CHEM 14A YOUR NAME (last name, first name) .....ANSWERS.....
Instructor: Dr. Laurence Lavelle

STUDENT ID# .....

SUMMER 2019
MIDTERM

(Total number of pages = 10)

(Total points = 120)

(Total time = 120 minutes)

__Carefully__ remove the last two pages: Constants and Formulas, and Periodic Table.

YOUR DISCUSSION SECTION .....

YOUR TA's NAME ……..

WRITE IN PEN

Do not use white-out.

Show all your work. Check units and significant figures.

Box your final answer.

This is a closed book exam: Only a pen and simple scientific calculator are allowed.

No other material allowed.

Good Luck

Do not write on this page.

QUESTION	SCORE
1	
2	
3	
4	
5	
6	
7	
8	
TOTAL (max 120)	

Q1A. The mass of an atom of beryllium is 1.50×10^{-26} kg. How many beryllium atoms are present in a beryllium film of mass 0.210 g used as a window on an x-ray tube? (8pt)

$$\text{number of beryllium atoms} = \frac{\text{mass of sample}}{\text{mass of one atom}}$$

$$= \left(\frac{0.210\ \text{g}}{1.50 \times 10^{-26}\ \text{kg} \cdot \text{atom}^{-1}}\right)\left(\frac{1\ \text{kg}}{1000\ \text{g}}\right)$$

$$= 1.40 \times 10^{22}\ \text{atoms}$$

2pt each line
1pt sig fig
1pt units

(Concept question)

Q1B. Bergamol (also known as linalyl acetate) is an aromatic compound found in bergamot and lavender oils. Bergamol contains atoms of carbon, hydrogen, and oxygen in the ratio 6:10:1. Its molecules each have two oxygen atoms. Write the chemical formula of bergamol. (7pt)

The empirical formula can be represented as: $(C_6H_{10}O_1)_n$ 3pt

Since each molecule has 2 oxygen atoms, n = 2 and the molecular formula is:

$C_{12}H_{20}O_2$ 4pt

Q2A. If an 800. mL aqueous solution contains 12.4 g of ethanol, CH_3CH_2OH, what is molarity of ethanol in this clinical and sterile solution? (8pt)

$$\text{MOLAR MASS OF } CH_3CH_2OH = 2\big(\text{mm(C)}\big) + 6\big(\text{mm(H)}\big) + \text{mm(O)}$$
$$= 2(12.01\ \text{g}\cdot\text{mol}^{-1}) + 6(1.008\ \text{g}\cdot\text{mol}^{-1}) + 16.00\ \text{g}\cdot\text{mol}^{-1}$$
$$= 46.068\ \text{g}\cdot\text{mol}^{-1}\ CH_3CH_2OH$$

2pt

$$n_{\text{ETHANOL}} = \frac{12.4\ \text{g}}{46.068\ \text{g}\cdot\text{mol}^{-1}} = 0.269\ \text{mol}\ CH_3CH_2OH$$

2pt

$$\text{MOLARITY}_{CH_3CH_2OH} = \frac{n_{CH_3CH_2OH}}{V} = \frac{0.269\ \text{mol}}{0.80\ \text{L}} = 0.336\ \text{mol}\cdot\text{L}^{-1}\ CH_3CH_2OH$$

2pt

1pt sig fig
1pt units

(Concept question)

Q2B. Balance the following chemical equation, $CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$, which represents the burning (combustion) of the natural gas, methane, as an energy source in a power station that generates electricity. (7pt)

(Balance the element that occurs the least: C & H)

$CH_4(g) + O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

(O occurs in three species, easier to balance last.)

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

Chemical equation is either balanced or not. 6pt
Include phases. 1pt

Q3. A stimulant in coffee and tea is caffeine, a substance of molar mass 194 g·mol^{-1}. When 0.376 g of caffeine was burned, 0.682 g of carbon dioxide, 0.174 g of water, and 0.110 g of nitrogen were formed. Determine the empirical and molecular formulas of caffeine, and write the equation for its combustion. (20pt)

1pt for each correct molar mass (4pt).

