Lakehead
UNIVERSITY

DEPARTMENT OF CHEMISTRY
Exam
Chemistry 1110 (Modern Chemistry I)
xx December, xxxx

Name: _____

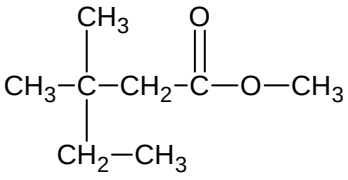
Student ID Number:_____

Instructions:

1. Not all questions are required (some have choices) - extra questions are not worth extra credit!
2. Part 1 (multiple choice) should be answered on this page (below). All other parts should be answered in the booklet provided unless otherwise stated in the question.
3. Allowed external materials: writing implements, calculator (any type), tables at end of exam
4. Print or write legibly!
4. The final 3 sheets of this exam paper are a periodic table, a formula sheet, and enthalpy tables. Feel free to remove them if desired.
5. There are 78 points on the exam. Time allowed = 180 minutes.
6. There are a total of xxx pages including this one.

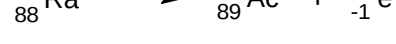
Part 1: Multiple Choice. Answer *all questions*. Worth 2 points each. There is no penalty for an incorrect answer. (22 points)

1. What is the correct IUPAC name for the following species:



a) **methyl 3,3-dimethylpentanoate**
b) methyl 3-dimethyl-1-pentanoate
c) methyl 3-methyl-3-ethylbutanoate
d) methyl 2-methyl-2-ethyl-4-butanoate

2. For the following nuclear reaction, the decay constant, *k*, is 2.75 x 10^{-4} s^{-1}. What is the half-life?

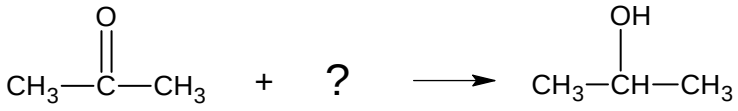


a) 2.75 x 10^{-4} s
b) 3.97 x 10^{-4} s
c) **2520 s**
d) 3640 s

3. Which of the following is *not* a component of DNA?

a) an amino acid
b) a deoxyribose sugar
c) an organic base with nitrogen-containing rings
d) a phosphate group

4. Give the missing reagent in the following conversion:



a) H_2O
b) $LiAlH_4$
c) MnO_4^-
d) an oxidising agent
e) heat

5. Which of the following is the ground state electron configuration for germanium, Ge, by the Aufbau and Pauli Exclusion principles?

a) [Ar] $3d^8\ 4s^2\ 4p^4$
b) [Ar] $3d^{10}\ 4s^2\ 4p^2$
c) [Ar] $3d^6\ 4s^2\ 4p^6$
d) [Kr] $3d^{10}\ 4p^4$

6. What is the oxidation state of vanadium in $H_2V_2O_5$?

a) -2
b) 0
c) 2
d) 4
e) 8

7. How much energy is required to change 10.0 g of liquid water at 100.°C to steam at 100.°C? The value of ΔH_{vap} for water is 40.7 kJ/mol

a) 0.0136 kJ

b) 0.246 kJ

c) 22.6 kJ

d) 40.7 kJ

e) 407 kJ

8. If 0.10 mol of H_2 effuses through a hole in a container in 4.6 s, how long will it take 0.10 mol of N_2 to effuse through the same hole?

a) 0.33 s

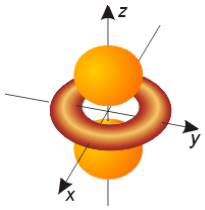
b) 1.2 s

c) 17 s

d) 64 s

e) 4.6 s

9. What is this orbital?



a) p_z

b) d_{z^2}

c) d_{xz}

d) 3*s*

10. What is the %C (by mass) in CO_2?

a) 27.30

b) 33.33

c) 42.86

d) 57.14

11. Polonium crystals have a simple cubic unit cell. If the edge length of a unit cell is 310. pm, what is the radius a polonium atom?

