Name: ____________________ Student number: ______________

Chemistry 1A03 **Test 1** **October 10, 2008**

McMaster University **VERSION 1** **ANSWERS in BLUE**

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Duration: 100 minutes

This test contains 20 numbered pages printed on both sides. There are **25** multiple-choice questions appearing on pages numbered 3 to 17. Page 18 is extra space for rough work. Page 19 includes some useful data and equations, and there is a periodic table on page 20. You may tear off the last page to view the periodic table and the data provided.

You must enter your name and student number on this question sheet, as well as on the answer sheet. Your invigilator will be checking your student card for identification. **You are responsible** for ensuring that your copy of the question paper is complete. Bring any discrepancy to the attention of your invigilator.

Questions 1 to 19 are each worth 2 marks, questions 20 – 25 are each worth 3 marks; the total marks available are 56. There is **no** additional penalty for incorrect answers.
BE SURE TO ENTER THE CORRECT VERSION OF YOUR TEST (shown near the top of page 1), IN THE SPACE PROVIDED ON THE ANSWER SHEET.

ANSWER ALL QUESTIONS ON THE ANSWER SHEET, IN PENCIL.
Instructions for entering multiple-choice answers are given on page 2.
SELECT ONE AND ONLY ONE ANSWER FOR EACH QUESTION from the answers **(A)** through **(E).** **No work written on the question sheets will be marked**. The question sheets may be collected and reviewed in cases of suspected academic dishonesty.

Academic dishonesty may include, among other actions, communication of any kind (verbal, visual, *etc.*) between students, sharing of materials between students, copying or looking at other students' work. If you have a problem please ask the invigilator to deal with it for you. Do not make contact with other students directly. Try to keep your eyes on your own paper – looking around the room may be interpreted as an attempt to copy.

Only Casio FX 991 electronic calculators may be used; but they must NOT be transferred between students. Use of periodic tables or any aids, other than those provided, is not allowed.

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See page 2 of the test for instructions.

Questions 1-19 are worth two (2) marks each.

1. The element oxygen consists of more than one isotope. One naturally occurring isotope of oxygen is $^{16}_{8}O$. Which of the following could also be an **isotope of oxygen**?

(A) $^{16}_{9}O$

(B) $^{17}_{8}O$

(C) $^{16}_{8}O^{2-}$

(D) Both (A) and (B)

(E) Both (B) and (C)

An isotope has a different number of neutrons.
(A) shows a different number of protons – this would indicate a different element.
(B) is correct.
(C) is an ion – different number of electrons.

2. To **increase the volume** of a fixed amount of gas from 0.100 L to 0.200 L, you would need to:

(A) increase the temperature from 25.0°C to 50.0°C at constant pressure.

(B) increase the pressure from 1.00 atm to 2.00 atm at constant temperature.

(C) reduce the pressure from 0.80 atm to 0.40 atm at constant temperature.

(D) reduce the temperature from 400 K to 200 K at constant pressure.

(E) decrease the temperature from 600 K to 400 K.

According to PV = nRT, if n remains constant and we have our gas constant (R = 0.08206 L·atm/K·mol), then in order for V to double in L, then P (in atm) must decrease by half, or T (in K) must double.
(A) does not show a doubling of T in K units.
(B) shows a pressure increase, but a decrease is needed.
(C) is correct – pressure (atm) cut in half.
(D) shows T cut in half, but an increase is required.
(E) shows a T decrease, but an increase is required.

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3. The Haber-Bosch process is one of the most important chemical reactions to produce large-scale amounts of ammonia (NH_3). Ammonia is used in the fertilizer industry for increased food production. Determine the **temperature** required to generate 20.0 kg of NH_3 when the reaction is performed in a vessel that has a volume of 250.0 L with external pressure of 200. atm?

