

Name: \_\_\_\_\_ Student Number: \_\_\_\_\_

**CARLETON UNIVERSITY****DURATION:** 3 **HOURS** No. of Students: 766

Department Name &amp; Course Number: CHEM 1001 A and T

**Instructor** Bob Burk

AUTHORIZED MEMORANDA: Calculator

Students **MUST** count the number of pages in this examination question paper before beginning to write, and report any discrepancy immediately to a proctor. This question paper has 13 pages. This examination paper **MAY NOT** be taken from this examination room.

**A Periodic Table and list of constants appears on page 13.**

**You may tear off page 13 if you wish.**

**Part A. Answer all twelve questions with a few sentences or equations (5 marks each).**

1. Why is the  $a$  term in the van der Waals equation larger for  $\text{NH}_3(\text{g})$  than for  $\text{CH}_4(\text{g})$ ?

$\text{NH}_3$  is a polar molecule and experiences hydrogen bonding forces.  $\text{CH}_4$  is not polar and experiences relatively weak dispersion forces. The  $a$  term is a measure of the strength of the intermolecular forces and so is larger for  $\text{NH}_3$ .

2. For water, the enthalpy of melting is  $6.0 \text{ kJ mol}^{-1}$  and the enthalpy of sublimation is  $50.0 \text{ kJ mol}^{-1}$ . Calculate the enthalpy of vapourization (in  $\text{kJ mol}^{-1}$ ).

$$\Delta H_{\text{sub}}^{\circ} = \Delta H_{\text{melt}}^{\circ} + \Delta H_{\text{vap}}^{\circ}$$

$$\text{thus } \Delta H_{\text{vap}}^{\circ} = \Delta H_{\text{sub}}^{\circ} - \Delta H_{\text{melt}}^{\circ}$$

$$= 50.0 - 6.0 = 44.0 \text{ kJ mol}^{-1}$$

3. Explain why the energies of photons from an atomic light source are quantized.

Energy levels of electrons in atoms are quantized, thus so are the differences in these energy levels. A photon is emitted when an electron drops from one quantized energy level to another. The energy of the photon is the same as this energy difference and so is also quantized.

4. Explain why electronegativity increases going up a group in the periodic table.

Going up a group, the atom becomes smaller. Electrons are therefore able to get closer to the nucleus, hence a greater force of attraction, hence a greater electronegativity.

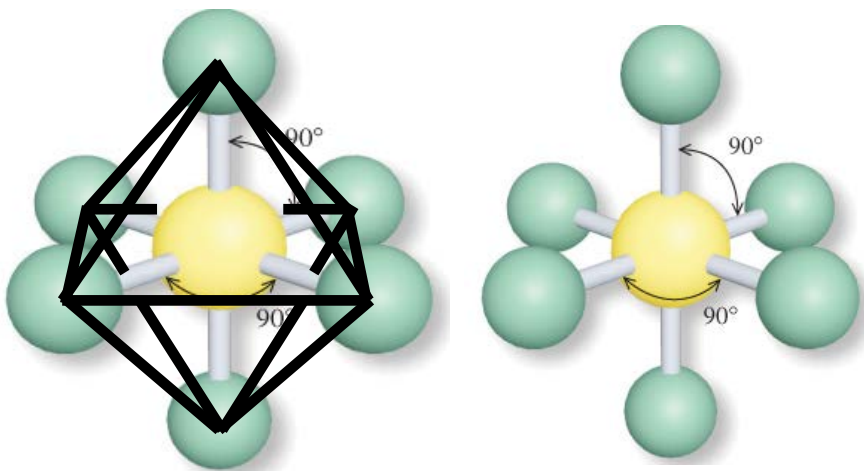
5. How many electrons (in total) can the  $\pi_{2p}^*$  molecular orbitals in a molecule hold?

A	
B1	
B2	
C1	
C2	
C3	
C4	
C5	
C6	
<b>Total</b>	

$\pi_{2p}^*$  orbitals are made by overlapping 2p orbitals from each atom. There are two such interactions (in the y and z axes), giving a total of two  $\pi_{2p}^*$  orbitals, each of which holds two electrons. Thus four electrons in total.

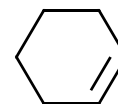
6. The structure shown below has only six terminal atoms. Why is its shape called an octahedron?

If we join the axial atoms to each of the equatorial ones as shown, the three-dimensional shape that results has eight sides, i.e. is an octahedron.