a) 77.5 pm

b) 110. pm

c) 134 pm

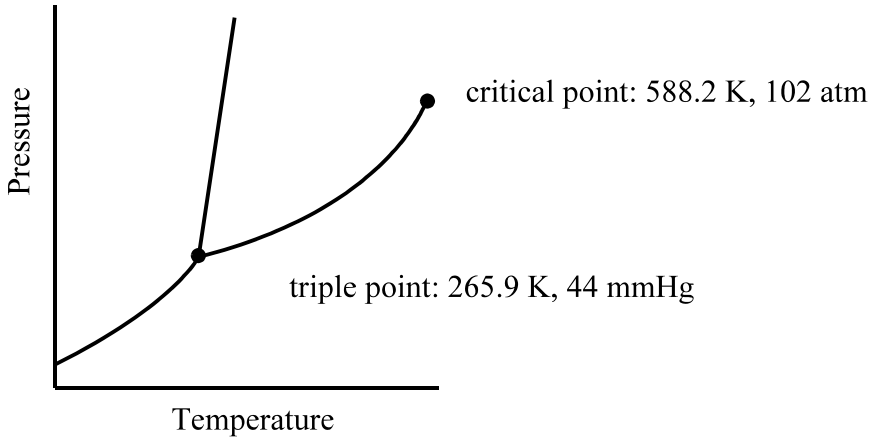
d) 155 pm

e) 310. pm

Part 2: Short Answer: Answer 4 of the following 6 (4 points each, 16 total).

1. The phase diagram for bromine is given:

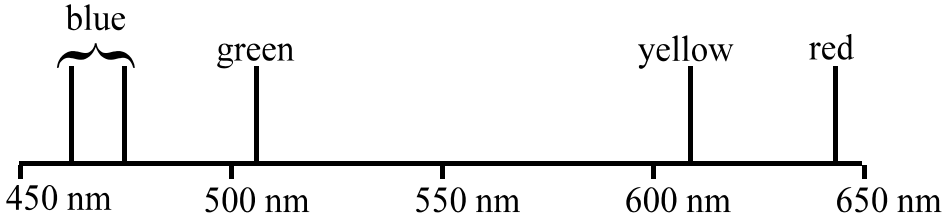
Explain the behaviour of bromine as you decrease the pressure (from 150 atm) at -200°C and at +200°C.



At 200˚C (473 K) and 150 atm, bromine is in the liquid state; as you decrease the pressure, it becomes a gas.

At -200˚C (73 K) and 150 atm, the material is a solid, that will sublime to a gas as the pressure is lowered.

2. The emission spectrum of cadmium is shown. Why are only certain, narrow lines seen in this spectrum with nothing in between?



Because atomic energy levels are quantised, only certain discreet energies are seen. The regions with no lines exist because there are no orbitals for the e- to enter when it relaxes from its excitation.

3. Explain why atomic radius decreases as you go left to right across the periodic table.

Outer shell electrons are shielded by inner shell electrons. Therefore, all electrons of the same period (row) will see the same number of core electrons (whatever the Noble Gas electron configuration is). However, as you move left to right across a period, the number of protons increases. Therefore, the effective nuclear charge is increasing (+ increases, - stays same), so electrons in outer shell see a larger nuclear charge (and are more attracted to it) as you go left to right across a period.

4. Using the Kinetic molecular theory, explain why pressure increases as volume decreases (at constant temperature).

At constant *T*, molecules have the same average KE, so are moving the same speed. *P* is defined as the number of collisions. If *V* increases, and *T* is constant, the molecules will hit the walls more often (going same speed, but a shorter distance to the wall). Therefore, *P* increases with decreasing *V*.

5. Define allotrope and give examples of the allotropes of at least 1 element.

Allotropes have the same chemical composition but different structure. Examples include the three allotropes of carbon (graphite, diamond, fullerene). Aother is O_2 and O_3 (ozone).

6. The density of iron is 7.87 g/cm^3 and the unit cell edge length of 286.6 pm. What type of unit cell does iron have?

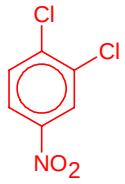
l = 286.6 pm = 2.866×10^{-10} m = 2.866×10^{-8} cm
$V = (2.866 \times 10^{-8}\ \text{cm})^3 = 2.35 \times 10^{-23}\ \text{cm}^3$
mass of a single unit cell = $(2.35 \times 10^{-23}\ \text{cm}^3) \times (7.87\ \text{g/cm}^3) = 1.853 \times 10^{-22}$ g/cell
mass of a single Fe atom = $(55.85\ \text{g/mol})/(6.022 \times 10^{23}\ \text{mol}^{-1}) = 9.274 \times 10^{-23}$ g/atom
atoms per cell = $(1.853 \times 10^{-22}\ \text{g/cell}) / (9.274 \times 10^{-23}\ \text{g/atom})$ = 2 atoms per cell

Therefore, the unit cell must be body-centred cubic, which is the only type of unit cell that has 2 atoms per unit cell.

