You are writing VERSION 1 of this test. Make sure you have correctly entered your version number (“1”) in the correct column on your scan sheet (see p. 2 for details).

Section #1 – These questions are worth two marks each.

____ 1. In the event that your teaching assistant has a seizure during a laboratory, the **most efficient** and **appropriate** method to obtain medical assistance would be to:

a. Run to the security office
b. Dial 88 from a campus line
c. Dial 911 from your cell phone
d. Press the panic alarm
e. Find and pull the nearest fire alarm

In order to dial 88, you would have to leave the lab to find a phone. The panic alarm is connected directly to security and by pressing it, you will also be contacting security and EFRT. This is clearly indicated in the safety video.

____ 2. You have precipitated $PbSO_4$ from an aqueous solution to determine the quantity of dissolved lead. To have the **most accurate result**, it is important to keep the sample under vacuum filtration for an extended period of time to:

a. Remove excess SO_4^{2-}
b. Allow the precipitation to proceed to completion
c. Remove as much water as possible
d. Allow time to accurately record the data
e. Allow the lead sulfate to react with air to form elemental lead

In order to accurately know how much lead you have collected, you need to ensure that the mass recorded is based on lead sulphate and not on a combination of lead sulphate and water.

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____ 3. A 2.0 g sample of sodium is reacted with excess water. All gaseous products are collected in a 2.0 L sealed vessel at 300. K. **What is the pressure** inside the vessel?

$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

a. 12 atm
b. 0.54 atm
c. 0.018 atm
d. 1.4 atm
e. 0.75 atm

$$2.0gNa\left(\frac{1mol}{22.990gNa}\right)\left(\frac{1molH_2}{2molNa}\right)$$
$$= 0.043497molH_2$$
$$PV = nRT$$
$$P = \frac{nRT}{V}$$
$$P = 0.54atm$$

____ 4. Which of the following have **a reasonable chemical formula** and **are correctly named**?

a. CaF_3	Calcium Flouride
b. HCl	Hypochlorus acid
c. NaO	Sodium Oxide
d. $AsCl_3$	Arsenic trichloride
e. $CrBr_4$	Carbon Tetrabromide

a. CaF_2 (calcium fluoride)
b. HCl (hydrochloric acid)
c. Na_2O (sodium oxide)
d. $AsCl_3$ (arsenic trichloride – correct)
e. CBr_4 (carbon tetrabromide)

____ 5. Given the following empirical formula for a stibazane; C_6H_5NSbCl; determine the **number of grams of nitrogen** contained in a 12.0 g sample of stibazane.

a. 0.0258
b. 0.677
c. 5.69
d. 1.98
e. 0.389

$$12.0g\left(\frac{1mol}{248.3155g}\right)\left(\frac{1molN}{1mol}\right)\left(\frac{14.007gN}{1molN}\right)$$
$$= 0.677g$$

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____ 6. A 1.0 L solution of 1.0 M KI is added to 0.500 L of water. What is the **new concentration of KI**?

a. 2.5
b. 1.0
c. 0.50
d. 0.67
e. 1.5

$$c_1v_1 = c_2v_2$$
$$c_2 = \frac{c_1v_1}{v_2}$$
$$c_2 = \frac{(1.0M)(1.0L)}{1.5L}$$
$$= 0.67M$$

____ 7. Which of the following has the **largest first ionization energy?**

a. B
b. Be
c. N
d. O
e. C

The trend is first ionization energy increases from left to right across the periodic table. However, there is a "blip" between groups 5 & 6 where we transition from a half-filled p-shell in to a p-shell with 4 electrons. The stability of the half-filled p-shell results in nitrogen having a higher I.E. than O

____ 8. Which of the following statements is/are **true**?

i. Fluoride ion can substitute for hydroxide ion in tooth enamel
ii. Fluorosis is a health benefit of fluorination of municipal water supply
iii. Hydronium ion in the mouth causes enamel decay
iv. In an Electron Capture Detector, halogenated compounds are selectively detected based on their electron affinity
v. Neon lamps are based on ionization energies of noble gases

a. i, iii, iv
b. iv
c. ii, iiii, v
d. i, iii 1 mark
e. i, ii, iv

i. True
ii. Fluorosis is the result of over-exposure to fluoride. In adults it causes discolouration of the teeth, in children it can actually prevent adult teeth from forming
iii. True
iv. True
v. Neon lamps are based on exiting electrons and having them fall back to ground state, not ionizing the atoms

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____ 9. Which of the following is/are **diamagnetic**?

i. Br^-

ii. C

iii. Ne

iv. Li

v. Mg

Diamagnetic means having no unpaired electrons.