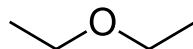


7. Shown below is a molecule of cyclohexene. For carbon number 1 (yes, I know it is not labelled), state:

The number of lone pairs	0
The steric number	3 (remember the implicit H atom)
The hybridization	$sp^2$
The bond angle	$120^\circ$
The VSEPR shape	trigonal planar



8. A molecule of diethyl ether is shown below. What is the strongest type of intermolecular force between two such molecules? Why?

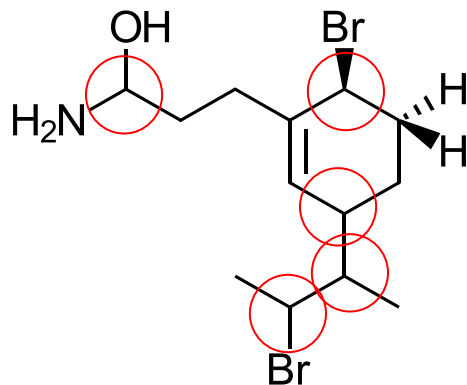


These molecules are polar, but cannot H-bond because the H atoms are not bound to the O atoms. Thus dipole-dipole are the strongest intermolecular forces.

9. Name the five functional groups that contain the carbonyl group (C=O).

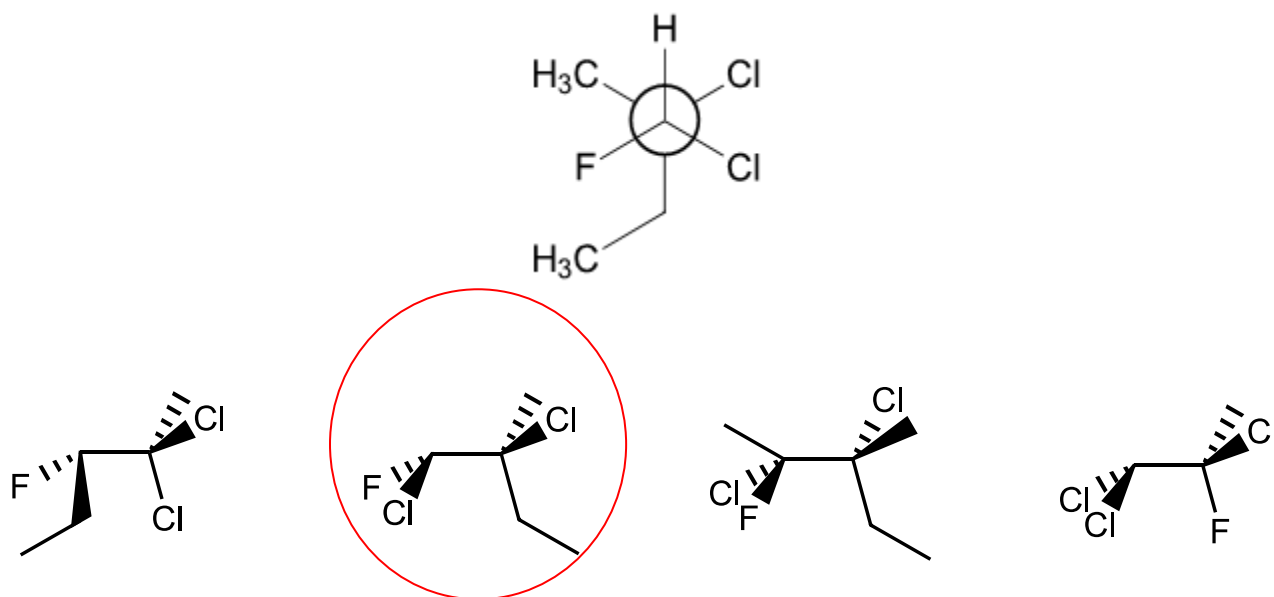
Aldehyde, ketone, carboxylic acid, ester, amide

10. Circle each chirality centre in the molecule shown below:



(1 mark for each correct chirality centre, -1 mark for each one circled that is not chiral)

11. Circle the molecule below that is correctly represented (as viewed from the left side) by the following Newman projection:



12. Which of 0.5 m NaCl<sub>(aq)</sub> or 0.25 m Na<sub>2</sub>SO<sub>4(aq)</sub> has the lower vapour pressure and why?

These salts ionize in water. The total concentration of ions in 0.25 m Na<sub>2</sub>SO<sub>4(aq)</sub> is 0.75 m (0.50 m Na<sup>+</sup><sub>(aq)</sub> and 0.25 m SO<sub>4</sub><sup>2-</sup><sub>(aq)</sub>) and that in 0.5 m NaCl<sub>(aq)</sub> is 1.0 m (0.5 m Na<sup>+</sup><sub>(aq)</sub> and 0.5 m Cl<sup>-</sup><sub>(aq)</sub>). Thus 1.0 m NaCl will have the lower vapour pressure.