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$$

(A) -450 K

(B) 5.12 K

(C) 519 K

(D) 220 K

(E) 25,000ºC

PV = nRT, where P = 200. atm, V = 250.0 L, R = 0.08206 L·atm/K·mol and n = mass/molar mass.
n (NH_3) = 20.0×10^3 g / 17.0337 g/mol
PV = nRT, so T = PV/nR

$$T = \frac{(200.\text{ atm})\,(250.0\text{L})}{(20.0 \times 10^3\text{ g} / 17.0337\text{ g/mol})\,(0.08206\text{ L·atm/K·mol})}$$

T = 519 K.

4. A solution of HCl was made by pipeting 10.00 mL of 0.2945 M HCl and diluting with distilled water to a final volume of 45.00 mL. The resulting solution was titrated to equivalence with 21.45 mL of NaOH. What is the **[NaOH] (M)**?

(A) 0.1373 M

(B) 0.6458 M

(C) 0.09871 M

(D) 0.1893 M

(E) 0.3489 M

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$ (Lab 1)
Since the titration shows 1:1 stoichiometry,
mol NaOH = mol HCl at the equivalence point.
mol HCl = c × V = (0.2945 M) (0.01000 L) = 0.002945 mol
mol NaOH = mol HCl = 0.002945 mol
[NaOH] = n / V = 0.002945 mol / 0.02145 L = 0.1373 M

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5. In which of the following circumstances would it be **most appropriate to hit the panic button** in the laboratory?

(A) In the event a large volume of concentrated acid was spilled

(B) If your lab partner cut themselves severely and are in need of immediate medical attention

(C) To see what it does

(D) In the event of a fire

(E) If an empty beaker fell and broke on the ground

If you wrote answer (D), please see Dr. Landry (ABB121) during office hours to see about the possibility of marks on this answer.

The panic button is used to draw people to the lab to provide help.
Answer (A) is correct according to the context of the question & safety video
Answer (B) is correct – the panic button would be used here in order to obtain medical assistance.
Answer (C) is not appropriate.
Answer (D) would require use of a fire extinguisher or the fire alarm, depending on size of fire.
Answer (E) simply requires careful handling of broken glass.

6. Which of the following statements regarding **quantum mechanics** are **FALSE**?

(i) The energy of a photon is proportional to its frequency.

(ii) In a hydrogen atom, the electron has a fixed distance from the nucleus.

(iii) As the velocity of a given particle gets bigger, its wavelength gets shorter.

(iv) The size of atomic orbitals is mainly determined by the magnetic quantum number.

(v) For a given shell of a many-electron atom, d orbitals have higher energy than s orbitals.

(A) i, ii, v

(B) i, iii, v

(C) ii, iii, v

(D) iii, iv

(E) ii, iv

(i) TRUE: $E = h\nu$
(ii) FALSE: The electron is housed in an atomic orbital which describes a region of probability of finding the electron.
(iii) TRUE: According to the de Broglie equation, $\lambda = h / mu$
(iv) FALSE: orbital size (and energy) is primarily determined by principal quantum number, n.
(v) TRUE: for an atom with more than 1 electron, the subshells do not have degenerate energy, and split such that s has lower energy than p. p has lower energy than d, etc.

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7. It takes 492 kJ of energy to remove one mole of electrons from the atoms on the surface of solid gold. What is the **minimum frequency (in s^{-1})** of light capable of doing this?

(A) $9.45 \times 10^{14}\ s^{-1}$

(B) $6.64 \times 10^{-19}\ s^{-1}$

(C) $2.82 \times 10^{15}\ s^{-1}$

(D) $1.23 \times 10^{15}\ s^{-1}$

(E) $5.56 \times 10^{-20}\ s^{-1}$

E = hν and watch the units: energy is given in kJ/mol, so use Avogadro's number to remove the mol unit. Also, convert from kJ to J, to match the unit in Planck's constant.

$$\frac{492\ \text{kJ}}{\text{mol electrons}} \times \frac{10^3\ \text{J}}{1\ \text{kJ}} \times \frac{1\ \text{mol electrons}}{6.022 \times 10^{23}} = (6.626 \times 10^{-34}\ \text{Js})\ \nu$$

$\nu = 1.23 \times 10^{15}\ s^{-1}$

8. Which one of the following is **<u>NOT</u>** a consequence of, or evidence for, **'quantization of energy'**?

(A) The Bohr model for the hydrogen atom.