i. Br^- has a noble gas config.
ii. C has 2 electrons in the p-orbital
iii. Ne has a noble gas config.
iv. Li has 1 electron in a s-orbital
v. Mg has 2 electrons in an s-orbital

a. i, iii, v
b. ii, iv, v
c. ii, iii, iv
d. iii, iv, v
e. i, iv

____ 10. The first ionization energy of beryllium is higher than that of boron. The **reason for this** is:

a. The electrons in boron are paired, therefore more difficult to remove
b. The statement is false. The first ionization energy of boron is higher than beryllium
c. Boron is paramagnetic, therefore it is easier to remove the electron
d. More energy is required to remove the electron from the low-energy s-orbital
e. More energy is required to remove the electron from the high-energy p-orbital

a. Electrons repel each other, therefore if the pairing was the cause, it should be easier to remove the electron
b. The statement itself is true
c. Boron is paramagnetic, but this doesn't lead to a lower ionization energy. For example, nitrogen is paramagnetic, yet it has a higher ionization energy than expected
d. Since the s-orbital is filled, it is more stable and therefore harder to remove the electron from it than a partially filled p-orbital
e. The electron in question is from a s-orbital, not a p-orbital

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____11. Organize the following atoms and ions into **decreasing atomic radii** (from largest radius to smallest radius). C, Li, Be^{2+}, N, Be, N^{3-}

a. Li, Be, C, N, Be^{2+}, N^{3-}

b. Be^{2+}, N, C, Be, Li, N^{3-}

c. Be^{2+}, Li, Be, C, N, N^{3-}

d. N^{3-}, Li, Be, C, N, Be^{2+}

e. N^{3-}, N, C, Be, Li, Be^{2+}

cations are smaller than neutral atoms and anions are larger than neutral atoms. Therefore the trend is anion first, atoms increasing from left to right, cation last.

____12. Which of the following reactions is **incorrect**?

a. $SO_3(g) + H_2O(l) \text{-->} SO_2(g) + 2OH^-\ (aq)$

b. $Rb(s) + H_2O(l) \text{-->} Rb^+(aq) + OH^-(aq) + ½\ H_2(g)$

c. $Br_2(l) + Cl^-\ (aq) \text{-->}$ No Reaction

d. $I^-(aq) + Cl_2(g) \text{-->} Cl^-(aq) + I_2(s)$ (0.5 marks)

e. $SO_3(g) + H_2O(l) \text{-->} H_2SO_4\ (aq)$

a. False - Non-metal oxides react with water to form acids (not bases)
b. True – Alkali metals react with water to form bases and hydrogen
c. True – bromine cannot oxidize chloride ion
d. True – chlorine can oxidize iodide ion (not balanced, so 0.5 marks)
e. True – non-metal oxides react with water to form acids

____13. Which of the following is an **allowed set of quantum numbers** for the valence shell electrons of silicon in the ground state?

a.	$n = 2$	$l = 1$	$m_l = 1$	$m_s = -½$
b.	$n = 3$	$l = 1$	$m_l = -1$	$m_s = -½$
c.	$n = 2$	$l = 1$	$m_l = 2$	$m_s = 0$
d.	$n = 3$	$l = 0$	$m_l = 1$	$m_s = +½$
e.	$n = 3$	$l = 2$	$m_l = 2$	$m_s = +½$

Si: $[Ne]3s^23p^2$
Therefore, eliminate any quantum numbers with n=2 (not the valence shell).

d. If l=0, then m_l can only equal 0
e. If l=2, then that is a d-orbital and Si in the ground state doesn't have an electron in the d-orbital.

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____14. Which of the following represent an **excited state electron configuration** of Argon?

a. $1s^2 2s^2 2p^6 3s^2 3p^7$
b. $1s^2 2s^2 2p^6 3s^2 3p^6$
c. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
d. $1s^2 2s^1 2p^6 3s^2 3p^6 4d^1$
e. $1s^2 2s^2 2p^6 3s^2 3p^5$

Electron configuration of Argon:

$1s^2 2s^2 2p^6 3s^2 3p^6$, therefore you have to continue to have 18 electrons. Eliminate a, c, e

b. is in ground state (not excited state)
d. has a 2s electron promoted to 4d, therefore excited state.

