1A03 TEST 1 - FALL 2018 - ANSWERS

1. Which statement about ${}^{37}_{17}X^{+}$ is **false**?

   A) The element is chlorine.
   B) There are 17 protons.
   C) There are 20 neutrons.
   D) There are 18 electrons = FALSE

The element has 17 protons, so it must be chlorine (the 17th element on the periodic table). With a mass number of 37, there must be 20 neutrons. To be cation, it must have one more proton than electrons, so it has 16 electrons.

2. A 10.0 g sample of propane (C_3H_8) (g) was combusted in a 25.0 L rigid vessel containing pure O_2 (g) at P_{O2} = 1.500 bar and an initial temperature of 25.0 °C. At the end of the reaction the temperature of the vessel is 250. °C. At the end of the reaction, what is the **mole fraction of CO_2(g)** in the vessel?

   A) 0.263
   B) 0.421
   C) 0.346
   D) 0.538

Balanced equation if there is complete combustion (i.e. if propane is the limiting reagent):

C_3H_8 (g) + 5 O_2 (g) → 3 CO_2 (g) + 4 H_2O (g)

Molar mass of C_3H_8 = 3 × 12.011 g mol^{-1} + 4 × 1.0079 g mol^{-1} = 44.0962 g mol^{-1}
Moles of C_3H_8 = 10.0 g / 44.0962 g mol^{-1} = 0.2268 moles

PV = nRT, so n = PV/RT

Moles of O_2 = (1.500 bar × 25.0 L)/(0.083145 L bar K^{-1} mol^{-1} × 298.15 K) = 1.513 moles

The number of moles of O_2 is more than 5x that of C_3H_8, so O_2 is in excess and propane is the limiting reagent.

Moles of C_3H_8 remaining = 0
Moles of O_2 remaining = 1.513 – (5 × 0.2268) = 0.379
Moles of CO_2 formed = 3 × 0.2268 = 0.680
Moles of H_2O formed = 4 × 0.2268 = 0.907
Total moles of gas at the end of the reaction = 0.379 + 0.680 + 0.907 = 1.966

Mole fraction of CO_2 in the resulting mixture = 0.680 / 1.966 = 0.346

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3. Lithium has two stable isotopes with natural abundances of 92.41% (^{7}Li) and 7.59% (^{6}Li). **How many atoms of ^{6}Li** are there in a 1.54 g sample of **lithium oxide**?

A) 1.87×10^{20}
B) 3.00×10^{20}
C) 7.32×10^{21}
D) 4.71×10^{21}

Molar mass of Li_2O = 2 × 6.941 g mol^{-1} + 15.9994 g mol^{-1} = 29.8814 g mol^{-1}
Moles of Li_2O = 1.54 g / 29.8814 g mol^{-1} = 0.0515 moles

Atoms of lithium (^{6}Li and ^{7}Li) in the sample = 0.0515 × 2 × N_A = 6.21×10^{22}
Atoms of ^{6}Li in the sample = $6.21 \times 10^{22} \times 0.0759 = 4.71 \times 10^{21}$

4. Select the ONE species from the following selections that has **sulfur** in a **different oxidation state** than the other three selections.

A) HSO_3^-
B) SO_3^{2-}
C) HSO_4F
D) $SOCl_2$

In all cases O is in oxidation state 2–, F or Cl are in oxidation state 1–, and H is in oxidation state +1. Therefore, S is in oxidation state +4 in HSO_3^-, SO_3^{2-} and $SOCl_2$, but in oxidation state +8 in HSO_4F

(note: for those paying attention, HSO_4F should have been HSO_3F with an oxidation state of +6, since an oxidation state of +8 is not attainable for sulfur and HSO_4F does not exist…)

5. Aluminum (1.15 g) reacts with oxygen gas (0.971 L) at 25 °C and 1.05 bar to produce aluminum oxide. What is the **% yield** of the reaction if 1.78 g of aluminum oxide is obtained?