$$(0.682\ \text{g}\ \text{CO}_2)\left(\frac{1\ \text{mol}\ \text{CO}_2}{44.01\ \text{g}\ \text{CO}_2}\right)\left(\frac{1\ \text{mol C}}{1\ \text{mol}\ \text{CO}_2}\right) = 0.0155\ \text{mol C}$$

$$(0.0155\ \text{mol C})(12.01\ \text{g}\cdot\text{mol}^{-1}\ \text{C}) = 0.186\ \text{g C}$$

$$(0.174\ \text{g}\ \text{H}_2\text{O})\left(\frac{1\ \text{mol}\ \text{H}_2\text{O}}{18.02\ \text{g}\ \text{H}_2\text{O}}\right)\left(\frac{2\ \text{mol H}}{1\ \text{mol}\ \text{H}_2\text{O}}\right) = 0.0193\ \text{mol H}$$

$$(0.0193\ \text{mol H})(1.0079\ \text{g}\cdot\text{mol}^{-1}\ \text{H}) = 0.0195\ \text{g H}$$

$$(0.110\ \text{g}\ \text{N}_2)\left(\frac{1\ \text{mol}\ \text{N}_2}{28.02\ \text{g}\ \text{N}_2}\right)\left(\frac{2\ \text{mol N}}{1\ \text{mol}\ \text{N}_2}\right) = 0.007\ 85\ \text{mol N}$$

$$(0.007\ 85\ \text{mol N})(14.01\ \text{g}\cdot\text{mol}^{-1}\ \text{N}) = 0.110\ \text{g N}$$

mass of $\text{O} = 0.376\ \text{g} - (0.186\ \text{g} + 0.0195\ \text{g} + 0.110\ \text{g}) = 0.060\ \text{g O}$

$$\frac{0.060\ \text{g O}}{16.00\ \text{g O}} = 0.0038\ \text{mol O}$$

1pt each line above (8pt).

Dividing each amount by 0.0038 gives C : H : N : O ratios = 4.1 : 5.1 : 2.1 : 1.

1pt

The empirical formula is

$\text{C}_4\text{H}_5\text{N}_2\text{O}$. 1pt

The molecular mass of caffeine is

$194\ \text{g}\cdot\text{mol}^{-1}$.

Its empirical mass is

$97.10\ \text{g}\cdot\text{mol}^{-1}$. 1pt

molecular $\text{formula} = 2 \times \text{empirical formula} = \text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$ 1pt

$$2\ \text{C}_8\text{H}_{10}\text{N}_4\text{O}_2(\text{s}) + 19\ \text{O}_2(\text{g}) \rightarrow 16\ \text{CO}_2(\text{g}) + 10\ \text{H}_2\text{O}(\text{l}) + 4\ \text{N}_2(\text{g})$$

Chemical equation is either balanced or not. 4pt

Q4. In 1.0 s, a 60 W bulb emits 11 J of energy in the form of infrared radiation (heat) of wavelength 1850 nm. What is the energy per photon of light emitted?
How many photons of infrared radiation does the lamp generate in 1.0 s? (10pt)

$$E = h\nu = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\ \text{J}\cdot\text{s})(2.998\times10^{8}\ \text{m}\cdot\text{s}^{-1})}{1850\times10^{-9}\ \text{m}} = 1.074\times10^{-19}\ \text{J/photon}$$

1pt 2pt 2pt 1pt units

$$\#\ \text{photons} = \frac{\text{total energy}}{\text{energy / photon}} = \frac{11\,\text{J}}{1.074\times10^{-19}\ \text{J}} = 1.0\times10^{20}\ \text{photons}$$

1pt 1pt 1pt 1pt units

Unless stated otherwise, in the following concept questions give the abbreviated (short) electron configuration.

Q5A. Which member of each pair has the higher first ionization energy? Circle your answer. (4pt)

(i) Ca or Ba (ii) Mg or Cl

(i) Ca 2pt

(ii) Cl 2pt

Q5B. Give the full ground-state electron configuration for the chloride anion, Cl^- . (4pt)

$1s^2 2s^2 2p^6 3s^2 3p^6$

Q5C. Write the ground-state electron configuration for Cu^+ and give the first two quantum numbers for the last electron. (5pt)

$[Ar]3d^{10}$ 3pt

n = 3 1pt

l = 2 1pt

Q5D. How many unpaired electrons does Cu^+ in the ground state have? (2pt)

None

Chemistry Community is about to reach 8.5 million page views this summer.
Many student questions and student-student discussion has centered on figuring out homework problems.