____15. The minimum wavelength of the photons that are able to break a bond in ozone, O_3 is 280. nm. The **energy of these photons** in kJ/mol is:

a. 98.6 kJ/mol
b. 427 kJ/mol
c. 1.55 kJ/mol
d. 2.28×10^{-7} kJ/mol
e. 8.89×10^{12} kJ/mol

$$E = \frac{hc}{\lambda}$$

$$E = 7.0944x10^{-19} J$$

$$E = 7.0944 \times 10^{-22} kJ / atom$$

$$\frac{7.0944 \times 10^{-22} kJ}{1 atom}\left(\frac{6.022 \times 10^{23} atoms}{1 mol}\right)$$

$$= 427 kJ / mol$$

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____ 16. Which of the following statements is/are **true**?

i. The Rydberg equation is based on an empirical relationship between energy levels, and was one of the first evidences of quantization.

ii. The Bohr model of the H-atom only holds true for H and H-like atoms, due to the effects of e^- screening on the energy levels of multi-electron atoms.

iii. The uncertainty principle states that electrons do not move in circular orbits, but rather in orbitals.

iv. Chemical sunscreens are effective due to their ability to interact with electrons in the UVA and UVB range.

v. For a subshell, l, the values of m_l represent the size of the orbitals.

a. i, ii
b. iii
c. ii, v
d. iv, v
e. Ii 1 mark

a. True
b. True
c. False – the uncertainty principle states that you cannot simultaneously know the position and momentum of an electron
d. False - they interact with photons of energy in the UVA/UVB range
e. False – they represent the orientation of the orbitals

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____17. In a photoelectric effect experiment, the wavelength of the incident photons is 40.0 nm. They strike a gold metal surface, which has a threshold energy of 8.15 x 10 $^{-19}$J. What is the **speed of the ejected photoelectron**?

a. 7.21 x10^5 m/s

b. 5.83 x10^3 m/s

c. 1.06 x10^{10} m/s

d. 2.25 x10^{-8} m/s

e. 3.02 x10^6 m/s

$$E_{inc} = \frac{hc}{\lambda}$$
$$E_{inc} = 4.9661 \times 10^{-18} J$$

$$E_{inc} = E_{thres} + E_{kin}$$
$$E_{kin} = E_{inc} - E_{thres}$$
$$E_{kin} = 4.1511 \times 10^{-18}$$
$$\tfrac{1}{2} mu^2 = 4.1511 \times 10^{-18}$$
$$u = 3.02 \times 10^6 m/s$$

____18. Which **ONE** of the following molecules would you expect to be **non-polar**?

a. CO
b. $AlCl_3$
c. H_2O
d. SO_2
e. ICl

a. Linear, polar molecule
b. Trigonal planar (non-polar)
c. Bent – polar
d. Bent – polar
e. Linear - polar

____19. Select the following **true** statement(s) that explain why the bond energy required for the photolysis of **ozone (O_3)** is **less than molecular oxygen (O_2)**:

i. The net dipole moment of O_2 is greater than O_3

ii. The average bond order of O_3 is less than O_2.

iii. The electron affinity of O_3 is greater than O_2

iv. The electronegativity of O_3 is less than O_2

v. The number of charge minimized structures for O_3 is greater than O_2

a. iii
b. i
c. i, iv
d. iii, v
e. ii, v

i. False – O_2 is non-polar, O_3 is weakly polar
ii. True – O_3 = 1.5 O_2 = 2. Since bond order is directly related to bond energy, this means that O_2 has a greater bond energy
iii. False – not related to bond energy
iv. False – EN difference is the same
v. True – due to resonance, therefore lower bond order

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____20. According to the VSEPR model, the **molecular shape and bond angle** (O-Cl-O) of $\mathbf{ClO_2^+}$ is:

a. Linear and 180°
b. Trigonal planar and less than 120°
c. Trigonal bipyramidal and 180°
d. Tetrahedral and 109.5°
e. Bent and less than120°

The lewis structure is oxygen (with 2 lone pairs) double bonded to chlorine (with 1 lone pair) double bonded to oxygen (with 2 lone pairs).

Trigonal planar electron pair geometry, however bent molecular shape. Lone pair electrons on chlorine push oxygens closer together, decreasing the bond angle to less than 120°

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Section #2 – These questions are worth three marks each.

____21. Choose the **TRUE** statements from the following list:

i. In the Bohr model of the hydrogen atom, $E = 1.45 \times 10^{-19}$ J is an allowed energy level.

ii. A transition from n = 3 to n = 8 is an absorption process which releases a photon.

iii. An electron in a transmission electron microscope is accelerated under an applied potential to a speed of 5.0×10^{6} m/s. Therefore its wavelength is 1.45 Å.

iv. The intensity of the incident light hitting a metal surface can be tuned to determine the threshold energy of the material.

a. ii
b. ii, iv
c. i, iii
d. i, iv
e. iii

i. False - n = 3.8, not an integer
ii. False – it is an absorption, but a photon isn't released
iii. True - $\lambda = h/mu$
iv. Intensity doesn't determine if the photoelectric effect occurs or not, wavelength (or frequency) does

