

ACDA4011 CHEMISTRY OME (HNC) FINAL EXAM

74

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SHOW ALL WORK. USE CORRECT UNITS AND SIGNIFICANT DIGITS. YOU MAY SHOW YOUR WORK ON THE BACK OF THE SHEET BUT INDICATE YOUR ANSWER ON THE FRONT.

PERIODIC TABLE AND REFERENCE DATA CAN BE TORN OFF OF THE EXAM

THERE ARE 10 QUESTIONS, 100 POINTS TOTAL (PLUS ANY EXTRA CREDIT EARNED IN THE CLASS). TIME 120 min

18p QUESTION 1:

For each of the following statements determine if it is **TRUE** or **FALSE**.

T F

✓ ☒ ☐ (2p) Multiple bonds are shorter and stronger than single bonds between the same atoms.

Protons ✓ ☐ ☒ (2p) The elements in the periodic table are arranged in the order of increasing number of electrons.

✓ ☒ ☐ (2p) In 1 mole of water there are 6.02×10^{23} atoms of oxygen.

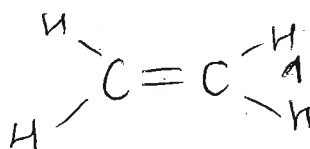
???? ✓ ☐ ☒ (2p) Ideal gas equation describes well the behaviour of gases when the pressure and temperature of this gas tend to 0 atm and 0 K, respectively.

✓ ☐ ☒ (2p) Activation energy of nitrocellulose and RDX is 86 kJ/mol and 199 kJ/mol, respectively. RDX is less stable than nitrocellulose.

✓ ☒ ☒ (2p) The C_2H_4 molecule has six bonding electron pairs and no lone pairs.

$\times \frac{1}{4}$ ✓ ☐ ☒ (2p) For a hypothetical reaction $A + B \rightarrow C$ that is a second order in A, doubling the concentration of A will double the rate of the overall reaction. $\frac{[A]^2[B]}{\times 2}$

✓ ☒ ☐ (2p) All combustion reactions are exothermic.



16
16

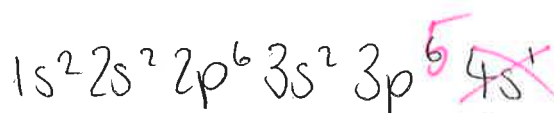
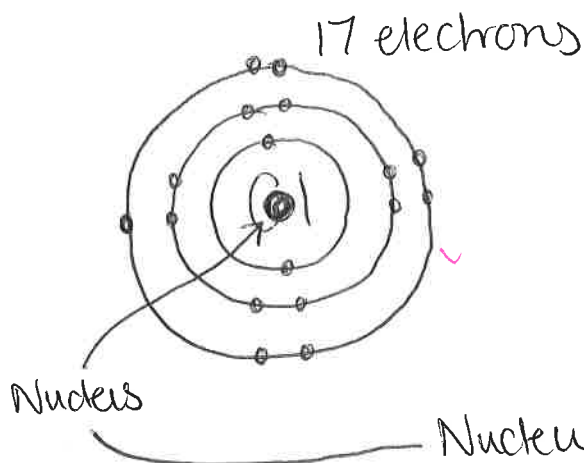
✓ (2p) Volume of gas produced in the detonation process decreases when the oxygen balance becomes less negative.

✓ (2p) The formula of potassium perchlorate is KClO_3 .

Chlorate $-\text{ClO}_3^-$
Perchlorate $-\text{ClO}_4^-$

QUESTION 2:

4p a) (4p) Draw the Bohr model for a chlorine atom. Specify the number of orbits and indicate the position of all subatomic particles within the atom and their charges.



Electrons (negative -)

Protons (positive +) = 17 ✓

Neutrons = $35 - 17 = 18$ ✓

↳ Neutral or no charge

3p b) (3p) Give the definition of the term *Mass Number* and explain why for Cl atom the average atomic mass is 35.453.

The mass number is the mass of the ~~element~~ ^{atom} including only the neutrons + protons (electrons have ~~a~~ negligible mass).