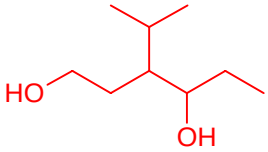
Part 3: Organic Chemistry. (12 points)

1. *Answer 3 of (a) to (d)* (2 points each):

a) Draw the structure for 1,2-dichloro-4-nitrobenzene.

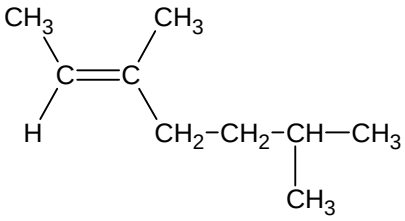


b) Draw the structure for 3-isopropyl-1,4-hexanediol.



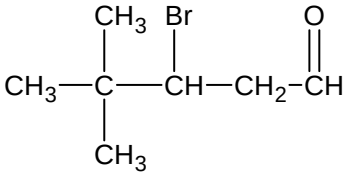
c) Name the following compound:

***trans*-3,6-dimethyl-2-heptene**

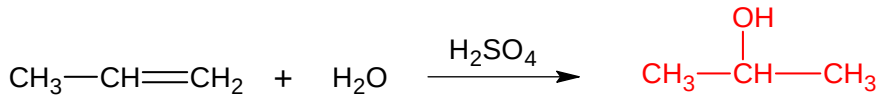


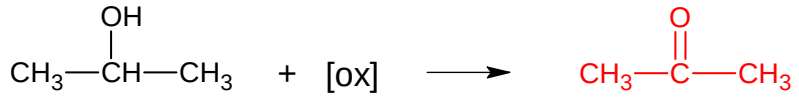
d) Name the following compound:

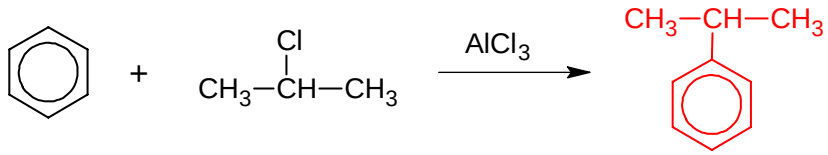
3-bromo-4,4-dimethylpentanal

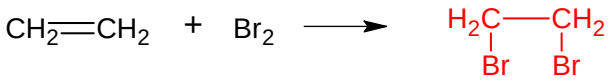


2. For 3 of the following reactions (a) to (d), give the organic product (the equation need not balance) (2 points each:

(a) 

(b) 

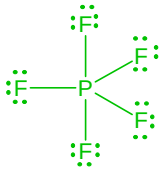
(c) 

(d) 

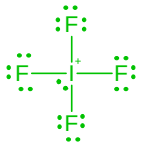
Part 4: Molecular Structures. (10 points)

1. For *2 of (a) to (c)*, give the Lewis structure and the three-dimensional geometry (linear, bent, trigonal planar, T-shaped, trigonal pyramidal, square planar, tetrahedral, see-saw, trigonal bipyramidal, square pyramidal, or octahedral). (3 points each)

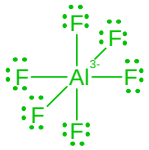
(a) PF_5
(b) IF_4^+
(c) AlF_6^{3-}



5 e^- pairs and 0 lone pairs
= trigonal bipyramidal shape



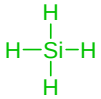
5 e^- pairs with 1 lone pair
= see saw shape



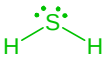
6 e^- pairs and 0 lone pairs
= octahedral shape

2. For *1 of (a) or (b)*, give the Lewis structure, the three-dimensional geometry, and whether or not the molecule has a dipole moment (do not need to indicate direction). (4 points)

(a) SiH_4
(b) H_2S



4 e^- pairs and 0 lone pairs
= tetrahedral
NO dipole moment



4 e^- pairs with 2 lone pairs
= bent
YES, has a dipole moment

Part 5: Inorganic/Nuclear. (6 points)

1. Answer *one of* (a) or (b) (2 points)

(a) ^{241}Am is used in smoke detectors and decays by α-emission. Write a balanced nuclear equation for this process.

$$^{241}_{95}Am \longrightarrow {}^{237}_{93}Np + {}^{4}_{2}He$$

(b) The decay constant for the decomposition of ^{212}Rn is 0.029 min^{-1}. How long will it take 90% of a sample to decay?