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____22. Qualitatively **rank** the following types of chemical bonds in terms of **increasing bond length** (from shortest to longest average bond length)

(i) C—O (ii) I—I (iii) C=C (iv) C—Cl (v) C—C

a. iii, i, v, iv, ii
b. v, iii, ii, i, iv
c. ii, v, iv, i, iii
d. ii, iii, v, iv, i
e. iii, ii, iv, i, v

Bond length is related to bond order as well as atomic radius.

iii – double bond will be shortest
i – C-O bond is shorter because of atomic radius of oxygen (compared to (v) C-C)
ii – largest because of atomic radius of iodine

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____23. Choose the **false** statement with respect to the **carbonate ion CO_3^{2-}** and **carbon monoxide CO**, when drawn with charge-minimized Lewis structures.

a. The formal charge on C in CO is -1.
b. The average C-O bond order in CO_3^{2-} is 4/3
c. The average C-O bond length in CO is shorter than in CO_3^{2-}
d. The CO_3^{2-} ion has eight pairs of non-bonding electrons.
e. There are two equivalent charge-minimized structures for CO_3^{2-}

Lewis structures:

Carbon monoxide: lone pair electron on carbon, triple bond to oxygen, lone pair electron on oxygen

Carbonate ion: 2 lone pair electrons on oxygen, double bond to carbon, single bond to another oxygen (with 3 lone pairs), single bond to another oxygen (with 3 lone pairs). Double bond resonates between the 3 oxygen

a. True
b. True
c. True (CO has a triple bond, where as CO_3^{2-} has 1.3 bonds)
d. True
e. False – there are three equivalent structures

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____24. Which **one** of the following molecules/ions has **no charge-minimized resonance structures**?

a. CO_2
b. O_3
c. NO_2
d. CO_3^{2-}
e. ClO_3^-

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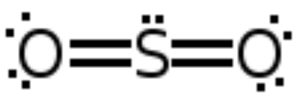
____25. To eject non-bonding valence electrons in a molecule requires progressively more energy as more electrons are removed. Each time a non-bonding valence electron is removed, 5 times as much energy is required (as compared to the previous electron). If the first non-bonding electron requires light of wavelength 12.4 nm to be ejected, what is the total energy required to eject all non-bonding valence electrons in 2.0 g of SO_2?

a. 2.1×10^{-5} J
b. 1.9×10^{23} J
c. 7.3×10^{11} J
d. 6.7×10^{8} J
e. 5.8×10^{-11} J



10 valence electrons to eject.

$$E = \frac{hc}{\lambda} \longleftarrow$$ Energy required to eject the 1st electron

$$E = 1.602 \times 10^{-17}$$

$E_n = 1.602 \times 10^{-17} \times 5^{n-1} \rightarrow$ energy required to eject a specific electron "n"

The energy required to eject the last series of electrons will overwhelm the energies for the first series of electrons, so calculate the total energy from n=6 → n=10

$E_{Total} = 3.9048 \times 10^{-11}$ J (for one SO_2)

Now calculate for 2.0g of SO_2:

$$\frac{3.9048 \times 10^{-11} J}{1\ SO_2}\left(\frac{6.022 \times 10^{23}\ SO_2}{1 mol\ SO_2}\right)(2.0 g\ SO_2)\left(\frac{1 mol\ SO_2}{64 g}\right)$$
$$= 7.3 \times 10^{11} J$$

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ROUGH WORK

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Some general data are provided on this page and the next page. Other data appear with the questions.

A periodic table is provided on the next page.

STP = 273.15 K, 1 atm   F = 96485 C/mol

R = 8.3145 J/K · mol = 0.08206 L · atm/K · mol $N_A = 6.022 \times 10^{23}\ mol^{-1}$

1 atm = 760 mm Hg = 101.325 kPa   0°C = 273.15 K

$1\ J = 1\ kg\ m^2\ s^{-2} = 1\ kPa \cdot L = 1\ Pa \cdot m^3$ $1\ m = 10^9\ nm = 10^{10}$ Å

$1\ cm^3 = 1\ mL$ $1\ g = 10^3\ mg = 10^{-3}\ kg$

1 Hz = 1 cycle/s $c = 2.9979 \times 10^8\ m/s$

$h = 6.6256 \times 10^{-34}\ J \cdot s$ $m_e = 9.10 \times 10^{-31}\ kg$

λ = h / mu = h / p

$E_n = -R_H / n^2 = -2.179 \times 10^{-18} J / n^2$ (R_H is the energy form of the Rydberg constant for H)

$K_w = 1.0 \times 10^{-14}$ (25 °C)   K.E. = $\frac{1}{2} mu^2$

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