The atomic mass of Cl is 35.453 as ~~there are 18 or 19~~ ^{it can contain} ~~different numbers of~~ neutrons and this number shows the percentage or likelihood of the different isotopes. ✓

2p c) (2p) How many protons and neutrons are there in chlorine-37?

Protons - 17 ✓

Neutrons - $37 - 17 = 20$ ✓

2p d) (2p) What will be the charge on chlorine atom when the outer shell is a complete octet? ✓

- (-1)

QUESTION 3:

Many fireworks contain metal compounds that emit visible light. The colour given by calcium species at the wavelength of 616 nm is orange-red.

1.5p a) (3p) Calculate the energy of one photon of orange-red light emitted by calcium atom. Show your calculations.

$$E = h \times \gamma \quad \checkmark$$

$$\lambda = 616 \text{ nm} = 0.616 \mu\text{m} = 0.000616 \text{ mm} = 0.000000616 \text{ m}$$

$$\gamma = 616 \text{ nm} = 616 \times 10^{-9} \text{ m} \rightarrow 2 \text{ not } \gamma = 6.16 \times 10^{-7} \text{ m} \quad \checkmark$$

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

$$E = (6.63 \times 10^{-34}) \times (6.16 \times 10^{-7}) = 4.08 \times 10^{-40} \text{ J}$$

2p b) (3p) Write the full and shorthand electron configuration for calcium and show ALL the electrons in orbitals.

~~Calcium (Na) - 11 electrons~~

Calcium (Ca) - 20 electrons

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

~~$[\text{Ne}] 3s^1$~~

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 \quad \checkmark$

$[\text{Ar}] 4s^2 \quad \checkmark$

3p c) (3p) The colours seen in fireworks are a result of the emission of visible light. Explain how these colours are produced.

Fireworks contain metal salts and compounds that emit visible light as photons of different ~~energy levels~~ wavelengths. The different wavelengths produce different colours as shown on the electromagnetic spectrum.

Blue → Red
Shorter wavelength longer wavelength

radius	↑	decrease
	→	decrease
IE	↑	Increase
	→	Increase
Electronegativity	↑	Increase
	→	Increase.

4p QUESTION 4:

(4p) Consider only the three elements: S, Se, Cl.

a) Which one is most metallic?

Selenium (electrons further away so easier to be free flowing) ✓

b) Which one has the greatest electronegativity?

Chlorine ✓

c) Which one has the highest ionisation energy?

Chlorine ✓

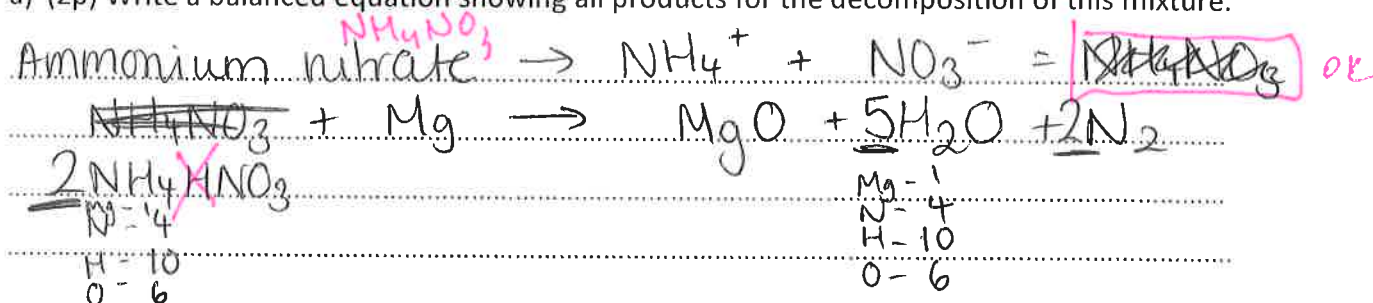
d) Which one has the smallest atomic radius?