(B) The frequency and wavelength of light are inversely related.

(C) Atoms can only emit and absorb light of particular frequencies.

(D) Bright red light is not able to eject an electron from a sheet of gold metal.

(E) Neon signs have a distinct color, determined by the electronic transitions available to the gas.

(A) Bohr model of the H atom describes quantized energy levels.
(B) $\nu = c\lambda$ is observed from the continuous electromagnetic spectrum (as ν increases, λ decreases). This indirect relationship does not pertain to quantization.
(C) Absorption and emission spectra are evidence of quantization.
(D) This situation describes the photoelectric effect experiment – evidence of quantization.
(E) This describes an emission process – evidence of energy quantization.

9. Which electron configuration represents an **excited state** of a **neutral Si atom**?

(A) $[Ar]4p^1$

(B) $[Ne]3s^23p^5$

(C) $[Ar]4s^24p^1$

(D) $[Ne]3s^23p^2$

(E) $[Ne]3s^23p^14s^1$

The Si atom (element #14) will have a ground state electron configuration of $[Ne]3s^23p^2$ (answer D). The ground state must show the correct number of electrons and obey the orbital filling rules. An excited state must also show the correct number of electrons (this eliminates answers A, B and C) and show that the configuration deviates from orbital filling rules (answer E).

10. A simplified version of a solar cell can be understood in terms of solid silicon (Si), responding to incoming electromagnetic radiation, and undergoing the photoelectric effect. If the binding energy of Si is 7.24×10^{-19} J, **what wavelength(s) (nm) of incident light will cause electrons will be emitted from Si**?

(A) $\lambda = 277$ nm

(B) $\lambda > 200$ nm

(C) $\lambda \leq 274$ nm

(D) $\lambda \geq 484$ nm

(E) $\lambda \neq 393$ nm

The photoelectric effect can be summarized by the statement:
E_{photon} = Binding energy + Kinetic energy
In this case there is zero kinetic energy described, so it simplifies to:
E_{photon} = Binding energy
Also, $E = hc / \lambda$, and we can use this relationship with the one above to solve for λ.
λ = hc / binding energy

$$\lambda = \frac{(6.626 \times 10^{-34}\ \text{Js})(2.9979 \times 10^{8}\ \text{m/s})}{7.24 \times 10^{-19}\ \text{J}}$$

$\lambda = 2.74 \times 10^{-7}$ m, or 274 nm.
Light with λ = 274 nm will cause electrons to be emitted from Si, and light of shorter wavelength will also cause electrons to be emitted, as it will have even greater energy.

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11. Which one of the following statements below is **FALSE** about the series of ions below:

Cl^{-} Na^{+} O^{2-} Rb^{+} Se^{2-}

(A) O^{2-} and Na^{+} are isoelectronic.

(B) Se^{2-} has the largest ionic radius.

(C) Na^{+} has the smallest ionic radius.

(D) Rb^{+} and Cl^{-} are isoelectronic.

(E) Rb^{+} has a larger ionic radius than Na^{+}.

(A) TRUE: 10 electrons each.
(B) TRUE: Se^{2-} and Rb^{+} are isoelectronic but Rb^{+} has more protons and is therefore smaller.
(C) TRUE: O^{2-} is isoelectronic but Na^{+} has more protons and is therefore smaller.
(D) FALSE: Rb^{+} and Br^{-} would be isoelectronic, but Cl is in the wrong period.
(E) TRUE: atomic radius increases going down a group, and the same trend holds for equivalently charged ions within the same group.

