

58.5

ACDA4011 CHEMISTRY OME (HNC) FINAL EXAM

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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

QUESTION 1:

12

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.

✓ ✓ ✓ (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.

✓ (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.

✓ (2p) All combustion reactions are exothermic.

10

T f

✓ ✓ (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 .

S2 P6 d10

~~1s~~
~~2s 2p~~
~~3s 3p 3d~~
~~4s 4p 4d~~

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.

17
CL

17 protons

18 neutrons

17 electrons

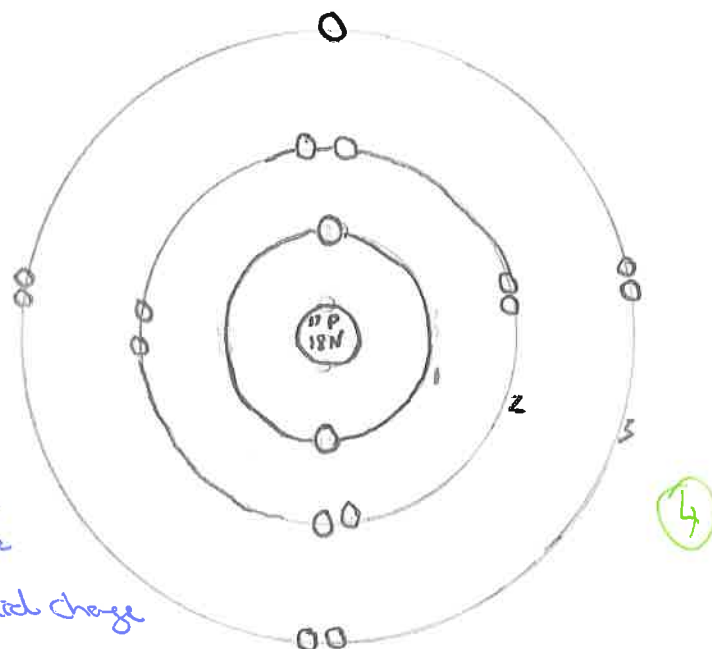
CL $1s^2 2s^2 2p^6 3s^2 3p^5$

Protons + charge

Neutrons 0 charge

electrons - charge

equal $P + e^-$ so Neutral 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.

Mass Number is the combined mass of protons and neutrons.
The average is taken from the Element and its isotopes,
from their abundance

3

2p

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

$$37 - 17 = 20$$

~~Protons = 17~~ protons = 17 ✓

~~Neutrons = 20~~ neutrons = 20 ✓

②

2p

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

$$-1$$
 ✓

②

QUESTION 3: 4

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

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

$$E = 6.6 \times 10^{-34} \frac{\text{J}}{\text{s}} \times 616 \text{ nm} = 4.07 \times 10^{-31} \text{ J}$$

①

1p b) (3p) Write the full and shorthand electron configuration for calcium and show ALL the electrons in orbitals.



①

2p

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

When ~~reacted~~ ^{heated} the ~~molecules~~ ^{electrons} are excited to a frequency that falls within its specific color when photons are emitted

(1)

QUESTION 4:

3

3p

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

- a) Which one is most metallic?

Se

(3)

- b) Which one has the greatest electronegativity?

Cl

- c) Which one has the highest ionisation energy?

Cl

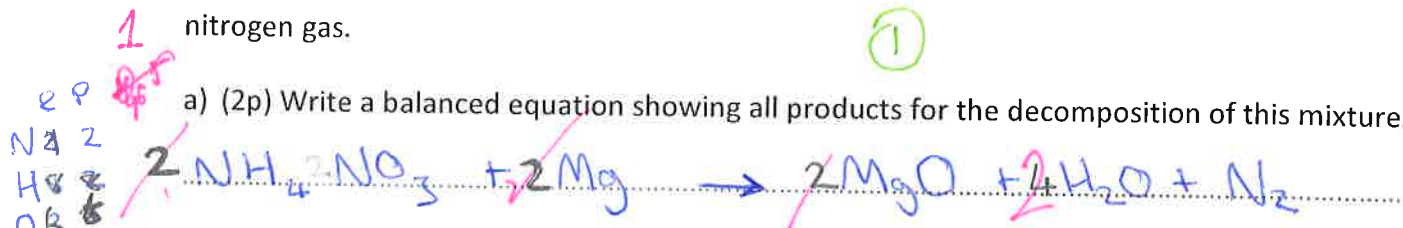
- d) Which one has the smallest atomic radius?