Remember that 90% decayed means 10% is left (out of originally 100%)

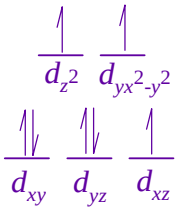
$\ln(N_t/N_0) = \ln(10/100) = -kt$

$t = -\ln(0.1)/0.029 = 79$ min

2. Answer *one of* (a) or (b) (4 points)

(a) $CoCl_6^{4-}$ is a high spin octahedral complex. Show the *d*-orbital splitting in an octahedral complex, and say how many unpaired electrons the complex has.

Cl^- is -1, therefore Co must be 2+ to give an overall charge of -4. Co is in Group 9 (with 9 valence e^-), therefore there are 7 electrons left, or Co^{2+} is a d^7 ion. Further, Cl- is a weak field ligand (therefore will half-fill orbitals before pairing).



(b) Element 109, Meitnerium, is made in the following way

$$^{209}_{83}Bi + ^{58}_{26}Fe \longrightarrow ^{266}_{109}Mt + ^{1}_{0}n$$

Calculate the mass change for this reaction, then calculate the energy change, in kJ/mol. Atomic masses (in amu or g/mol) are: ^{209}Bi, 208.98037; ^{58}Fe, 57.933277; ^{266}Mt, 266.13764.

Δm = 266.13764 + 1.009665 - (208.98037 + 57.933277) = 0.232658 g/mol
= 2.32658 x 10^{-4} kg/mol

$E = \Delta mc^2$ = (2.32658 x 10^{-4} kg/mol)(2.998 x 10^8 m/s)^2 = 2.09 x 10^{13} J/mol
= 2.09 x 10^{10} kJ/mol

Part 6: Biochemistry. Answer *3 of the following 4* (4 points each). (12 points)

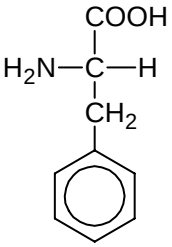
1. Explain the minimum requirements for DNA replication (*i.e.* how DNA makes copies of itself).

DNA needs a replication enzyme, access to the parts of the DNA molecule (deoxyribose sugars, the bases, and phosphate). If all that is available, then the double strand of DNA unravels from one end and each of the now separated strands becomes half of a new double helix. The new strands are complimentary to the old strands, so that the new "strand 2" attached to the old "strand 1" is the same as the "old strand 2" that is separating off.

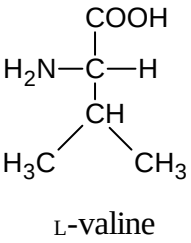
2. Explain the difference between primary, secondary, and tertiary structure in a protein.

Primary structure is the simple order of amino acids. Secondary structure refers to areas of α-helices and β-sheets (pleated sheets). They are held together by hydrogen bonds, usually. The tertiary structure is how all these parts (α-helices, β-sheets, and areas with no secondary structure) twist around to form the overall structure of the protein. Tertiary structure is controlled by all types of intermolecular interaction, including hydrogen bonding between those side chains that can H-bond; similarly, hydrophobic side chains tend to cluster in the centre of the protein (to escape the water surrounding the protein in solution).

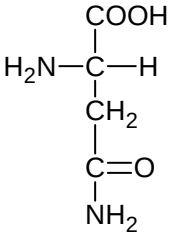
3. The structures of 4 amino acids are shown:



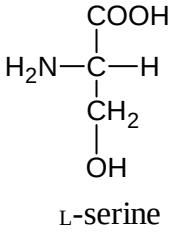
L-phenylalanine



L-valine



L-asparagine



L-serine

(a) Label each as having a hydrophobic or a hydrophilic side chain.

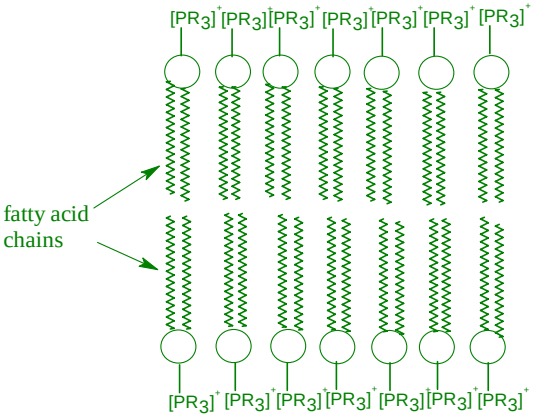
hydrophobic hydrophobic hydrophilic hydrophilic

(b) Which side chains are likely to be in the interior of the protein? Which on the outside? Explain briefly.

