition in the Paschen series from the n = 4 level to n = 3 level. [3]

ANSWER

$\mathbf{1/\lambda = R_H\ (1/n^2_f - 1/n^2_i)}$ **[1]**

$= 10\ 973\ 731.6\ m^{-1}\ (1/3^2 - 1/4^2)$

$= 10\ 973\ 731.6\ m^{-1}\ (1/9 - 1/16)$

$\lambda = \mathbf{1.88 \times 10^{-6}\ m}$ **[2]**

c) Calculate the number of photons that reached the detector when of 3.928×10^{-18}J of blue light of wavelength 4.552×10^{-7} meters reached the detector. **[5]**

ANSWER

$\nu = c/\lambda$

$= 2.998 \times 10^{8}\ ms^{-1}/ 4.552 \times 10^{-7}m$

$= \mathbf{6.586 \times 10^{14}\ s^{-1}}$ **[2]**

$E = h\nu$

$= 6.626 \times 10^{-34} J{\cdot}s \times 6.586 \times 10^{14}\ s^{-1}$

$= \mathbf{4.364 \times 10^{-19} J}$ per photon [2]

Number of photons $= 3.928 \times 10^{-18}J / 4.364 \times 10^{-19}J$

$= \mathbf{9\ photons}$ **[1]**

d) Calculate the speed of an electron with mass 9.1×10^{-31} kg and the de Broglie wavelength is 1.46×10^{-10} m. [3]

ANSWER

$\mathbf{V = h/m\lambda}$ [1]

$= 6.626 \times 10^{-34}\ kg{\cdot}m^2{\cdot}\ s^{-2}\ {\cdot}s / 9.1 \times 10^{-31}kg\ X\ 1.46 \times 10^{-10}\ m$

$= \mathbf{498720.576\ ms^{-1}}$

$= 5.0 \times 10^5\ ms^{-1}$ **[2]**

e) The uncertainty in the momentum (Δp) of a football thrown by Tom Brady during the Super Bowl is $16\times10^{-6}\ kg \cdot m \cdot s^{-1}$. What is its uncertainty in position Δx? [2]

ANSWER

$\Delta x \Delta p \geq \frac{h}{4\pi}$ **[0.5]** $\Delta x = 6.626 \times 10^{-34} kg{\cdot}m^2{\cdot}\ s^{-2}/4 \times 3.143 \times 16 \times 10^{-6}\ kg{\cdot}m{\cdot}\ s^{-1}$ **[0.5]**

$\Delta x \geq h/4\pi\Delta P\Delta x = 3.3 \times 10^{-30}\ m$ **[1]**

f) Write down the quantum numbers that define the three P (3p) atomic orbital. [3]

ANSWER

(i) **Principal Quantum Number (n)** = 3 [1]

(ii) **Azimuthally or Angular Momentum Quantum Number (l)** = 1 [1]

(iii) **Magnetic Quantum Number (ml)** = −1, 0, 1 [1]

g) Write the full electron configuration, compressed electron configuration, and valence electron configuration of the following; [9]

ANSWER

(i) Rubidium

Electron configuration: $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2\ 3d^{10}, 4p^6\ 5s^1$ [1]

Compressed electron configuration: $[Kr]\ 5s^1$ [1]

Valence electron configuration: $5s^1$ [1]

(ii) Sulphur

Electron configuration: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$ [1]

Compressed electron configuration: $[Ne]\ 3s^2 3p^4$ [1]

Valence electron configuration: $3s^2\ 3p^4$ [1]

(iii)Titanium

Electron configuration: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 4S^2\ 3d^2$ [1]

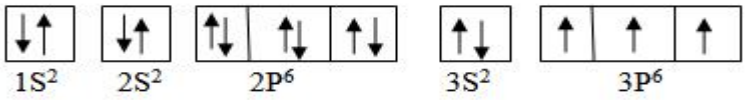
Compressed electron configuration: $[Ar]\ 4s^2\ 3d^2$ [1]

Valence electron configuration: $4s^2\ 3d^2$ [1]

h) Write the orbital diagram for a phosphorus atom. Is the phosphorusatom paramagnetic or diamagnetic? [2]

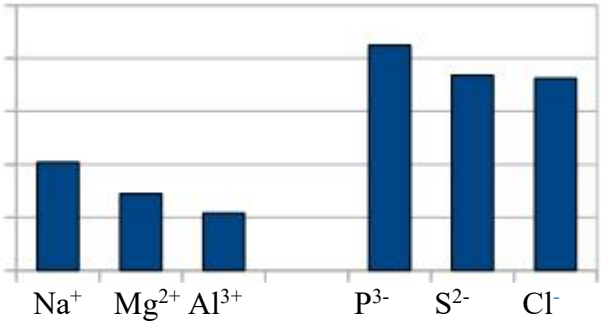
ANSWER

Orbital diagram **[1]**



Since there are unpaired electrons, phosphorus is paramagnetic [1]

i) The bar chart below shows the relative radii of the ions of the elements in Period 3. [3]