A) 67.2
B) 81.9
C) 71.2
D) 98.1

Balanced equation: $4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$

Molar mass of Al_2O_3 = 101.96 g mol^{-1}

Moles of Al = 1.15 g / 26.9815 g mol^{-1} = 0.0426
Moles of O_2 = PV/RT = (1.05 bar × 0.971 L)/(0.083145 L bar K^{-1} mol^{-1} × 298.15 K) = 0.0411

The number of moles of Al is less than 4/3 times that of O_2, so aluminum is the limiting reagent

100% yield of Al_2O_3 in moles = 0.0426 / 2 = 0.0213
100 % yield of Al_2O_3 in grams = 0.0213 moles × 101.96 g mol^{-1} = 2.173 g

Yield = (mass of product / theoretical yield) × 100 = (1.78 g / 2.173 g) × 100 = 81.9 %

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6. Boron and hydrogen form various compounds with formula B_xH_y. When 0.161 g of a particular B_xH_y compound was burned in **excess** O_2(g) it produced 0.420 g of B_2O_3(s) according to the following **unbalanced** reaction equation:

$$B_xH_y\,(s) + O_2(g) \rightarrow B_2O_3\,(s) + H_2O\,(l)$$

Which of the following could be the **molecular formula** for B_xH_y?

A) B_5H_9
B) B_2H_6
C) B_6H_{10}
D) B_4H_{10}

From this information we can only determine the empirical formula (i.e. the ratio between boron and hydrogen), so we can start by setting *x* to be equal to 1.

[Note: if $x = 1$, then 2 moles of B_xH_y are required to form 1 mole of B_2O_3]

Molar mass of B_2O_3 = 69.6182 g mol^{-1}
Moles of B_2O_3 formed = 0.420 g / 69.6182 g mol^{-1} = 6.033×10^{-3}
Moles of B_xH_y (with *x* set to be 1) consumed = $6.033 \times 10^{-3} \times 2 = 1.207 \times 10^{-2}$

n = m / M, so M = m / n
Molar mass of B_xH_y (with *x* set to be 1) = 0.161 g / 1.207×10^{-2} moles = 13.343 g mol^{-1}

10.81 g mol^{-1} of this is attributable to boron (because $x = 1$).
The remainder, 2.534 g mol^{-1}, is attributable to hydrogen.
Therefore, y = 2.534 g mol^{-1} / 1.0079 g mol^{-1} = 2.51
The empirical formula = $BH_{2.5}$ = B_2H_5, which only matches molecular formula D: B_4H_{10}

7. Which one of the following is **NOT an allowed set** of quantum numbers (n, ℓ, m_ℓ, m_s) for an excited electron in a sodium atom?

A) 3, 2, 0, –½
B) 3, 1, 0, ½
C) 2, 1, 1, –½
D) 4, 0, 0, ½

Answers A, B, C and D correspond to 3d, 3p, 2p and 4s orbitals, respectively.
In all cases, the values of m_l are allowed, as are the values for m_s.

Choices A, B and D correspond to excited electrons, since these orbitals would not be occupied in a ground state sodium atom. By contrast, C corresponds to a core 2p electron.

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8. In a photoelectric effect experiment, light is shone on a sample of tantalum (threshold energy 6.89×10^{-19} J), and photoelectrons are released with a speed of 1.40×10^{6} m/s. **How many** of these statements are **true**?

    I. The frequency of incident light required is $2.39 \times 10^{15}\ s^{-1}$.
    II. The kinetic energy of the ejected photoelectrons is 8.93×10^{-19} J.
    III. The wavelength of the emitted photoelectrons is 0.520 nm.

    A) 3
    B) 2
    C) 0
    D) 1

$KE = ½ mu^2 = 0.5 \times 9.109 \times 10^{-31}$ kg $\times (1.40 \times 10^{6}\ ms^{-1})^2 = 8.93 \times 10^{-19}$ J → Answer II is correct

$\lambda = h / mu = 6.6256 \times 10^{-34}$ Js / $(9.109 \times 10^{-31}$ kg $\times 1.40 \times 10^{6}\ ms^{-1}) = 5.20 \times 10^{-10}$ m = 0.520 nm → Answer III is correct

Energy of the incident light = $E_{threshold} + KE = 6.89 \times 10^{-19}$ J + 8.93×10^{-19} J = 1.58×10^{-18} J

Frequency of the incident light = E / h = 1.58×10^{-18} J / 6.6256×10^{-34} Js = $2.39 \times 10^{15}\ s^{-1}$ → Answer I is correct

9. A valence electron in a nitrogen atom is excited to n = 4. Which electron configuration could **NOT** represent the excited state nitrogen atom?