12. Select the **CORRECT** order of **increasing ionization energy** (from lowest ionization energy to highest): B, Be, C, F, Na.

(A) F < C < B < Be < Na

(B) B < Be < C < F < Na

(C) Be < B < C < F < Na

(D) Na < Be < C < B < F

(E) Na < B < Be < C < F

In general, ionization energy increases from bottom to top of a group, and from left to right across a period, with 2 notable exceptions: there are dips in the trend between groups 2A and 3A, and groups 5A and 6A. Thus, the correct ordering for the given elements is:

Na < B < Be < C < F (note the relative position for B (Group 3A) and Be (Group 2A)).

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13. Select the statement which best explains why **electron-capture detection (ECD)** can be used to detect trace levels of the synthetic refrigerant and ozone depletor, **CFC-11 (CCl_3F)** in air samples.

CFC-11 contains halogen groups that:

(A) have low ionization energies.

(B) have high electron affinities.

(C) have small atomic radii.

(D) are unreactive because of their full valence shells.

(E) are strong reducing agents.

Answer (B) is correct. The halogen atoms, with high electron affinities, produce a molecule that also has a high electron affinity. Electron capture detection is based on this principle.

14. Select the **TRUE** statement(s):

(i) Silicon atoms in their ground state are paramagnetic.

(ii) Rubidium is more easily oxidized than potassium.

(iii) Bromine is a weaker oxidizer than chlorine.

(iv) When dissolved in water, sulfur dioxide is more acidic than potassium oxide.

(v) When dissolved in water, sodium oxide is more basic than aluminum oxide.

(A) all statements are true

(B) i, iii, iv

(C) i, ii, v

(D) ii, iii, v

(E) ii, iii, iv

(i) TRUE – Si has the electron configuration $[Ne]3s^2 3p^2$ and this means that, according to orbital filling rules, there are 2 unpaired electrons in the p orbitals.
(ii) TRUE – ionization energy decreases down a group (i.e., the metal is more easily oxidized the lower it is in the group).
(iii) TRUE – the oxidizing power of the halogens increases up the group, towards fluorine.
(iv) TRUE – SO_2 is a non-metal oxide, which is acidic. K_2O is a metal oxide, which is basic.
(v) TRUE – Na_2O is a metal oxide, which is basic. Al_2O_3 is an amphoteric oxide, with Al being on the cusp of the metalloids. Metallic character decreases across a period from left to right.

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15. In class the following reaction was demonstrated: adding a chunk of sodium metal to water. $Na(s) + H_2O(l) \rightarrow$ products

Based on the correctly completed, balanced reaction, **how many grams (g) of hydrogen gas** can be produced from 50.0 g of sodium at 25.0°C?

(A) 1.20 g
(B) 2.19 g
(C) 3.52 g
(D) 4.48 g
(E) 6.03 g

$Na(s) + H_2O(l) \rightarrow NaOH(aq) + \frac{1}{2} H_2(g)$

One mole of Na generates 0.5 mol $H_2(g)$.

$$50.0 \text{ g Na} \times \frac{1 \text{ mol Na}}{22.99 \text{ g Na}} \times \frac{\frac{1}{2} \text{ mol } H_2}{1 \text{ mol Na}} \times \frac{2.016 \text{ g } H_2}{1 \text{ mol } H_2} = 2.19 \text{ g } H_2$$

16. Ozone (O_3), an allotrope of oxygen, is found in the Earth's upper atmosphere where it protects the Earth's surface from UVB radiation. For a charge-minimized Lewis structure of O_3, what is the **average O-O bond order** and the **average formal charge on the terminal O atoms**?