ANSWER

(i) The ions Na^+, Mg^{2+} and Al^{3+} are said to be called **isoelectronic** [1]

(ii) Which of the following ions above has the shortest ionic radius? [1]

Shortest ionic radius Cl^- [1]

(iii) Which of the following ions above has the longest ionic radius? [1]

Longest ionic radius Na^+ [1]

QUESTION THREE(CHEMICAL BONDING AND GEOMETRY) [34 Marks]

(i) MARKING GUIDE AFTER THE QUESTION!

(a) Appropriately answer the following questions

(i) **True or false:** An ionic bond is a chemical bond formed by the electrostatic attraction between ions of different positive charges. [1]

(ii) **True or false:** A Lewis electron-dot formula and a Lewis electron-dot symbol can both be defined as; A formula using dots to represent valence electrons. [1]

(iii) Use Lewis electron-dot symbols to represent the transfer of electrons from calcium to chlorine atoms to form ions with noble-gas configurations. [2]

(b) **For the PO_4^{3-} ion:**

(i) Draw the Lewis structure [2]

(ii) Assign the formal charges to each atom [2]

(iii) State the geometry of the ion [2]

(c) Use the data provided below to calculate the lattice energy of NaCl. [4]

Electron affinity of Cl = −394kJ/mol

1st ionization energy of Na = 496 kJ/mol

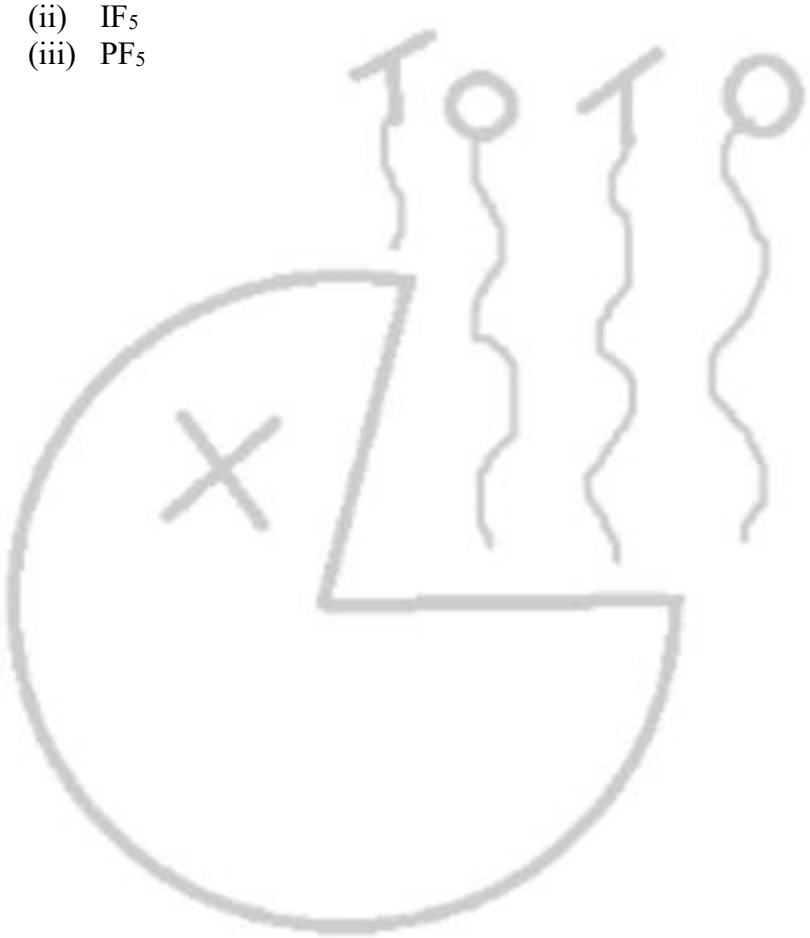
Bond energy of Cl_2 = 242kJ/mol

Sublimation energy of Na = 108kJ/mol

ΔH_f [NaCl (s)] = − 411kJ

(d) Answer the following questions:
(i) Arrange the following compounds in order of increasing lattice energy NaCl, $MgCl_2$, and MgO. [3]
(ii) Arrange the NO_2^- and NO_3^- ions in order of increasing N−O bond length. [2]
(iii) Draw the two possible resonance structures for NCO^- [3]