**Part B. Answer both questions B1 and B2 (20 marks each).**

- B1.** (a) [6 marks] A solution is made by adding 3.0 mol  $\text{Na}_2\text{SO}_{4(s)}$  to 2 kg  $\text{H}_2\text{O}_{(l)}$ . What is the vapour pressure of this solution at  $30^\circ\text{C}$ ? The vapour pressure of pure water at  $30^\circ\text{C}$  is 31.82 mm Hg.

$3.0 \text{ mol Na}_2\text{SO}_4 \rightarrow 6.0 \text{ mol Na}^+ + 3.0 \text{ mol SO}_4^{2-}$ , or 9.0 moles of solute all together.

$2 \text{ kg H}_2\text{O} = 2,000 \text{ g} = 2000 \text{ g} / 18 \text{ g mol}^{-1} = 111.1 \text{ mol H}_2\text{O}$

Thus,  $X_{\text{H}_2\text{O}} = 111.1 / (111.1 + 9.0) = 0.925$

$$\begin{aligned} p_{\text{H}_2\text{O}} &= p^\circ_{\text{H}_2\text{O}} X_{\text{H}_2\text{O}} \\ &= 31.82 \text{ mm Hg} (0.925) \\ &= 29.44 \text{ mm Hg} \end{aligned}$$

- (b) [6 marks] A solution is made by adding 0.12 mole of iron chloride to 500 g water. The freezing point of this solution is  $-1.79^\circ\text{C}$ . Is the iron chloride  $\text{FeCl}_2$  or  $\text{FeCl}_3$ ? ( $K_f$  for water is  $1.86^\circ\text{C kg mol}^{-1}$ )

$$\Delta T_f = iK_f m$$

$$\text{Thus, } i = \frac{\Delta T_f}{K_f m} = \frac{1.79^\circ\text{C}}{1.86^\circ\text{C kg mol}^{-1} \left( \frac{0.12 \text{ mol}}{0.500 \text{ kg}} \right)} = 4$$

The salt must therefore be  $\text{FeCl}_3$ .

- (c) [3 marks] Calculate the freezing point ( $^\circ\text{C}$ ) of 0.106 m  $\text{Na}_2\text{SO}_{4(aq)}$ .  $K_f = 1.86^\circ\text{C kg mol}^{-1}$  for water.

$$\Delta T_f = iK_f b = (3)(1.86^\circ\text{C kg mol}^{-1})(0.106 \text{ mol kg}^{-1}) = 0.591^\circ\text{C}$$

$$T_f = 0.00 - 0.591 = -0.591^\circ\text{C}$$

- (d) [5 marks] A 0.15 g sample of a protein is dissolved in water to make 2.0 mL of solution. The osmotic pressure of this solution is 0.0295 bar  $25^\circ\text{C}$ . Calculate the molecular weight of the protein ( $\text{g mol}^{-1}$ ).

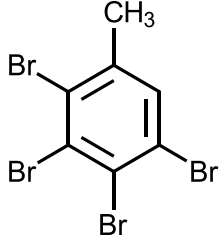
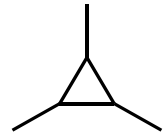
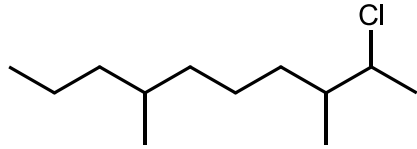
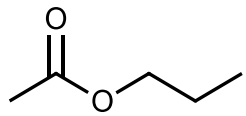
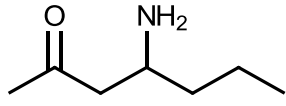
$$\Pi = MRT = 0.0295 \text{ bar}$$

$$\begin{aligned} \text{Thus,} \\ M &= \Pi / (RT) \\ &= 0.0295 \text{ bar} / (0.08314 \text{ L bar K}^{-1} \text{ mol}^{-1} \times (273.15 + 25.0) \text{ K}) \\ &= 0.00119 \text{ mol L}^{-1} \end{aligned}$$

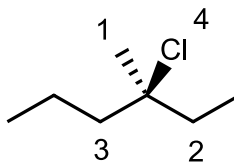
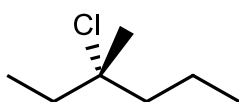
In this 2.0 mL solution there would be  $0.00119 \text{ mol L}^{-1} \times 0.002 \text{ L} = 2.38 \times 10^{-6} \text{ mol}$  of protein. The molecular weight is therefore  $0.15 \text{ g} / (2.38 \times 10^{-6} \text{ mol}) = 6.30 \times 10^4 \text{ g mol}^{-1}$ .