Chlorine (less shielding and higher attraction moving across periods) ✓

QUESTION 5:

When ammonium nitrate and magnesium metal are mixed in a stoichiometric ratio, they form a pyrotechnic composition that decomposes to form magnesium oxide, water vapour and nitrogen gas.

a) (2p) Write a balanced equation showing all products for the decomposition of this mixture.



b) (2p) What percentage of magnesium, by mass, is contained in the stoichiometric mixture?

$M_r = 24.3 \text{ g/mol}$

$M_r = ((14 \times 2) + (1 \times 5) + (16 \times 3)) = 81 \text{ g/mol} \times 2 = 162 \text{ g/mol}$

$\frac{24.3}{162 + 24.3} = 13\%$

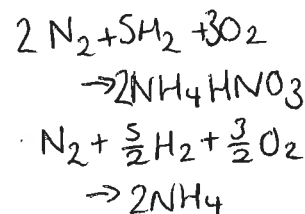
c) (3p) Using the standard heats of formation listed below, calculate the heat of reaction for molar quantities of the reactants. Is this process exothermic or endothermic? Explain

(negative) $\times 2$ Ammonium nitrate (solid) -365 kJ/mol

$\times 1$ Magnesium oxide (solid) -601 kJ/mol

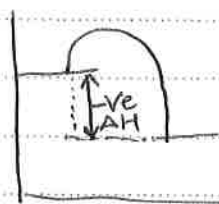
$\times 5$ Water (gas) - 242 kJ/mol

-ve = exo
+ve = endo



$\Delta H = 365 - 601 - 242$

$= -478 \text{ kJ/mol}$ $\leftarrow$ as negative, this is exothermic



$\Delta H = (365) - 601 - (242 \times 5)$
 $\Delta H = -1081 \text{ kJ/mol}$

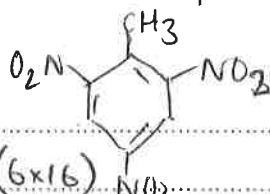
d) (3p) How does the heat of reaction from this reaction compare with 2.8 kJg^{-1} provided by one gram of TNT.

$M_{r \text{ TNT}} = 227 \text{ g/mol}$

$(7 \times 12) + (5 \times 1) + (3 \times 14) + (6 \times 16)$

$n = \frac{m}{M_r} = \frac{1}{227} = 4.4 \times 10^{-3} \text{ mol}$

$M_r \text{ 227}$



$C = 7$

$H = 5$

$N = 3$

$O = 6$

$2.8 \times 1 = 2.8 \text{ kJ}$

$\frac{2.8 \text{ kJ}}{4.4 \times 10^{-3}} = -635.6 \text{ kJ/mol}$

4.4×10^{-3}

TNT is almost half of other.

QUESTION 6:

Some high explosives have the general formula $C_a H_b N_c O_d$. The oxidiser (O) and the fuel (C, H) are present in the same molecule. Nitrogen atoms are present, so there is a highly exothermic production of hot N_2 gas.

a) (4p) For an unknown explosive of general formula $C_a H_b N_c O_d$ and a molar mass of 152 g/mol , determine the coefficients a, b c and d if 152 g of this material decomposes to, form 44.8 dm^3 of CO_2 , 44.8 dm^3 of H_2O , and 22.4 dm^3 of N_2 .

$M_r = 152 \text{ g/mol}$

$m = 152 \text{ g}$

$n = \frac{m}{M_r} = \frac{152}{152} = 1 \text{ mol}$

$M_r \text{ 152}$



44.8 dm^3

$M_r = 44$

$\frac{m}{M_r} = 1.0$

44.8 dm^3

$M_r = 18$

$= 2.5$

22.4 dm^3

$M_r = 28$

$= 0.8$

a - 2

b - 4

c - 2

d - 4



$2.5 : 1 : 1.5$



3.5

3.5

b) (2p) Which of the produced gases will move fastest and explain why?

0p Gases $\rightarrow$ CO_2 and N_2

N_2 will be moving faster because it is hotter, and particles move faster when heated.

2p*

c) (3p) The oxygen balance of an explosive is the mass of oxygen either in excess (the balance is positive) or in deficit (the balance is negative) of that required for complete oxidation of C and H. The oxygen balance is expressed as a percentage of this oxygen weight over the molar mass of the explosive. Calculate the oxygen balance for explosive with the formula determined in part a).