    A) $1s^2\ 2s^2\ 2p^3\ 4s^1$
    B) $1s^2\ 2s^1\ 2p^3\ 4s^1$
    C) $1s^2\ 2s^2\ 2p^2\ 4p^1$
    D) $1s^2\ 2s^1\ 2p^3\ 4d^1$

Answer A does not have the correct number of electrons for a nitrogen atom

[All other answers involve excitation of a 2s or 2p electron to a higher energy orbital]

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10. The change in energy for a particular electronic transition in a hydrogen atom is **negative**. What can you conclude?

A) Energy was emitted as a result of the transition.
B) The hydrogen atom was ionized.
C) The transition is not possible due to the specific radii of hydrogen's energy levels.
D) The electron transitioned from a lower energy level to a higher one.

Only answer A is true (a negative change in energy occurs when an electron falls to a lower energy level - i.e. when an electron in hydrogen falls to a shell with a lower principal quantum number).

11. A scientist runs an experiment to recreate the photoelectric effect using red and blue light with two different metals. Red and blue light both eject electrons from Metal 1. However, only blue light ejects electrons from Metal 2.

Which statement is **false**?

A) Increasing the intensity of red light will cause electrons to eject from Metal 2.
B) Decreasing the intensity of blue light will decrease the number of electrons ejected from Metal 1.
C) For Metal 1, the electrons ejected using blue light have greater speed than the electrons ejected using red light.
D) Metal 2 has a greater threshold energy than Metal 1.

B, C and D are correct.

A is incorrect - if red light has insufficient energy to eject electrons from metal 2, increasing the intensity (i.e. the number of photons) will have no effect.

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12. What **wavelength of light (in nm)** is emitted when an electron transitions from a *3d* orbital to a *2p* orbital in a **hydrogen atom**?

A) 486.2 nm
B) 656.3 nm
C) 364.6 nm
D) 205.7 nm

Note: In a hydrogen atom, the energy only depends on the principal quantum number, so we don't need to pay attention to whether the electron is in a d or p orbital.

For $n = 3$, $E = –R_H/9 = –2.421 \times 10^{–19}$ J
For $n = 2$, $E = –R_H/4 = –5.448 \times 10^{–19}$ J
$\Delta E = –3.026 \times 10^{–19}$ J

$E_{photon} = 3.026 \times 10^{–19}$ J
$\lambda = hc/E = (6.6256 \times 10^{–34}\ \text{Js x } 2.9979 \times 10^{8}\ \text{ms}^{–1}) / 3.026 \times 10^{–19}\ \text{J} = 6.563 \times 10^{–7}\ \text{m} = 656.3$ nm

13. Which statement is **false**?

A) Orbitals describe regions of high probability of finding an electron.
B) For objects moving at a given speed, the larger the mass of an object, the shorter its wavelength.
C) Results from experiments on the photoelectric effect indicate that electrons have wave properties.
D) For an electron in an atom, the larger the value of *n*, the larger the average distance from the nucleus.

A = correct
B = correct (the De Broglie equation is: $\lambda = h/mu$)
C = false (the photoelectric effect doesn't give any info about the wave properties of electrons)
D = correct

14. **How many** of these statements are **true**?

I. Metal oxides generate acidic solutions when dissolved in water.
II. Metallic character of atoms increases moving to the right on the periodic table.
III. Amphoteric oxides can react with both acids and bases.