As mentioned above (in 2, above), hydrophobic side chains tend to be on the interior to escape from the water that is the solvent in organisms. These interact by London forces with each other. By contrast, the hydrophilic side chains have lots of hydrogen bonding opportunities, and can H-bond with each other or with the water that surrounds the protein. Therefore, they are on the outside of the protein.

4. Describe the structure of a phospholipid and how/why a bilayer membrane is formed using this molecule.

A phospholipid has three ester linkages to a glycerine group - two are fatty acids and one is a polar phosphate-based unit (as opposed to a triglyceride, which has three fatty acids attached). The non-polar fatty acid chains want to be away from water, whereas the phophate part is hydrophilic. Therefore, the phospholipid will tend to form a bilayer with the domains of the fatty acids pointing towards each other (and away from the water of the fluid in which the bilayer is formed) and the phosphate pieces on the outside (in contact with the water), *i.e.*:



Appendix 1: Formula Sheet

$\Delta H = q_p = \Delta E + P\Delta V$ $q = sm\Delta T = C_p \Delta T$ $\Delta U = q + w$	$\ln \frac{N_t}{N_0} = -kt$ $t_{\frac{1}{2}} = \frac{\ln 2}{k}$ $E = mc^2$ $c = \lambda\nu \ (= \lambda f)$
$PV = nRT$ $P_{total} = P_1 + P_2 + ...$ $\left(P + \frac{n^2 a}{V^2}\right) \cdot (V - nb) = nRT$ $\bar{u} = \sqrt{\frac{3RT}{M_m}}$ $\frac{\text{rate}_A}{\text{rate}_B} = \frac{\bar{u}_A}{\bar{u}_B} = \frac{\sqrt{M_{mB}}}{\sqrt{M_{mA}}}$	$E = h\nu \ (= hf)$ $\overline{E}_k = \frac{1}{2} m\bar{u}^2$ $\Delta E = -2.178 \times 10^{-18} \text{J} \left(\frac{1}{n^2_{final}} - \frac{1}{n^2_{initial}}\right)$ $\lambda = \frac{h}{mv}$

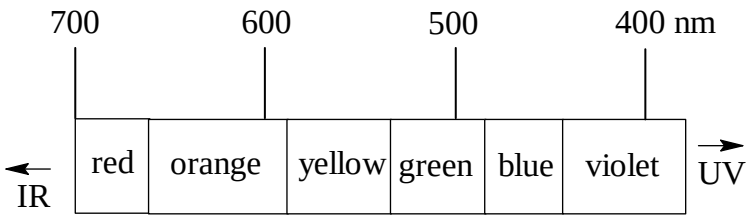
Constants:

h = 6.626 x 10^{-34} J s
c = 2.9979 x 10^8 m/s
joules = kg m^2 s^{-2}
0°C = 273.15 K
N_A = 6.022 x 10^{23} mol^{-1}

1 atm = 101.325 kPa = 760.00 Torr
mass of an electron: 0.000549 amu (g/mol)
mass of a proton: 1.00728 amu
mass of a neutron: 1.008665 amu
elementary charge (e) = 1.60218 x 10^{-19} C

R = 8.314 J mol^{-1} K^{-1} = 8.314 L Pa mol^{-1} K^{-1} = 0.08206 L atm mol^{-1} K^{-1}
STP = 1 atm, 0°C
standard conditions = 1 atm, 25°C, 1 M

kilo = 10^3 centi = 10^{-2} milli = 10^{-3} micro = 10^{-6} nano = 10^{-9} pico = 10^{-12}



For water: ΔH_{fusion} = 6.02 kJ/mol $\Delta H_{vaporization}$ = 40.7 kJ/mol
specific heat capacities (J/°C•g): s_{ice} = 2.03 s_{liquid} = 4.18

Attached at this point were:

Appendix 2: Some Thermodynamic Data ($\Delta H°$ values, bond enthalpies, etc.)

Appendix 3: Periodic Table