(Could also do it via  $M = \frac{mRT}{\Pi V}$  where m is the mass of protein (0.15 g) and V is the solution volume (0.002 L).)

B2. (a) [10 marks] Name the following compounds

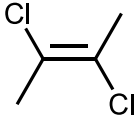
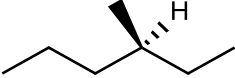
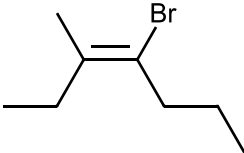
	<p>2,3,4,5-tetrabromo-1-methylbenzene or 2,3,4,5-tetrabromotoluene (NOT 3,4,5,6-...)</p>
	<p>1,2,3-trimethylcyclopropane</p>
	<p>2-chloro-3,7-dimethyldecane (NOT 9-chloro-4,8-dimethyldecane)</p>
	<p>propyl acetate or propyl ethanoate</p>
	<p>4-amino-2-heptanone or methyl-2-aminopentyl ketone</p>

(b) [4 marks] For the 3-Chloro-3-methylhexane molecule shown below, rotate (if necessary) and redraw the molecule, indicate the priorities of the four groups on the chiral carbon, and state whether the molecule is *R*- or *S*.



Reading from highest priority to lowest (4-3-2) is counterclockwise, so this is (*S*)-3-Chloro-3-methylhexane

- B2.** (c) [6 marks] Name the following compounds, including any necessary stereochemical descriptors such as *cis/trans*, *E/Z*, or *R/S*:

	<i>trans</i> -dichloro-2-butene or <i>trans</i> -dichloro-but-2-ene
	<i>S</i> -3-methylhexane
	<i>E</i> -4-bromo-3-methyl-3-heptene

**Part C. Answer any four of the six questions C1 – C6. If you answer more than four, the best four will be used to calculate your mark (20 marks each).**

**C1.** (a) [10 marks] The density of a metal is found to be  $19.32 \text{ g cm}^{-3}$ . X-ray diffraction shows that the unit cell is face centred cubic with an edge length of  $4.08 \times 10^{-8} \text{ cm}$ . Determine which metal this is.

$$V_{\text{unit cell}} = (4.08 \times 10^{-8} \text{ cm})^3 = 6.79 \times 10^{-23} \text{ cm}^3$$

$$m = \rho V = 19.32 \text{ g cm}^{-3} (6.79 \times 10^{-23} \text{ cm}^3) = 1.31 \times 10^{-21} \text{ g}$$

Face centred cubic structures contain four atoms per unit cell, so the mass of one atom is

$$\frac{1.31 \times 10^{-21} \text{ g}}{4} = 3.28 \times 10^{-22} \text{ g}$$

And the mass of one mole of atoms is therefore  $3.28 \times 10^{-22} \text{ g} (6.02 \times 10^{23} \text{ mol}^{-1}) = 197 \text{ g mol}^{-1}$

Gold (Au) has this atomic weight.

(b) [10 marks] Photons emitted by a hydrogen lamp in the Lyman series ( $m = 1$ ) have a wavelength of 97.20 nm. From which level did these electrons fall?

$$\frac{1}{\lambda} = R \left[ \frac{1}{m^2} - \frac{1}{n^2} \right]$$

$$\frac{1}{R\lambda} = \frac{1}{m^2} - \frac{1}{n^2}$$

$$\frac{1}{n^2} = \frac{1}{m^2} - \frac{1}{R\lambda}$$

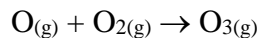
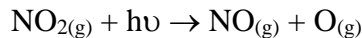
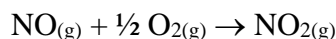
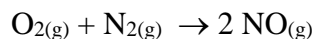
$$n^2 = \frac{1}{\frac{1}{m^2} - \frac{1}{R\lambda}}$$

$$n = \left( \frac{1}{\frac{1}{m^2} - \frac{1}{R\lambda}} \right)^{1/2}$$

$$= \left( \frac{1}{\frac{1}{1^2} - \frac{1}{0.01097 \text{ nm}^{-1} (97.20 \text{ nm})}} \right)^{1/2}$$

$$= 4$$

**C2.** (a) [8 marks] Beginning with  $O_2$  and  $N_2$  in the cylinder of a car engine, show four reactions that lead to the production of ozone in a smoggy city.



(b) [4 marks] A sample of an ideal gas exerts a pressure of 15.5 bar in 20.0 L at 100°C. The sample is compressed and heated to 34.0 bar and 200°C. Calculate its final volume (L).

