

ACDA4011 CHEMISTRY OME (HNC) FINAL EXAM

79.5

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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

14p

QUESTION 1:

14

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.

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

☒ ☐ (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. *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. *it would x4*

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

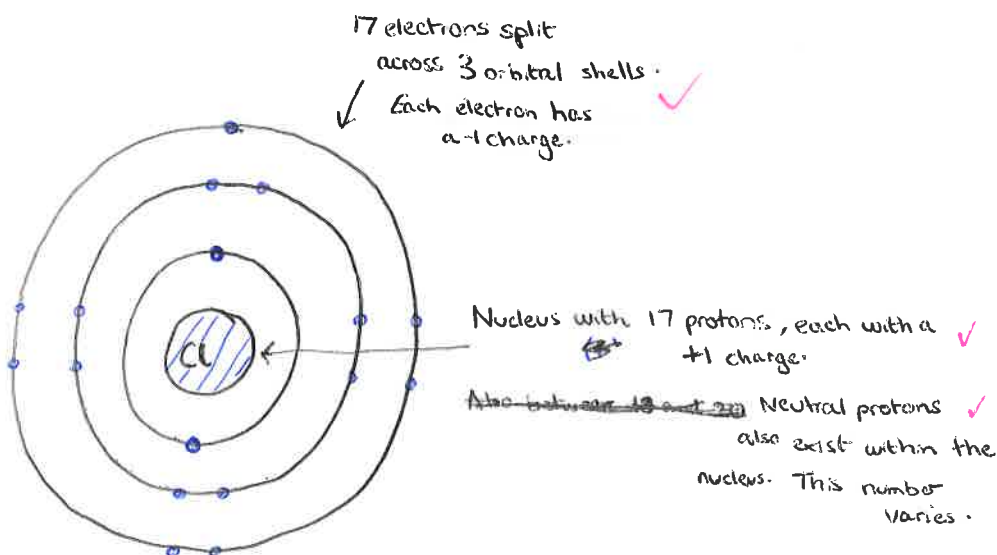
- ____ ✓ (2p) Volume of gas produced in the detonation process decreases when the oxygen balance becomes less negative. *solid C produced when more negative, so less gas when more negative*
- ✓ ____ ✓ (2p) The formula of potassium perchlorate is KClO_4 .

QUESTION 2: 11

- 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.

4p

4



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

Mass number refers to the combined atomic mass of protons and neutrons in the atom where each particle has a mass of 1. Chlorine, like many other elements, has a decimal mass number due to existence of isotopes. Isotopes are different types of the same element and differ in their number of neutrons. ~~Mass~~ The average atomic mass of all chlorine isotopes, weighted with respect to their abundance, comes out as 35.453.

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

17 protons and 20 neutrons. ✓

2

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

Chlorine sits in group 7, so requires one more electron to complete its outer shell.

This means it will have a charge of -1. ✓

2

QUESTION 3:

8.5

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

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

First, calculate frequency using $c = \lambda \nu$. Rearrange to give $\nu = \frac{c}{\lambda}$.

$\lambda = 616 \times 10^{-9} \text{ m}$ and $c = 3 \times 10^8 \text{ m/s}$. $\nu = \frac{3 \times 10^8}{616 \times 10^{-9}} = 4.87 \times 10^{14} \text{ Hz}$. ✓

Energy is given by $E = h\nu$ where h is Planck's constant, $6.6 \times 10^{-34} \text{ Js}$.

$\nu = 4.87 \times 10^{14} \text{ Hz}$ so $E = (6.6 \times 10^{-34}) \times (4.87 \times 10^{14}) = 3.21 \times 10^{-19} \text{ (2dp)}$ ✓

3

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

Short hand: $[\text{Ne}] 3s^2 \rightarrow [\text{Ne}] \boxed{\uparrow\downarrow}^{3s}$

Ca not K !!!

Full: $\boxed{\uparrow\downarrow}^{1s} \boxed{\uparrow\downarrow}^{2s} \boxed{\uparrow\downarrow\uparrow\downarrow\uparrow\downarrow}^{2p} \boxed{\uparrow\downarrow}^{3s}$ or $1s^2 2s^2 2p^6 3s^2$

2.5

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

Visible light is emitted due to the release of photons from metal compounds at their excited energy state. This is the photoelectric effect. Each ^{metal} compound has its own unique emission spectra at certain frequencies, which gives each one its distinctive colour.

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QUESTION 4: 4

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

a) Which one is most metallic?

Se is the most metallic.

b) Which one has the greatest electronegativity?

Cl is the most electronegative.

c) Which one has the highest ionisation energy?

Cl has the highest ionisation energy.

d) Which one has the smallest atomic radius?