S

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?

$$\begin{aligned} \text{Mg} &= 24.3 \frac{\text{g}}{\text{mol}} \times 2 \text{ mols} = 48.6 \frac{\text{g}}{\text{mol}} \\ \text{NH}_4 &= 14 + (4 \times 1.008) = 18.032 \frac{\text{g}}{\text{mol}} \times 2 \text{ mols} = 36.064 \frac{\text{g}}{\text{mol}} \\ \text{NO}_3 &= 14 + (3 \times 16) = 62 \frac{\text{g}}{\text{mol}} \times 2 \text{ mols} = 124 \frac{\text{g}}{\text{mol}} \\ \text{Total mixture} &= 285.5 \frac{\text{g}}{\text{mol}} \\ \frac{48.6 \text{ g}}{285.5 \text{ g}} \times 100\% &= 17.02\% \quad (2 \text{ d.p.}) \quad \checkmark \end{aligned}$$

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



$$\text{Final} - \text{initial} = (-601 + (-242)) - (-365) = -478 \text{ kJ/mol}$$

Endothermic
Exothermic reaction due to heat being absorbed at reaction

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

Exothermic due to heat being released



QUESTION 6: 2

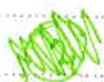
Some high explosives have the general formula $C_a H_b N_c O_d$. The oxidiser (O) and the fuel (C, H) are present in the same molecule. Nitrogen atoms are present, so there is a highly exothermic production of hot N_2 gas.

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 .

$$\%C = \frac{12}{mw} \times \left[(a - 2a) - \left(\frac{b}{2} \right) \right] \times 100$$



$$12 + (2 \times 1508) + (2 \times 14) + (6 \times 16) = 108.032 \quad ? \quad \frac{2}{mw} = n \quad \frac{152.9}{108.032} = 1.41 \text{ mols}$$



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

N_2 will move fastest due to being the lightest product.

①

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).

$$OB = \frac{16}{M_w} \times \left[(a - 2a) - \left(\frac{b}{2} \right) \right] \times 100\%$$

$$\frac{16}{108.32} \times \left[(4 - 2 \times 1) - \left(\frac{4}{2} \right) \right] \times 100 = 0$$

C

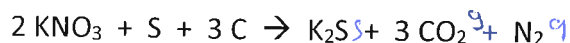
②



QUESTION 7:

5

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 ?

$$\text{KNO}_3 = 39 + 14 + (3 \times 16) = 101 \frac{\text{g}}{\text{mol}} \times 2 = 202 \frac{\text{g}}{\text{mol}} \text{KNO}_3$$

$$\frac{45 \text{ g}}{202 \frac{\text{g}}{\text{mol}}} = 0.22 \text{ mol}$$

$$\text{CO}_2 = 12 + 32 = 44 \frac{\text{g}}{\text{mol}} \times 3 = 132 \frac{\text{g}}{\text{mol}}$$

$$0.22 \text{ mol} \times 132 \frac{\text{g}}{\text{mol}} \text{CO}_2 = 29.04 \text{ g CO}_2 \text{ formed}$$

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

$$PV = nRT \quad V = \frac{nRT}{P}$$

$$V = \frac{101325 \times 10^5 \text{ Pa}}{(12 + 28) \times (0.0821) \times (298)} = 28.37 \text{ L (2 d.p.)}$$

$$T = 298 \text{ K}$$

$$P = 1 \text{ atm}$$

$$V = 22.4 \text{ L}$$

$$R = 0.0821$$

4.5

0.5

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.