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$

$$V_2 = \frac{p_1 V_1 T_2}{T_1 p_2} = \frac{15.5 \text{ bar}(20.0 \text{ L}) (200 + 273)\text{K}}{(100 + 273)\text{K} \cdot 34.0 \text{ bar}} = 11.6 \text{ L}$$

(c) [2 marks] A sample of 50.0 g  $F_{2(g)}$  is contained in 0.5 L at 100°C.

(i) [2 marks] Calculate the ideal pressure (bar).

$$p = \frac{nRT}{V} = \frac{1.32 \text{ mol}(0.08314 \text{ L bar K}^{-1}\text{mol}^{-1})(100 + 273)\text{K}}{0.50 \text{ L}} = 81.8 \text{ bar}$$

(ii) [6 marks] Calculate the actual pressure (bar). For  $F_{2(g)}$ ,  $a = 1.17 \text{ bar L}^2\text{mol}^{-2}$  and  $b = 0.0290 \text{ L mol}^{-1}$ .

$$n = \frac{50.0 \text{ g}}{2(19.00) \text{ g mol}^{-1}} = 1.32 \text{ mol}$$

$$p = \frac{nRT}{V - nb} - a \left( \frac{n}{V} \right)^2$$

$$= \frac{1.32 \text{ mol}(0.08314 \frac{\text{L bar}}{\text{mol K}})(100 + 273)\text{K}}{0.50 \text{ L} - 1.32 \text{ mol}(0.0290 \text{ L mol}^{-1})} - 1.17 \text{ bar L}^2\text{mol}^{-2} \left( \frac{1.32 \text{ mol}}{0.50 \text{ L}} \right)^2$$

$$= 88.7 \text{ bar} - 8.2 \text{ bar}$$

$$= 80.5 \text{ bar}$$

**C3.** The enthalpy of combustion for octane is  $-5471 \text{ kJ mol}^{-1}$ . The reaction is  $\text{C}_8\text{H}_{18(l)} + 12.5 \text{ O}_{2(g)} \rightarrow 8 \text{ CO}_{2(g)} + 9 \text{ H}_2\text{O}_{(g)}$ . For  $\text{CO}_{2(g)}$  and  $\text{H}_2\text{O}_{(g)}$ , the standard enthalpies of formation are  $-393.5$  and  $-241.8 \text{ kJ mol}^{-1}$  respectively.

(a) [10 marks] Calculate the standard enthalpy of formation of octane ( $\text{kJ mol}^{-1}$ ).

$$\begin{aligned}\Delta H_{\text{comb}}^{\circ} &= 8\Delta H_{\text{f}}^{\circ}(\text{CO}_{2(g)}) + 9\Delta H_{\text{f}}^{\circ}(\text{H}_2\text{O}_{(g)}) - \Delta H_{\text{f}}^{\circ}(\text{C}_8\text{H}_{18(l)}) - 12.5\Delta H_{\text{f}}^{\circ}(\text{O}_{2(g)}) \\ \Delta H_{\text{f}}^{\circ}(\text{C}_8\text{H}_{18(l)}) &= 8\Delta H_{\text{f}}^{\circ}(\text{CO}_{2(g)}) + 9\Delta H_{\text{f}}^{\circ}(\text{H}_2\text{O}_{(g)}) - 12.5\Delta H_{\text{f}}^{\circ}(\text{O}_{2(g)}) - \Delta H_{\text{comb}}^{\circ} \\ &= 8(-393.5) + 9(-241.8) - 12.5(0) - (-5471) \\ &= 146.8 \text{ kJ mol}^{-1}\end{aligned}$$

(b) [5 marks] Calculate the work done ( $\text{kJ mol}^{-1}$ ) when one mole of octane is burned in oxygen at  $300^{\circ}\text{C}$ .

For this reaction,  $\Delta n = 17 - 12.5 = 4.5$  (note that the octane is a liquid).

$$\begin{aligned}w &= -p\Delta V \\ &= -RT\Delta n \\ &= -8.314 \text{ J K}^{-1} \text{ mol}^{-1} (300 + 273) \text{ K} (4.5) \\ &= -2.14 \times 10^4 \text{ J mol}^{-1} \\ &= -21.4 \text{ kJ mol}^{-1}\end{aligned}$$

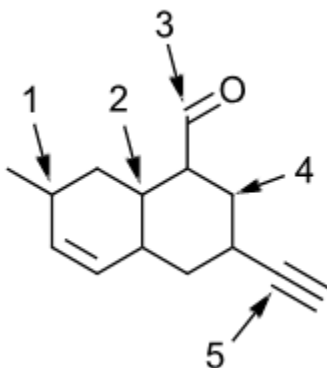
(c) [2 marks] Explain why the work is negative.