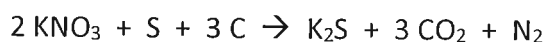
$$\text{C}_2\text{H}_4\text{N}_2\text{O}_{\frac{4}{2}} \quad \Omega = \frac{M_{\text{req O}}}{M_{\text{total}}} \times 100 \times \left(d - 2a - \frac{b}{2} \right)$$

$$\Omega = \frac{4 \times 16}{152} \times 100 \times \left(\frac{4}{2} - (2 \times 2) - \frac{4}{2} \right)$$

$$\Omega = -84.2\%$$

QUESTION 7:

A simple chemical equation for the combustion of gun powder can be written as:



- a) (4p) Assuming that the reaction above can be carried out at STP, how many grams of CO_2 are formed from the decomposition of 45 g of KNO_3 ?

1p

$$2 \text{KNO}_3 \rightarrow 3 \text{CO}_2$$

m - 45g ? = 14.5g

Mr - 101.1g/mol Mr = 44g/mol

n = 0.45 mol (for 1 mole) ✓ n = 0.33 (for 3 moles)

n = 0.22 mol (for 2 mole)

mass of CO_2 formed = 14.5g ?

- a.s
- b) (4p) How many litres of gas products would form from the decomposition of 45 g of potassium nitrate at STP?

KNO_3

$$V = \frac{nRT}{P} = \frac{0.45 \times 0.08206 \times 298}{1} = 11.0 \text{ L}$$

$PV = nRT$

$P = 1 \text{ atm}$

$V = ? \text{ L}$

$n = 45 \div 101.1 = 0.45 \text{ mol}$

$R = 0.08206$

$T = 273 \text{ K} + 25 \text{ K} = 298 \text{ K}$

c) (4p) 45 g KNO_3 at STP is heated to 100 degC and the pressure is reduced to 700 mmHg.

What is the new volume of the gases? Use the appropriate gas laws to support your answer.