Q6. In a recent suspense film two secret agents must penetrate a criminal's stronghold monitored by a lithium photomultiplier cell continually bathed in light from a laser. If the beam of light is broken an alarm sounds. The agents want to use a handheld laser to illuminate the cell while they pass in front of it. They have two lasers, a high-intensity red-ruby laser (694 nm) and a low-intensity violet GaN laser (405 nm), but disagree on which one would be better. Determine (a) which laser they should use and (b) the kinetic energy of the electrons emitted. The work function of lithium is 2.93 eV. (22pt)

(a) An electron can be driven out of a metal only if a photon possessing a minimum energy equal to that of the work function for that metal strikes it.
Here, to eject the electron from lithium we need

$$E_{work\ function} = (2.93\ \text{eV})\,(1.602\,18 \times 10^{-19}\ \text{J}\cdot\text{eV}^{-1}) = 4.69 \times 10^{-19}\ \text{J}.$$

2pt

For the red-ruby laser (694 nm):

$$E_{694} = hc\lambda^{-1}$$
$$= (6.626\,08 \times 10^{-34}\ \text{J}\cdot\text{s})\,(2.997\,92 \times 10^{8}\ \text{m}\cdot\text{s}^{-1})\,(694 \times 10^{-9}\ \text{m})^{-1}$$
$$= 2.86 \times 10^{-19}\ \text{J}.$$

2pt each line (6pt)

For the violet GaN laser (405 nm):

$$E_{405} = hc\lambda^{-1}$$
$$= (6.626\,08 \times 10^{-34}\ \text{J}\cdot\text{s})\,(2.997\,92 \times 10^{8}\ \text{m}\cdot\text{s}^{-1})\,(405 \times 10^{-9}\ \text{m})^{-1}$$
$$= 4.90 \times 10^{-19}\ \text{J}.$$

2pt each line (6pt)

The violet GaN laser will provide enough energy to eject the electron. 2pt

(b) The kinetic energy of the ejected electron can be determined by subtracting the work function from the energy supplied by the laser:

$$E_K = hc\lambda^{-1} - E_{work\ function}$$
$$= (4.90 \times 10^{-19}\ \text{J}) - (4.69 \times 10^{-19}\ \text{J})$$
$$= 2.10 \times 10^{-20}\ \text{J}.$$

2pt each line (6pt) -1pt units

(Concept questions)

Q7A. What ion with a +2 charge is predicted to have the following ground-state electron configuration? $[Ar]3d^{10}4s^24p^1$ (3pt)

As^{2+}

Q7B. In class we discussed in detail the relationship between the quantum numbers n, l, m_l, and m_s. For an electron in a p-orbital what values can m_l have? (3pt)

-1, 0, 1

Q7C. _____ Which specific subshell will accommodate an electron that has the following set of quantum numbers? (2pt)

$n = 3, l = 1, m_l = +1, m_s = +1/2$

A. 3p
B. 4*s*
C. 4*d*
D. This is not a possible combination of quantum numbers.

A

In class there have been many excellent student questions.
(Concept question)

Q8A. Which of the following experiments most directly supports de Broglie's hypothesis of the wave nature of matter? Answer _____D (2pt)

A. black-body radiation
B. the photoelectric effect
C. α-particle scattering by a metal foil
D. electron diffraction by a crystal
E. the emission spectrum of the hydrogen atom

(Concept question)

Q8B. State whether each of the following support the theory of light as a particle or a wave. (4pt)

After traveling through a double slit, constructive and destructive interference result in diffraction. Answer _____ wave

When light of sufficient energy strikes a metal surface an electron is ejected.
Answer _____ particle

Q8C. A baseball weighing 0.150 kg is thrown at 40.0 $m.s^{-1}$ $\pm$2.0 $m.s^{-1}$.
Calculate the minimum uncertainty in its position Δx. (5pt)

$\Delta p \cdot \Delta x \geq h/(4\pi)$ 1pt

$\Delta p = m\Delta v$ 1pt

$\Delta x \geq h/(4\pi\, \Delta p) = h/(4\pi\, m\, \Delta v) \geq 6.62608\times10^{-34} J\cdot s / (4\pi \times 0.150\ kg \times 4.0\ m.s^{-1})$ 1pt

$\Delta x \geq 8.8 \times 10^{-35}$ m 1pt

Minimum uncertainty in its position is 8.8×10^{-35} m (essentially zero). 1pt

Q8D. Calculate the velocity of an electron that has a wavelength of 2.00×10^{-10} m. (4pt)

$\lambda = h/p = h/(m\cdot v)$ 1pt

$v = h/(m_e\cdot\lambda) = 6.62608 \times 10^{-34} J\cdot s / (9.109 \times 10^{-31}\ kg \times 2.00 \times 10^{-10}\ m)$ 1pt

$v = 3.64 \times 10^{6}\ m.s^{-1}$ 2pt -1pt units -1pt sig fig