This reaction must do work because there is an increase in the number of moles of gas. The system therefore loses a little energy in the form of work, and by convention this makes the work negative.

(d) [3 marks] Calculate  $\Delta E^{\circ}$  for this reaction ( $\text{kJ mol}^{-1}$ ) at  $300^{\circ}\text{C}$ .

$$\begin{aligned}\Delta E^{\circ} &= \Delta H^{\circ} - RT\Delta n \\ &= -5471 - 21.4 \text{ kJ mol}^{-1} \\ &= -5492 \text{ kJ mol}^{-1}\end{aligned}$$

C4. (a) [10 marks] Fill in the table below for each of the five indicated atoms in the molecule shown.



Atom	Steric Number	Hybridization	VSEPR Shape	Chiral? (yes or no)
1	4	sp <sup>3</sup>	Tetrahedral	Yes
2	4	sp <sup>3</sup>	Tetrahedral	Yes
3	3	sp <sup>2</sup>	trigonal planar	No
4	4	sp <sup>3</sup>	Tetrahedral	No
5	2	sp	Linear	No

(b) [4 marks] It takes 100.0 J of heat to raise the temperature of 52.5 g of lead (Pb<sub>(s)</sub>) from 28.0 to 47.6°C. Calculate the heat capacity of lead in  $\text{J mol}^{-1} \text{ } ^\circ\text{C}^{-1}$ .

$$q = mC\Delta T$$

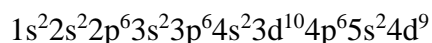
$$C = \frac{q}{m\Delta T}$$

$$= \frac{100.0 \text{ J}}{52.5 \text{ g}(47.6 - 28.0) ^\circ\text{C}}$$

$$= 0.0972 \text{ J g}^{-1} \text{ } ^\circ\text{C}^{-1}$$

$$\times 207.2 \text{ g mol}^{-1} = 20.1 \text{ J mol}^{-1} \text{ } ^\circ\text{C}^{-1}$$

(c) [3 marks] Use AUFBAU to predict the ground state electronic configuration for silver (Ag). Write the entire configuration, beginning at 1s<sup>2</sup>...



(d) [3 marks] The actual electronic configuration for silver is not what is predicted by AUFBAU. What do you think it might actually be, and why? (You may use the shorthand version of the configuration if you wish.)

It is in fact  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1 4d^{10}$ . The additional stability of the half-filled 5s subshell and filled 4d subshell makes this more energetically favourable.

C5. (a) [8 marks] Use VSEPR to predict the shapes of the following two species. Wrong name = zero marks.



Electrons =  $6 + 4(7) = 34$ . Connecting the Cl atoms to the S atom using single bonds uses 8 of these. Completing the octets around the Cl atoms uses another 24, for a total of 32. The two extra electrons go on the S atom as a lone pair. The molecule is therefore of the form  $\text{AX}_4\text{E}$ , which has the shape of a **SEESAW**.



Electrons =  $6 + 6(7) = 48$ . Connecting the Cl atoms to the Se atom using single bonds uses 12 of these. Completing the octets around the Cl atoms uses another 36, for a total of 48. The molecule is therefore of the form  $\text{AX}_6$ , which has the shape **OCTAHEDRAL**.

(b) [4 marks] Calculate the root mean square speed (in  $\text{m s}^{-1}$ ) of nitrogen ( $\text{N}_2$ ) molecules at  $100^\circ\text{C}$ .

$$v = \left( \frac{3RT}{M} \right)^{1/2} = \left( \frac{3(8.314 \text{ J K}^{-1} \text{ mol}^{-1})(100 + 273)\text{K}}{0.028 \text{ kg mol}^{-1}} \right)^{1/2} = 576 \text{ m s}^{-1}$$

(c) [4 marks] Calculate the average kinetic energy (in  $\text{kJ mol}^{-1}$ ) of  $\text{H}_{2(\text{g})}$  at  $25^\circ\text{C}$ .

$$\overline{\text{KE}} = \frac{3}{2}RT \quad (\text{for any gas!})$$

$$\begin{aligned} \overline{\text{KE}} &= \frac{3}{2}(8.314 \text{ J K}^{-1} \text{ mol}^{-1})(25 + 273)\text{K} \\ &= 1240 \text{ J mol}^{-1} \\ &= 1.24 \text{ kJ mol}^{-1} \end{aligned}$$