A) 1
B) 2
C) 3
D) 0

A = false (metal oxides generate basic solutions when dissolved in H_2O)
B = false (metallic character decreases as you go across a period)
C = correct

15. Which of the following represents the **second ionization energy** of zinc?

A) $Zn \rightarrow Zn^{2+} + 2e^-$
B) $Zn^{2+} + 2e^- \rightarrow Zn$
C) $Zn^+ + e^- \rightarrow Zn^{2+}$
D) $Zn^+ \rightarrow Zn^{2+} + e^-$

A = false = this represents the combined 1st and 2nd ionization energies for zinc
B = false = this is the reverse of reaction A, and does not correspond to ionization
C = false = the charges don't even balance!
D = correct

16. Given the ionization values below, **predict the identities of elements X and Y**:

Ionization Energy	Element X (kJ mol^{-1})	Element Y (kJ mol^{-1})
1^{st}	590	738
2^{nd}	1145	1451
3^{rd}	4912	7733
4^{th}	8153	10542
5^{th}	10496	13630

A) Element X is Calcium, Element Y is Magnesium
B) Element X is Potassium, Element Y is Calcium
C) Element X is Magnesium, Element Y is Calcium
D) Element X is Calcium, Element Y is Potassium

Both X and Y have much larger 3^{rd} ionization energies compared to their 1^{st} and 2^{nd} ionization energies. Therefore, both must have just 2 valence electrons, so are alkaline earth elements, and the answer must be A or C.

All of the ionization energies are lower for element X, so it is easier to remove electrons from element X, in which case it must be a heavier element (easier to remove valence electrons because they are in a higher energy shell). Therefore, X must be Ca, and Y must be Mg = choice A.

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17. **How many** of these statements are **true**?

I. When comparing Si, N, C, and O, the magnitude of electron affinity is smallest for N.

II. When comparing Al, Si, Na, and Cl, the value of Z_{eff} for a valence electron is smallest for Na.

III. When comparing Li, F, Cs, and At, the atomic radius is largest for At.

A) 1
B) 0
C) 2
D) 3

I = true - the general trend for electron affinity would predict Si ~ C < N < O. However, N has an energetically favourable half-filled p-shell, so the electron affinity is actually close to zero, and the magnitude will follow the order N < Si ~ C < O. Therefore, N is smallest in magnitude.

II - true - Z_{eff} increases across a period, approximately following the relationship $Z_{eff} = Z - S$. Therefore Z_{eff} increases in the order Na < Al < Si < Cl (i.e. Z_{eff} is smallest for Na)

III - false - these elements are from periods 3 and 6. The largest elements are further to the left of the periodic table (lower Z_{eff}), and further down a group (higher value of n). Therefore, atomic radius will be largest for Cs.

18. Arrange the following ions in order of **increasing ionic radius** (smallest to largest):

S^{2-}, K^+, Cl^-, Na^+

A) $Na^+ < K^+ < S^{2-} < Cl^-$
B) $Cl^- < S^{2-} < Na^+ < K^+$
C) $S^{2-} < Cl^- < Na^+ < K^+$
D) $Na^+ < K^+ < Cl^- < S^{2-}$

$Na^+ < K^+$ (this is correct in all answers)
$Cl^- < S^{2-}$ (this is only correct in B and D)

Na^+ will be similar in size to neutral Cl, and Cl^- will be much larger. Therefore, $Na^+ < Cl^-$: this is incorrect in answer B, but correct in answer D.

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19. Which of the following **reactions** takes place when calcium oxide is added to water at room temperature?

A) $CaO + H_2O \rightarrow Ca(OH)_2$
B) $CaO + H_2O \rightarrow Ca + O_2 + 2H^+$
C) No reaction.
D) $CaO + H_2O \rightarrow Ca + H_2O_2$

A is correct = Metal oxides form basic solutions of metal hydroxides when added to water. (note: B and D don't make much sense, since they form calcium metal, and we know calcium reacts with water…; also, the charges in equation B do not balance…)

20. The ground state of elements A and B have the following electron configurations:

$$A = [He]2s^22p^4 \quad B = [He]2s^22p^3$$

Which of the following statements about ionization energy (IE) is **true**?

A) IE (B) > IE (A) because losing an electron from A results in a half-filled shell.
B) IE (A) > IE (B) because losing an electron from A results in a half-filled shell.
C) IE (A) > IE (B) because A is further to the right in the periodic table.
D) IE (B) > IE (A) because A is further to the right in the periodic table.