	Average O-O bond order	Average formal charge on terminal O
(A)	1	-1
(B)	1.5	-1
(C)	1	-2
(D)	1.5	0
(E)	1.5	-1/2

The Lewis structure for ozone has a skeleton of 3 O atoms connected. The central O atom has a lone pair of electrons. It has 1 double bond to a terminal O, and this O atom has 2 lone electron pairs. The central O atom also has1 single bond to the other terminal O, and this terminal O atom has 3 lone electron pairs. The formal charges are: +1 on the central) atom, -1 on the singly bonded terminal) atom, 0 on the doubly bonded terminal 0 atom.
The average O-O bond order is: (2+1)/2 = 1.5.
The average formal charge on the terminal) atoms is: (-1 + 0)/2 = -1/2.

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17. Choose the **TRUE** statements concerning polarity and bonding:

(i) All molecules with polar bonds have permanent dipoles.

(ii) The compound SrO will exhibit covalent bonding.

(iii) The bond length in N_2 is shorter than the bond length inO_2.

(iv) The O-H bond in H_2O is more polar than the N-H bond in NH_3.

(A) i, iii

(B) ii, iii

(C) ii, iv

(D) iii, iv

(E) i, ii

(i) FALSE – if the bond dipoles cancel out, then the molecule has no permanent dipole (e.g. CO_2).
(ii) FALSE – SrO is an ionic compound formed from a group II metal and a group XVI non-metal.
(iii) TRUE – the atomic sizes of N and O are similar, with N slightly larger, but in N_2 there is a triple bond and in O_2 there is a double bond.
(iv) TRUE – since O is more electronegative than N, the electronegativity difference between O and H is greater than N and H, and the O-H bond is more polar.

18. According to the VSEPR model, the **F-As-F bond angles in the AsF_4^- ion** are predicted to be:

(A) 109.5°

(B) 90° and 120°

(C) 90°

(D) < 109.5°

(E) < 90° and < 120°

The AsF_4^- ion is a 34 electron system. Its Lewis structure will have As as the central atom, with 4 F atoms attached by single bonds, each F atom with 3 lone pairs of electrons, and a lone pair of electrons on the As atom. Thus it is an AX_4E system and the bond angles will be non-ideal.
The AX_4E shape is derived from an AX_5 system where the bond angles are 90° and 120°, thus the non-ideal angles will be < 90° and < 120°.

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19. Which of the following molecules have a **permanent dipole?**

(i) CBr_4

(ii) $SOCl_2$ (S is the central atom)

(iii) NH_3

(iv) PF_5

(v) ICl_5

(A) ii, iii, v

(B) i, ii, iii

(C) i, iii, v

(D) ii, iv

(E) i, iv

An approach to answering this question is to draw the Lewis structures for each molecule, then determine their VSEPR class. Symmetrical molecules: AX_n or AX_2E_3, AX_4E_2 with all X groups the same are non-polar. All other systems are polar.

(i) non-polar: AX_4 molecule
(ii) polar: AX_3 molecule with different X groups
(iii) polar: AX_3E molecule
(iv) non-polar: AX_5 molecule
(v) polar: AX_5E molecule

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Questions 20-25 are worth three (3) marks each.

20. The molecule 2,7-dihydroxynaphthalene is one component of certain hair dyes. It has the composition C 75.00%, H 5.03%, O 19.97% by mass, and 2.389×10^{23} molecules of 2,7-dihydroxynaphthalene weigh 63.4526 g. What is the **molecular formula of 2,7-dihydroxynaphthalene**?

(A) C_6H_5O

(B) C_5H_4O

(C) $C_8H_6O_2$

(D) $C_{15}H_{12}O_3$

(E) $C_{10}H_8O_2$

To obtain empirical formula: Assume a 100. g sample.

Then we have: 75.00 g C, 5.03 g H and 19.97 g O. Divide each by molar mass to obtain number of moles:
C: 75.00 g / 12.01 g/mol = 6.245 mol
H: 5.03 g / 1.0079 g/mol = 4.991 mol
O: 19.97 g / 15.999 g/mol = 1.248 mol

Now divide each by the smallest mole value (1.248) to obtain whole numbers:
C: 6.245 mol / 1.248 mol = 5
H: 4.991 mol / 1.248 mol = 4
O: 1.248 mol / 1.248 mol = 1
Since all are whole numbers there is no need to multiply by a factor. The empirical formula is C_5H_4O.