$PV = nRT$

$$100^\circ\text{C} + 273 = 373\text{K} \quad \checkmark$$

$$100 \times \frac{760 \text{ mmHg}}{700 \text{ mmHg}} = 108.57\text{L}$$

Charles Law T

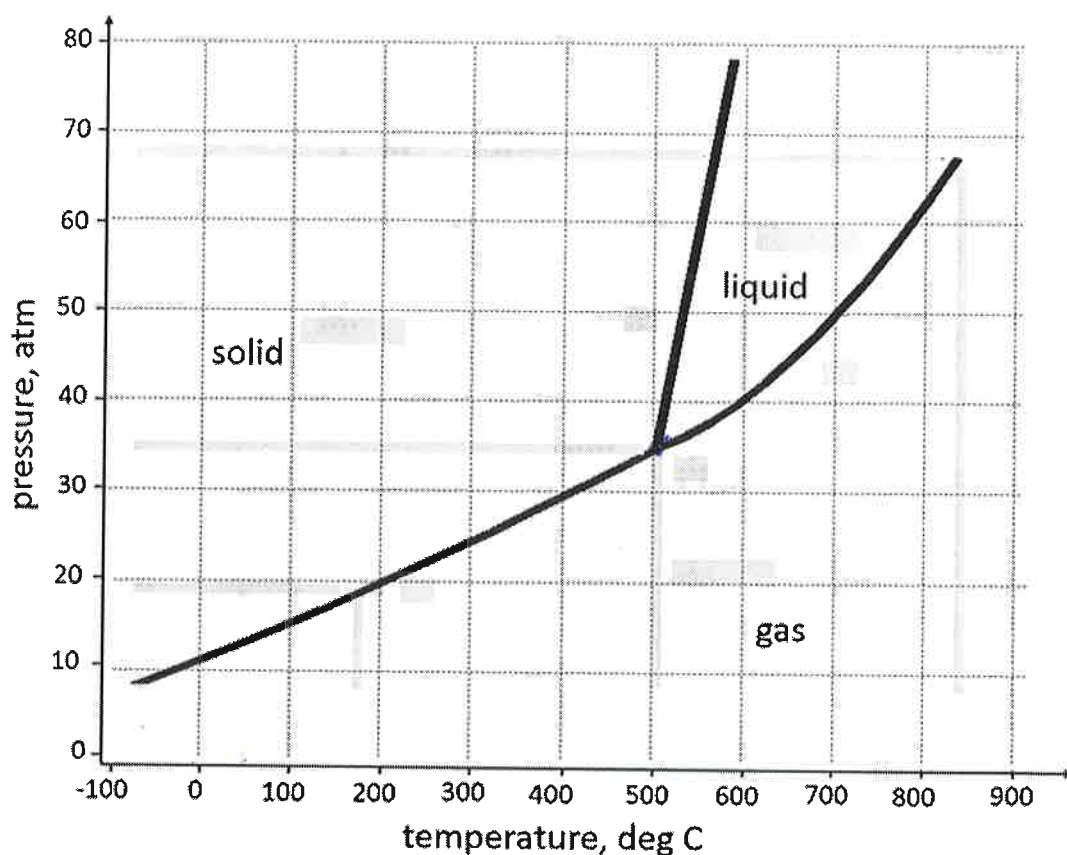
~~$T \uparrow P \downarrow$~~
Charles

0.5

QUESTION 8:

10

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



- 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?

~500°C 35 atm triple point

- 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?

Solid 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.

500°C / 35 atm / Vaporisation and Condensation

2

2p

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

No. Gas cannot be boiled.

2

2p

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

50 atm

2

2p

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

Increases

2

QUESTION 9: 4

- 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.

Hydrogen bonds are stronger than the ~~covalent~~ bond of NH_3 requiring more energy to change state breaking the bonds



2

- 2p 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.

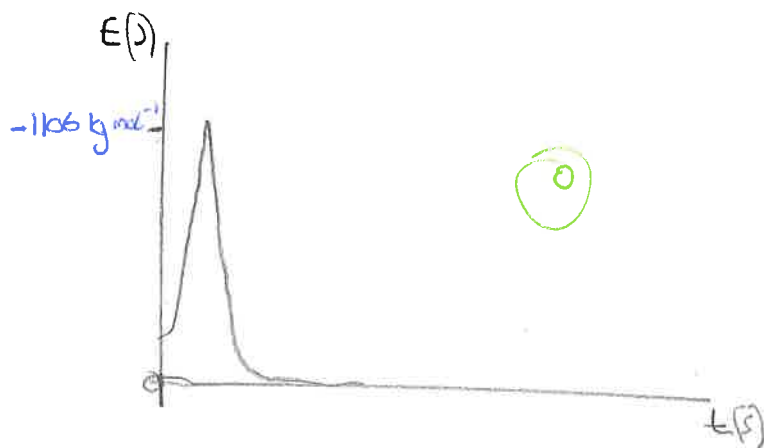
Water can leach the OME reducing the stability of the device/substance

2

QUESTION 10:

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

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



- 0.8 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.

0.8

3.5

3.5

EXTRA CREDIT (if earned in class): 3.5 points