Cl has the smallest atomic radius.

smaller radius
more electronegative
most ionising
more metallic

4

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. N_2



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



1

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

Molar Mass of Mg = 24 g/mol $\rightarrow$ 24g $\rightarrow$ Total mass = 24g

Molar Mass of $\text{NH}_4\text{NO}_3 = (14 + (4 \times 1) + 14 + (3 \times 16)) = 80 \text{ g/mol} \rightarrow$ Total Mass = 80g

Total Molar Mass = 104 g/mol $\rightarrow$ Total Mass of mixture = 104g

$$\frac{24\text{g}}{104\text{g}} \times 100\% = 23.08\% \text{ mass (2dp)}$$

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

Ammonium nitrate (solid) -365 kJ/mol

Magnesium oxide (solid) -601 kJ/mol

Water (gas) - 242 kJ/mol

$$\Delta^\circ\text{H} = \text{formed} = \Delta^\circ\text{H}_{\text{reactants}} - \Delta^\circ\text{H}_{\text{products}}$$

$$601 + (2 \times 242) - 365 = \Delta^\circ\text{H} = -720 \text{ kJ/mol}$$

$$365 - (601 + (2 \times 242)) =$$

It requires more heat to form the products than to break down the reactants, so heat is taken in to form the products. The reaction is endothermic.

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

The reaction of the detonation of TNT is highly exothermic. There is a vast release of heat energy associated with the reaction. It requires for more energy to break TNT down than to form the products as the combustion of TNT is incomplete, so large amounts of heat are transferred to the surroundings.

QUESTION 6:

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Some high explosives have the general formula $\text{C}_a \text{H}_b \text{N}_c \text{O}_d$. 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.

4p a) (4p) For an unknown explosive of general formula $\text{C}_a \text{H}_b \text{N}_c \text{O}_d$ 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 .

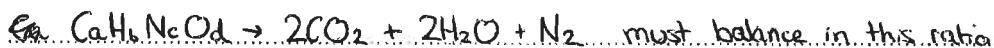
$22.4 \text{ dm}^3/\text{mol of gas}$

Gas occupies $22.4 \text{ dm}^3/\text{mol}$ at STP



If $\text{C}_a \text{H}_b \text{N}_c \text{O}_d$ has MM of 152 g/mol then $152 \text{ g} = 1 \text{ mol}$.

So,



On product side there are: 2C, 4H, 6O and 2N

So, $\text{C}_a \text{H}_b \text{N}_c \text{O}_d$ must be $\text{C}_2 \text{H}_4 \text{O}_6 \text{N}_2$

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

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3p 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).

In any composition $C_aH_bN_cO_d$, oxygen balance, $\Omega = \frac{16}{MM} \left(d - 2a - \left(\frac{b}{2} \right) \right)$ 0.5p

In this case, $a=2$, $b=4$, $c=2$ and $d=6$. Molar Mass = 152.

$$\Omega = \frac{16}{152} \left(6 - (2 \times 2) - \left(\frac{4}{2} \right) \right) = 0\%$$

QUESTION 7:

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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 ?

STP = 0°C , 1 atm of pressure

Molar Mass of $\text{KNO}_3 = (39 + 14 + (16 \times 3)) = 101 \text{ g/mol}$

Molar Mass of $\text{CO}_2 = 12 + 32 = 44 \text{ g/mol}$

45 g of $\text{KNO}_3 = 0.45 \text{ mol}$

$\uparrow$ $2 \text{KNO}_3 = 162 \text{ g}$

$3 \text{CO}_2 = 132 \text{ g}$

162 g of KNO_3 produces 132 g of CO_2

$\div 2$ 81 g of KNO_3 produces 66 g of CO_2

(3.5)

55.5% of 45 g of KNO_3 produces 36.6 g of CO_2

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

$\rightarrow \text{CO}_2$ and N_2 are the gaseous products.

Molar Mass of $\text{N}_2 = 28 \text{ g/mol}$

From a) 36.6 g of CO_2 is formed.

81 g of KNO_3 produces 14 g of N_2

equivalent to 0.83 mol

55.5% of 45 g of KNO_3 produces 7.7 g of N_2

equivalent to 0.27 mol

Total gas ~~products~~ 36.6 + 7.7 = 44.3 g

At STP, 1 mol of gas occupies 22.4 dm^3 of space.

Total mols of gas = $0.83 + 0.27 = 1.1 \text{ mols}$

$1.1 \times 22.4 = 24.6 \text{ dm}^3$

(4)

34 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.

STP = 0°C and 760 mmHg . Now = 100°C and 700 mmHg $\rightarrow (1 \div 760) \times 700 = 0.92$
273K and 1 atm 373K and 0.92 atm