$$P = 760 \text{ mmHg} \rightarrow 0.92 \text{ atm } (700 \div 760) \checkmark$$

$$V = ?$$

$$n = 0.45$$

$$V = 0.45 \times 0.08206 \times 373$$

$$R = 0.08206$$

$$0.92$$

$$T = 273 + 100 = 373 \text{ K}$$

$$V = 15.0 \text{ L}$$

Boyles law - Pressure decrease makes volume increase. ✓

~~Charles law - Pressure decreases + temp decreases.~~

Luc Gussac law - Volume increases ^{when} ~~and~~ Temp increases

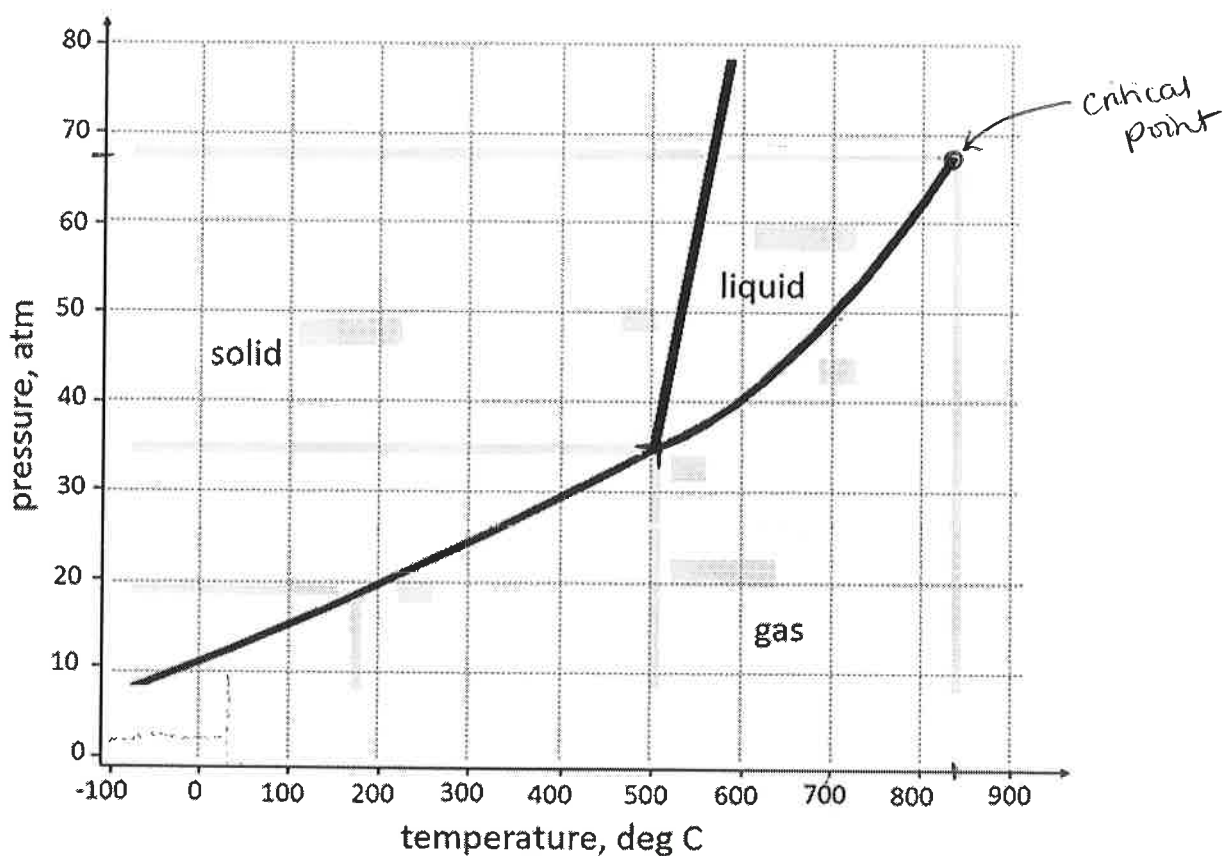
B - $P \downarrow$ and $V \uparrow$

C - $P \downarrow$ and $T \downarrow$

L - $V \uparrow$ $T \uparrow$

QUESTION 8:

The phase diagram of an unknown compound X, is shown below:



- 1p a) (2p) What is the value of temperature and pressure at a critical point? What is the term used to describe the state of substance X above this point?

Temp = 830°C Pressure = 67 atm ✓

~~Unstable~~ ~~supersonic~~ plasma

- 2p b) (2p) If you stored a bottle containing compound X on the work desk in the lab, what phase would it most likely be in?

gas (1 atm + 25°C)

- c) (2p) If a sample of pure X is to be a mixture of liquid and gas, which point marks the sample's lowest possible temperature and pressure? Name all transitions occurring at this specific temperature and pressure.

510°C and 35 atm. marked by the triple point. ✓

Liquid $\rightarrow$ gas = evaporation / boiling.
gas $\rightarrow$ liquid = condensation.

- d) (2p) Can compound X be boiled at 200 deg C? Why?

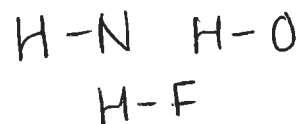
No, it is never in liquid state at 200°C at any pressure and boiling is liquid $\rightarrow$ gas.

- e) (2p) What is the vapour pressure of substance X at 700 deg C?

50 atm.

- f) Does the melting point of X increase, decrease or stay the same as the pressure is increased?