Given these configurations, A = oxygen, and B = nitrogen.

The general trend (not including blips) of ionization energy (IE) across the 2nd period would be: Li < Be < B < C < N < O < F. However, Be has a filled s-shell, and N has a half filled p-shell, so IE is higher than expected for these elements --- they leapfrog over their neighboring element and the resulting order is Li < B < Be < C < O < N < F.

Therefore, IE (N) > IE (O) = IE (B) > IE (A), and the only possible correct answers are A and D.

A = true (losing an electron from A would result in a half-filled shell, and losing an electron from B would disrupt a half-filled shell: these factors are responsible for the larger ionization energy of N vs O).

D = false (oxygen (A) is further to the right on the periodic table, but the general trend, which is based solely on position in a period and Z_{eff}, would predict that IE (A) > IE (B), which is not what we observe)

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Some general data are provided on this page.

A periodic table with atomic weights is provided on the next page.

STP = 273.15 K, 1 atm

$N_A = 6.022 \times 10^{23}$ mol^{-1}

$h = 6.6256 \times 10^{-34}$ Js

density(H_2O, l) = 1.00g/mL

Specific heat of water = 4.184 J / g·°C

$R = 8.3145$ J K^{-1} mol^{-1} = 0.08206 L atm K^{-1} mol^{-1} = 0.083145 L bar K^{-1} mol^{-1}

F = 96485 C/mol

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

$m_e = 9.109 \times 10^{-31}$ kg

$\Delta H^o_{vap}[H_2O] = 44.0$ kJ mol^{-1}

1 bar = 100.00 kPa = 750.06 mm Hg = 0.98692 atm

1 J = 1 kg m^2 s^{-2} = 1 kPa L = 1 Pa m^3

1 cm^3 = 1 mL

1 Hz = 1 cycle/s

0°C = 273.15 K

1 m = 10^6 µm = 10^9 nm = 10^{10} Å

1 g = 10^3 mg

De Broglie wavelength:

$\lambda = h / mu = h / p$

Hydrogen atom energy levels:

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

$KE = \frac{1}{2}mu^2$

Nernst Equation:

$$E = E° - \frac{RT}{zF}\ln Q \quad = E° - \frac{0.0257\text{ V}}{z}\ln Q \quad = E° - \frac{0.0592\text{ V}}{z}\log_{10} Q$$

Entropy change: $\Delta S = \dfrac{q_{rev}}{T}$

Solubility Guidelines for Common Ionic Solids

Follow the lower-numbered guideline when two guidelines are in conflict. This leads to the correct prediction in most cases.

1. Salts of group 1 cations and the NH_4^+ cation are soluble . Except LiF and Li_2CO_3 which are insoluble.
2. Nitrates, acetates, bicarbonates, and perchlorates are soluble.
3. Salts of silver, lead and mercury (I) are insoluble. Except AgF which is soluble.
4. Fluorides, chlorides, bromides, and iodides are soluble. Except Group 2 fluorides which are insoluble
5. Carbonates, phosphates, chromates, sulfides, oxides, and hydroxides are insoluble. Except Group 2 sulfides and hydroxides of Ca^{2+}, Sr^{2+}, and Ba^{2+} which are soluble.).
6. Sulfates are soluble except for those of calcium, strontium, and barium.

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PERIODIC TABLE OF THE ELEMENTS

I 1	II 2	3	4	5	6	7	8	9	10	11	12	III 13	IV 14	V 15	VI 16	VII 17	VIII 18
		Transition Metals															
1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc [98]	44 Ru 101.07	45 Rh 102.91	46 Pd 105.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 *La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]
87 Fr [223]	88 Ra 226.03	89 **Ac 227.03	104 Unq [261]	105 Unp [262]	106 Unh [263]												

Atomic weights are based on $^{12}C = 12$ and conform to the 1987 IUPAC report values rounded to 5 significant digits. Numbers in [ ] indicate the most stable isotope.

* Lanthanides	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
** Actinides	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]	103 Lr [262]

END OF EXAM