$$\frac{P_1 T_2 V_1}{P_2 T_1 V_2} = 1 \quad V_1 = 24.8 \text{ dm}^3$$

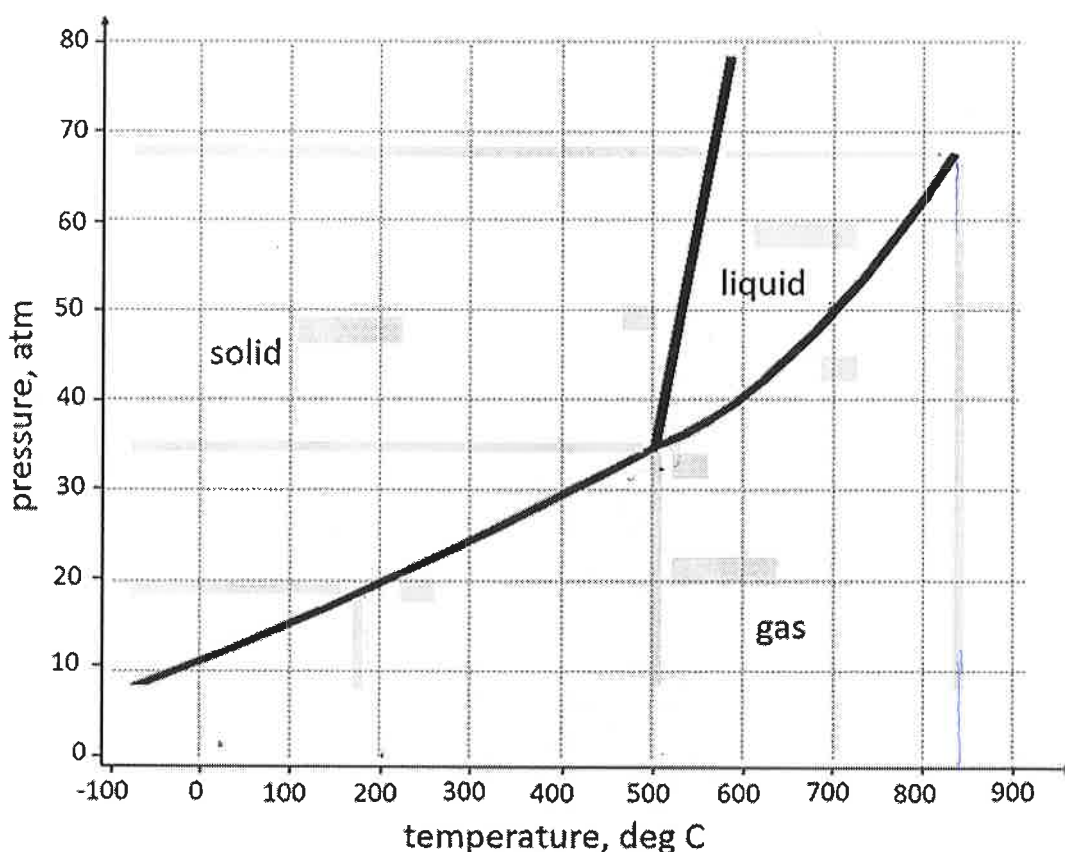
$$V_2 = \frac{P_1 T_2 V_1}{P_2 T_1} = \frac{1 \times 373 \times 24.8}{0.92 \times 273} = 36.96 \text{ dm}^3 (2 \text{ dp})$$

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QUESTION 8:

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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?

The critical point lies at the end of the liquid/gas boundary. For substance X, $T \approx 840^\circ\text{C}$ and $P \approx 68\text{atm}$. Beyond the critical point, gas becomes incompressible. It cannot be returned to liquid form.

- 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?

At room temperature of $20-25^\circ\text{C}$ and at $\approx 1\text{atm}$ of pressure, the substance would likely be a gas.

2p

- 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.

The lowest possible temperature and pressure for coexistence of X as liquid and gas, but not solid, is just above 500°C and at 35atm . At this point there will be equilibrium between liquid and gas states; and the transitions occurring are evaporation from liquid to gas and condensation from gas to liquid. ✓ ②

2p

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

Compound X cannot be boiled at 200°C as at no point does the 200°C sit on the boundary between liquid and gas. Sublimation from solid to gas can occur at 200°C however at 20atm , as well as deposition from gas back to solid. ②

2p

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

50atm is the vapour pressure at $T = 700^{\circ}\text{C}$ ②

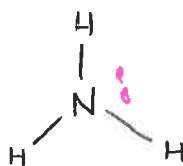
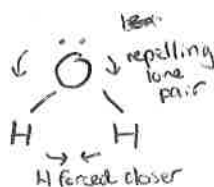
2p

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

The melting point steadily increases as pressure is increased. ②

QUESTION 9:

- 2p 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.



Water has a much higher boiling point than NH_3 due to an intermolecular force called Hydrogen bonding. When hydrogen reacts with ^{electronegative} O-group elements, there are ~~two~~ lone pairs that repel the bond pairs and force the bond to be 'bent' and pushes the two H atoms closer together, creating a much stronger bond and raising the energy required to break the bonds much higher than a molecule of similar weight such as NH_3 , where no lone pairs remain and bonds are as far apart as possible.

- 3p 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 is a good oxidiser. OME devices containing Group 1 metals and metal compounds as fuels, such as magnesium and potassium, react very easily with the oxygen in water to oxidise and form oxides and use up the fuels. Oxidation also can effect the casings of OME articles, many of which are at least partly metallic and may contain metals such as iron, which can be gradually corroded. Oxidation caused by water in this way can cause underperformance of OME devices, as well as safety concerns caused by the presence of H_2 gas in the composition as a product of oxidation.

QUESTION 10:

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

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

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b) (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.

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EXTRA CREDIT (if earned in class): 3.5 points

3.5

3.5