(d) [4 marks] Calculate the rate of effusion of methanol ( $\text{CH}_3\text{OH}$ ) relative to that of ethanol ( $\text{C}_2\text{H}_5\text{OH}$ ).

$$\frac{\text{rate}_{\text{CH}_3\text{OH}}}{\text{rate}_{\text{C}_2\text{H}_5\text{OH}}} = \sqrt{\frac{M_{\text{C}_2\text{H}_5\text{OH}}}{M_{\text{CH}_3\text{OH}}}} = \sqrt{\frac{46.1 \text{ g mol}^{-1}}{32.0 \text{ g mol}^{-1}}} = 1.199$$

Could also be inverted in which case the ratio is:

$$\frac{\text{rate}_{\text{C}_2\text{H}_5\text{OH}}}{\text{rate}_{\text{CH}_3\text{OH}}} = \sqrt{\frac{M_{\text{CH}_3\text{OH}}}{M_{\text{C}_2\text{H}_5\text{OH}}}} = \sqrt{\frac{32.0 \text{ g mol}^{-1}}{46.1 \text{ g mol}^{-1}}} = 0.833$$

**C6.** Aqueous ammonia ( $\text{NH}_3(\text{aq})$ ) at a concentration of 6.69 M has a density of  $0.9501 \text{ g mL}^{-1}$ .

(a) [10 marks] Calculate the mole fractions of water and of ammonia in this solution.

$$6.69 \text{ M} = 6.69 \text{ mol/L}$$

In 1 L of solution, there are  $6.69 \text{ mol NH}_3 \times 17 \text{ g/mol} = 113.7 \text{ g NH}_3$

$$1 \text{ L solution} = 1000 \text{ mL} = 1000 \text{ mL} \times 0.9501 \text{ g/mL} = 950.1 \text{ g}$$

The mass of water in this solution is  $950.1 \text{ g} - 113.7 \text{ g} = 836.4 \text{ g H}_2\text{O}$

$$n_{\text{NH}_3} = 6.69$$

$$n_{\text{H}_2\text{O}} = \frac{836.4 \text{ g}}{18.0 \text{ g mol}^{-1}} = 46.5 \text{ mol}$$

$$X_{\text{NH}_3} = \frac{n_{\text{NH}_3}}{n_{\text{NH}_3} + n_{\text{H}_2\text{O}}} = \frac{6.69 \text{ mol}}{6.69 + 46.5 \text{ mol}} = 0.126$$

$$X_{\text{H}_2\text{O}} = 1 - X_{\text{NH}_3} = 1 - 0.126 = 0.874$$

(b) [4 marks] Calculate the molality of ammonia in this solution.

$$m_{\text{NH}_3} = 6.69 \text{ mol} / 0.8364 \text{ kg} = 8.00 \text{ m}$$

(c) [6 marks] Calculate the vapour pressure (in bar) above this solution at  $25^\circ\text{C}$ . The vapour pressures of pure water and ammonia at this temperature are 0.0317 bar and 10.0 bar respectively.

$$\begin{aligned} p_{\text{tot}} &= X_{\text{H}_2\text{O}}p_{\text{H}_2\text{O}}^\circ + X_{\text{NH}_3}p_{\text{NH}_3}^\circ \\ &= 0.874(0.0317 \text{ bar}) + 0.126(10.0 \text{ bar}) \\ &= 1.29 \text{ bar} \end{aligned}$$

**Data and Constants**

$$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1} = 0.08314 \text{ L bar K}^{-1} \text{ mol}^{-1}$$