To obtain molecular formula, use the other data in the question to determine the molar mass, using Avogadro's number of molecules per mole:

$$\frac{2.389 \times 10^{23} \text{ molecules}}{63.4526 \text{ g}} = \frac{6.022 \times 10^{23} \text{ molecules}}{x \text{ g}}$$

x = 159.95 g/mol

The empirical formula mass is 80.0806 g/mol, and since 159.95 / 80.0806 = 2, the molecular formula is twice the empirical formula.
Molecular formula = $C_{10}H_8O_2$.

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21. Calculate **the longest wavelength** (in nm) of light **emitted** by an electron in the hydrogen atom initially in the n = 6 excited state.

(A) 7.46×10^{-6} m

(B) 2.48×10^{-8} m

(C) 3.82×10^{-7} m

(D) 1.05×10^{-6} m

(E) 9.38×10^{-8} m

Since $E = hc/\lambda$, a long wavelength indicates a small energy. The longest wavelength will be emitted by making the smallest energy jump. This indicates the n=6 to n=5 transition.

For any n level in the H atom,

$$E_n = \frac{-R_H}{n^2} = \frac{-2.179 \times 10^{-18}\text{ J}}{n^2}$$

$$E_f - E_i = \frac{-R_H}{n_f^2} - \frac{(-R_H)}{n_i^2} = R_H\,(1/n_i^2 - 1/n_f^2) \text{ where } n_f = 5,\ n_i = 6$$

Also, $E_f - E_i = hc / \lambda$

Put these 2 equations together to solve for λ.

Since this is an emission, the calculated energy will be negative; however the wavelength we calculate must be positive.

$$\lambda = \frac{(6.626 \times 10^{-34}\text{ Js})(2.9979 \times 10^{8}\text{ m/s})}{\left|2.179 \times 10^{-18}\text{ J }(1/36 - 1/25)\right|}$$

$\lambda = 7.46 \times 10^{-6}$ m

22. An element is a molecular solid at room temperature. It burns to form a solid oxide, which is acidic when dissolved in water. The element's first ionization energy is lower than either of its neighbouring elements (to the left and right) in the periodic table. **Which element is this**?

(A) Al

(B) Si

(C) P

(D) S

(E) Cl

From the pieces of information given:
The element is a solid at room temperature, which eliminates Cl (the element is a gas at room temperature). The element is also molecular, which eliminates Al (metallic bonding) and Si (covalent network). Its oxide is acidic, which also confirms a non-metal element (P, S or Cl). Since Cl is already eliminated, the choices are P or S. However its oxide is also given to be a solid, which eliminates S and leaves us only with P.
The final piece of information about ionization energy is therefore conflicting: the IE is lower than its neighbours, which tells us it is S, according to the exception between groups 15 & 16 in the ionization energy trend.
Regrettably, because of editorial changes in the question, there is no single correct answer which correctly accounts for *all* of the answers given. Thus, all answers will be awarded full marks.

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23. Choose the **FALSE** statement with respect to the sulfite ion, $\mathbf{SO_3^{2-}}$, and sulfur trioxide, $\mathbf{SO_3}$, when drawn with charge-minimized Lewis structures.

(A) The formal charge on S in SO_3 is zero.

(B) The average S-O bond energy in SO_3^{2-} is less than in SO_3.

(C) The SO_3 molecule has six pairs of nonbonding electrons.

(D) The average S-O bond order in SO_3 is 4/3.

(E) There are three equivalent charge-minimized structures for the SO_3^{2-} ion.