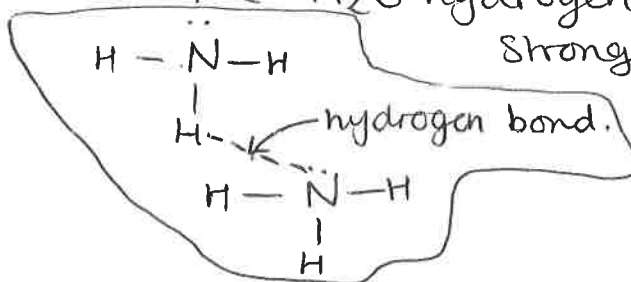
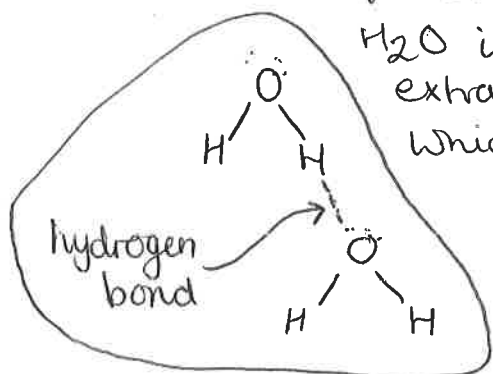
Increase.



QUESTION 9:

- a) (4p) The normal boiling point is 100°C for H_2O and -33.3°C for NH_3 , even though the two molecules have almost identical atomic weights. Explain this difference in terms of intermolecular forces, using words or pictures, or both.

There is hydrogen bonding between the molecules. This makes a strong force between the molecules and increasing the boiling point as a lot more energy is required to break these bonds. The dipole in H_2O is much larger than in NH_3 as there are extra electrons ~~is~~ at the O than at the N, which makes the H_2O hydrogen bonding stronger than the NH_3 bonding.



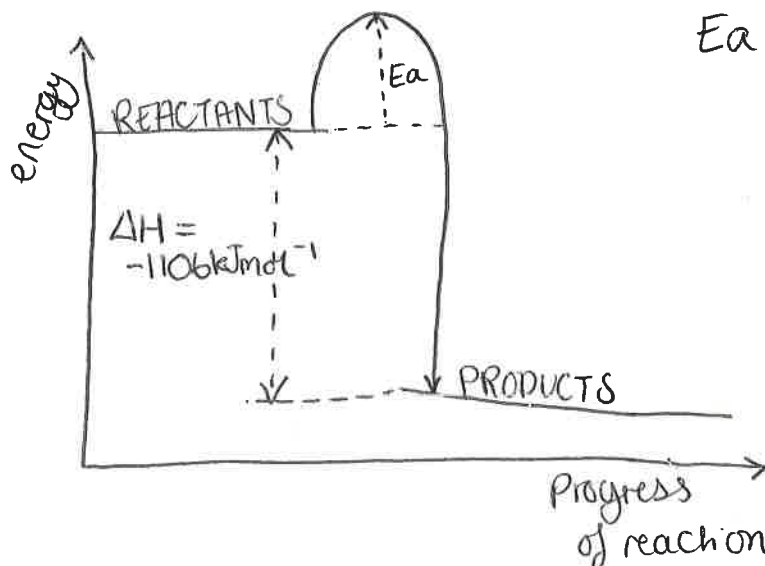
- b) (3p) Give **ONE** specific example of how might water react to give undesirable performance from OME devices? Explain why. To answer this question, refer to your assignment.

Water can react with Iron to cause rusting. This is not good in OME devices as it can cause compatibility issues leading to faster degradation or higher sensitivities making them much more dangerous to work with as their properties have now changed.

QUESTION 10:

An explosive, RDX has an enthalpy of detonation of $-1106 \text{ kJ mol}^{-1}$.

- 3p a) (3p) Sketch the reaction profile ("energy" vs. "progress of reaction") showing the reactants, products, activated complex, enthalpy of detonation and the activation energy



E_a = activation energy.

ΔH = enthalpy of detonation.

- 1p b) (3p) (3p) Using the Arrhenius equation $k = A \exp(-E_a / RT)$ to support your answer, explain the relationship between activation energy, E_a , and the fraction of colliding molecules that result in a reaction.

A = the fraction of colliding molecules

The activation energy affects the number in the exponential so increased E_a means it gets more negative.

EXTRA CREDIT (if earned in class):

~~1~~

3 points

6a)

$$2.5 : 1 : 1.5$$

$$5 : 2 : 3$$



$$(12 \times 5) + (16 \times 10) + (4 \times 1) + (16 \times 2) + (6 \times 14)$$

$$60 + 160$$