(e). Indicate the molecular geometry of the following molecules and state for each whether they are polar or non-polar.
(i) $BeCl_2$ [4]
(ii) IF_5 [4]
(iii) PF_5 [4]



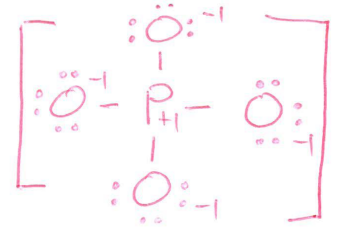
MARKING GUIDE FOR QUESTION THREE

(a) (i) False [1] (ii) False [1]

(iii) $Ca^{\cdot} + 2\ \cdot\ddot{\underset{\cdot\cdot}{Cl}}: \rightarrow [:\ddot{\underset{\cdot\cdot}{Cl}}:]^{-}[Ca]^{2+}[:\ddot{\underset{\cdot\cdot}{Cl}}:]^{-}$

[2]

(b) (i)

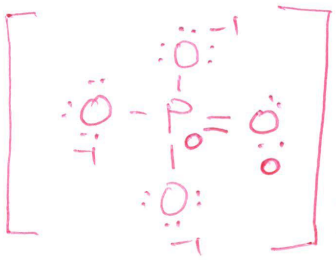
(ii) 

[1] For structure; [-1] for Structure ~~and [3]~~

[2] for Formal charges

[3]

or



[2] For structure and [2] For Formal charges

[4]

(iii) Geometry of PO_4^{3-} is Tetrahedral [2]

(c) $Na_{(s)} \longrightarrow Na_{(g)}$ $\Delta H_1 = 108\ kJ/mol$ [½]

$Na_{(g)} \longrightarrow Na^+_{(g)} + e^-$ $\Delta H_2 = 496\ kJ/mol$ [½]

$\frac{1}{2}Cl_{2(g)} \longrightarrow Cl_{(g)}$ $\Delta H_3 = 121\ kJ/mol$ [½]

$Cl + e^- \longrightarrow Cl^-$ $\Delta H_4 = -394\ kJ/mol$ [½]

$Na^+_{(s)} + Cl^- \longrightarrow NaCl$ Lattice energy $\Delta H_5 = ???$

$Na_{(s)} + \frac{1}{2}Cl_{2(g)} \longrightarrow NaCl_{(s)}$ $\Delta H_6 = -411\ kJ$

$\Delta H_6 = \Delta H_1 + \Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_5$ [1]

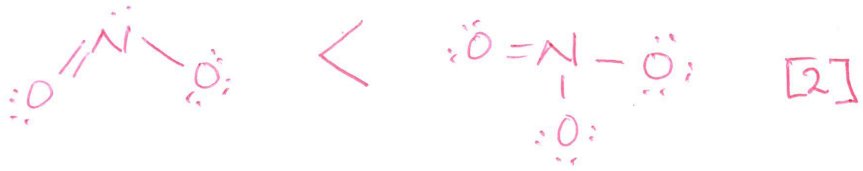
Lattice energy $= \Delta H_5 = \Delta H_6 - (\Delta H_1 + \Delta H_2 + \Delta H_3 + \Delta H_4)$ [½]

$= -411 - (108 + 496 + 121 - 394)$

$= -742\ kJ$

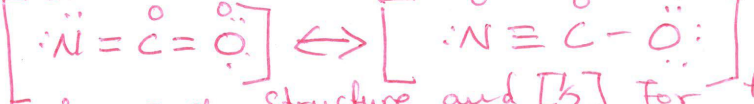
∴ The lattice energy of sodium chloride $[NaCl_{(s)}]$ is 742 kJ [½].

(d) (i) $NaCl < MgCl_2 < MgO$ [3]

(ii)  [2]

[½] For each right lewis structure and

[1] For the order

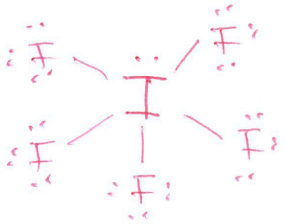
(iii)  [3]

[1] Mark for each structure and [½] for the right Formal charges.

(e) (i)  [2]

Molecular geometry of $BeCl_2$ is Linear [1]

$BeCl_2$ is non-polar [1]

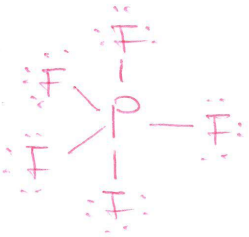
(ii)  [2]

Molecular geometry of IF_5 is

Square pyramidal [1]

([½] For octahedral)

IF_5 is Polar [1]

(iii)  [2]

Molecular geometry of PF_5 is

Trigonal bypyramidal [1]

PF_5 is non-polar [1]