The charge-minimized Lewis structure for SO_3 shows 3 S=O double bonds, with 2 lone pairs of electrons on each O atom. The formal charge on all atoms is zero.
The charge-minimized Lewis structure for SO_3^{2-} shows 1 S=O double bond, with 2 lone pairs of electrons on that O atom, and 2 S-O single bonds, with 3 lone pairs of electrons on each of those O atoms; there is also a lone pair of electrons on the S atom. The formal charge on S is zero, on the doubly bonded O is zero, and on the singly bonded O atoms is -1.
Given these structures, the answers are therefore:
(A) TRUE
(B) TRUE: average bond order in SO_3 is 2, and in SO_3^{2-} is 4/3. Lower bond order indicates lower bond energy.
(C) TRUE: 6 pairs on the 3 O atoms.
(D) FALSE: average bond order in SO_3 is 2.
(E) TRUE: there are 3 resonance structures (three equivalent charge-minimized structures).

24. Select the **TRUE** statements regarding bonding and VSEPR model shapes.

(i) The electron pair geometry in PO_3^{3-} is trigonal pyramidal.

(ii) The molecular shape of XeF_4 is square planar.

(iii) The F-N-F angles in NF_3 are 109.5º.

(iv) BF_3 is a non-polar molecule.

(A) i, ii, iv

(B) ii, iii

(C) ii, iv

(D) i, iii, iv

(E) all are true

(i) FALSE – the electron pair geometry is tetrahedral.
(ii) TRUE – there are 4 atoms and 2 lone pairs of electrons, thus AX_4E_2, square planar.
(iii) NF_3 is an AX_3E molecule, and so the F-N-F bond angles are less than ideal (<109.5º).
(iv) TRUE – BF_3 is an AX_3 molecule with all X groups the same and so all bond dipoles cancel out.

25. A toxic heavy metal, cadmium, can be detected by atomic absorption spectroscopy (AAS), based on an absorption at 228.8 nm for the $Cd^{2+}(g)$ ion.

A urine sample was taken from a patient with chronic exposure to heavy metals in his work environment, and analyzed using an AAS experiment. The sample was atomized [$Cd^{2+}(aq) \rightarrow Cd^{2+}(g)$] in the AAS flame, and then irradiated with 228.8 nm light.

Light absorption by the $Cd^{2+}(g)$ caused the photon count at the detector to drop by 1.046 J per litre (L) of sample. **What is the concentration (M) of Cd^{2+}(aq)** in the sample?

(A) 2.002×10^{-6} M

(B) 6.783×10^{-6} M

(C) 5.000 M

(D) 0.4873×10^{-3} M

(E) 3.333×10^{-4} M

For an absorption process, one photon will be absorbed by one atom (or ion). Thus, the number of photons absorbed will indicate the number of Cd^{2+} ions present. Converting the number of ions to moles of ions, using Avogadro's number, along with the sample volume of one litre, will give the sample concentration.

Photon energy = hc / λ

$$E = \frac{(6.626 \times 10^{-34}\text{ Js})(2.9979 \times 10^{8}\text{ m/s})}{228.8 \times 10^{-9}\text{ m}}$$

$E = 8.682 \times 10^{-19}$ J for 1 photon.

Since the photon count dropped by 1.046 J, use a ratio to determine the number of photons absorbed:

$$\frac{1.046\text{ J}}{x\text{ photons}} = \frac{8.682 \times 10^{-19}\text{ J}}{1\text{ photon}}$$

$x = 1.204_8 \times 10^{18}$ photons

∴Since 1 photon is absorbed by 1 ion, there are $1.204_8 \times 10^{18}$ ions present.

Now convert to moles:

$$\frac{1.204_8 \times 10^{18}\text{ ions}}{x\text{ mol}} = \frac{6.022 \times 10^{23}\text{ ions}}{1\text{ mol}}$$

$x = 2.002 \times 10^{-6}$ mol per litre of sample, or concentration of Cd^{2+} in the sample = 2.002×10^{-6} M.

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