$$N_{\text{Av}} = 6.02 \times 10^{23} \text{ mol}^{-1}$$

$$1 \text{ amu} = 1.66054 \times 10^{-27} \text{ kg}$$

$$1 \text{ atm} = 760 \text{ Torr} = 760 \text{ mm Hg} = 1.01325 \text{ bar}$$

$$1 \text{ bar} = 10^5 \text{ Pa}$$

$$1 \text{ Pa m}^3 = 1 \text{ J}$$

$$0^\circ\text{C} = 273.15 \text{ K}$$

$$\text{Density of water at } 25^\circ\text{C} = 997 \text{ g L}^{-1}$$

$$R = 0.01097 \text{ nm}^{-1}$$

$$c = 3.00 \times 10^8 \text{ m s}^{-1}$$

$$h = 6.63 \times 10^{-34} \text{ J s}$$

$$\text{electron mass} = 9.11 \times 10^{-31} \text{ kg}$$

<b>IA</b> <b>(1)</b>																		<b>VIIIA</b> <b>(18)</b>
1 <b>H</b> 1.008	<b>IIA</b> <b>(2)</b>											<b>IIIA</b> <b>(13)</b>	<b>IVA</b> <b>(14)</b>	<b>VA</b> <b>(15)</b>	<b>VIA</b> <b>(16)</b>	<b>VIIA</b> <b>(17)</b>	2 <b>He</b> 4.003	
3 <b>Li</b> 6.941	4 <b>Be</b> 9.012											5 <b>B</b> 10.81	6 <b>C</b> 12.01	7 <b>N</b> 14.01	8 <b>O</b> 16.00	9 <b>F</b> 19.00	10 <b>Ne</b> 20.18	
11 <b>Na</b> 22.99	12 <b>Mg</b> 24.31											13 <b>Al</b> 26.98	14 <b>Si</b> 28.09	15 <b>P</b> 30.97	16 <b>S</b> 32.06	17 <b>Cl</b> 35.45	18 <b>Ar</b> 39.95	
19 <b>K</b> 39.10	20 <b>Ca</b> 40.08	21 <b>Sc</b> 44.96	22 <b>Ti</b> 47.90	23 <b>V</b> 50.94	24 <b>Cr</b> 52.00	25 <b>Mn</b> 54.94	26 <b>Fe</b> 55.85	27 <b>Co</b> 58.93	28 <b>Ni</b> 58.70	29 <b>Cu</b> 63.55	30 <b>Zn</b> 65.39	31 <b>Ga</b> 69.72	32 <b>Ge</b> 72.61	33 <b>As</b> 74.92	34 <b>Se</b> 78.96	35 <b>Br</b> 79.90	36 <b>Kr</b> 83.80	
37 <b>Rb</b> 85.47	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.91	40 <b>Zr</b> 91.22	41 <b>Nb</b> 92.91	42 <b>Mo</b> 95.94	43 <b>Tc</b> 98	44 <b>Ru</b> 101.1	45 <b>Rh</b> 102.9	46 <b>Pd</b> 106.4	47 <b>Ag</b> 107.9	48 <b>Cd</b> 112.4	49 <b>In</b> 114.8	50 <b>Sn</b> 118.7	51 <b>Sb</b> 121.8	52 <b>Te</b> 127.6	53 <b>I</b> 126.9	54 <b>Xe</b> 131.3	
55 <b>Cs</b> 132.9	56 <b>Ba</b> 137.3	57 <b>La</b> 138.9	72 <b>Hf</b> 178.5	73 <b>Ta</b> 180.9	74 <b>W</b> 183.9	75 <b>Re</b> 186.2	76 <b>Os</b> 190.2	77 <b>Ir</b> 192.2	78 <b>Pt</b> 195.1	79 <b>Au</b> 197.0	80 <b>Hg</b> 200.6	81 <b>Tl</b> 204.4	82 <b>Pb</b> 207.2	83 <b>Bi</b> 209.0	84 <b>Po</b> (209)	85 <b>At</b> (210)	86 <b>Rn</b> (222)	
87 <b>Fr</b> (223)	88 <b>Ra</b> (226)	89 <b>Ac</b> (227)	104 <b>Rf</b> (261)	105 <b>Db</b> (262)	106 <b>Sg</b> (266)	107 <b>Bh</b> (264)	108 <b>Hs</b> (269)	109 <b>Mt</b> (268)	110 <b>Ds</b> (269)	111 <b>Rg</b> (280)	112 <b>Cp</b> (277)	113 <b>Nh</b> (286)	114 <b>Fl</b> (289)	115 <b>Mc</b> (290)	116 <b>Lv</b> (293)	117 <b>Ts</b> (294)	118 <b>Og</b> (294)	

58 <b>Ce</b> 140.1	59 <b>Pr</b> 140.9	60 <b>Nd</b> 144.2	61 <b>Pm</b> (145)	62 <b>Sm</b> 150.4	63 <b>Eu</b> 152.0	64 <b>Gd</b> 157.3	65 <b>Tb</b> 158.9	66 <b>Dy</b> 162.5	67 <b>Ho</b> 164.9	68 <b>Er</b> 167.3	69 <b>Tm</b> 168.9	70 <b>Yb</b> 173.0	71 <b>Lu</b> 175.0
90 <b>Th</b> 232.0	91 <b>Pa</b> (231)	92 <b>U</b> 238.0	93 <b>Np</b> (237)	94 <b>Pu</b> (244)	95 <b>Am</b> (243)	96 <b>Cm</b> (247)	97 <b>Bk</b> (247)	98 <b>Cf</b> (251)	99 <b>Es</b> (252)	100 <b>Fm</b> (257)	101 <b>Md</b> (258)	102 <b>No</b> (259)	103 <b>Lr</b> (260)