

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:

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. e.g. Covalent

☒ ~~T~~ ☒ F (2p) The elements in the periodic table are arranged in the order of increasing number of electrons. Arranged via Proton, but this is true as a side effect.

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

☒ ~~T~~ ☒ F (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.

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

☐ ~~T~~ ☒ F (2p) The C_2H_4 molecule has six bonding electron pairs and no lone pairs.

☒ ~~T~~ ☐ F (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.

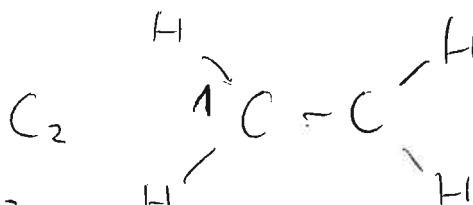
☒ ~~T~~ ☒ F (2p) All combustion reactions are exothermic.

$H_2O =$

$2 + 16 = 18$

$18 \text{ g/mole} \times$

$\frac{16}{18} \times 6.02 \times 10^{23} = 5.35 \times 10^{23}$



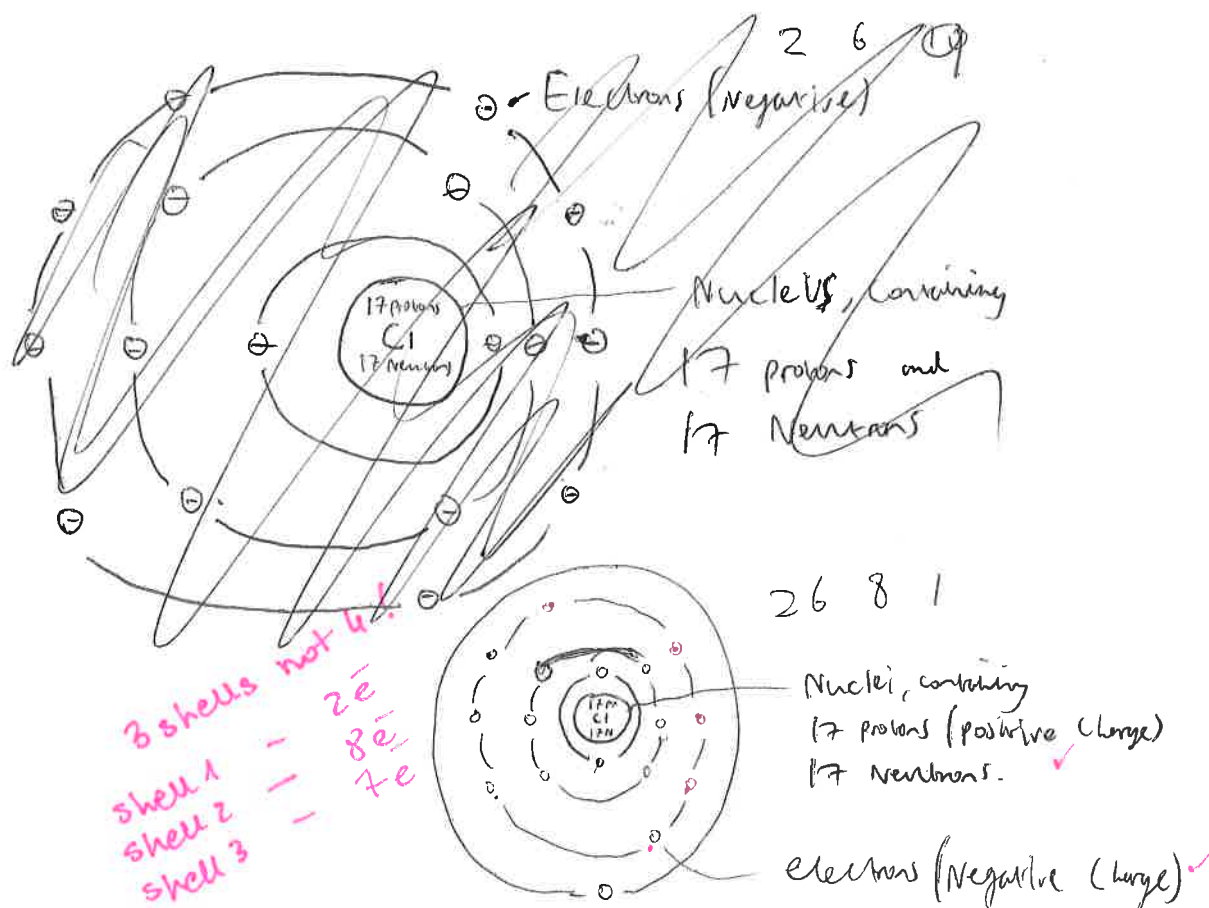
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- ____ ✓ (2p) Volume of gas produced in the detonation process decreases when the oxygen balance becomes less negative.
- ✓ ____ (2p) The formula of potassium perchlorate is KClO_3 .

QUESTION 2:

2)

- 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.



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

Op

The mass number for an element represents the mass of that element contained in 1 mol ~~of~~ particles of that element. So, in Chlorine case, there are 35.453g/mol. ~~particles~~ This number is a combination of the masses of electrons, protons and neutrons, each of which also have their own masses.

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

Chlorine has 17p-17n, ~~Chlorine - 37~~ has 18p-18n.

0

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

Cl will lose an electron and ~~become~~ Cl^+ . (Cl^{+1})

0

QUESTION 3: 3.5

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

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

~~616nm~~ $\times 6.6 \times 10^{-34} \text{ J}\cdot\text{s} = 4.0656 \times 10^{-31}$

$= 4.0656 \times 10^{-31} \text{ J}$

0

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

Calcium: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$

Shorthand: $3d^2$

Orbitals:

1b 1b 1b 1b 1b 1b

1b 1b

1b 1b

1b 1b 1b 1b

1b

1b

1b 1b 1b 1b 1b 1b

s p d s
2 6 10 18

- 2p
- c) (3p) The colours seen in fireworks are a result of the emission of visible light. Explain how these colours are produced.

3

Photo emission occurs when photons are ejected by the electrons in an atom at a specific frequency, which determines their visible colour and wavelength. The higher energy level released, the smaller the resulting wavelength, and the higher the output frequency.

2

QUESTION 4:

3

- 3p
- (4p) Consider only the three elements: S, Se, Cl.

- a) Which one is most metallic?

Selenium (Se)

- b) Which one has the greatest electronegativity?

Chlorine (Cl)

- c) Which one has the highest ionisation energy?

Chlorine (Cl)

- d) Which one has the smallest atomic radius?

~~Sulphur (S)~~

NH₄NO₃

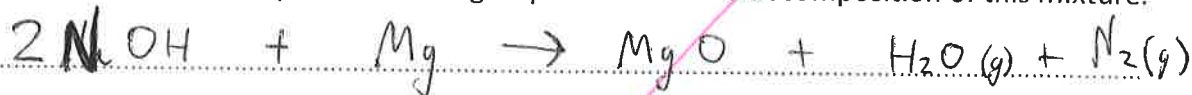
QUESTION 5:

5.5

NO²H NO₂H NH₄O₂
HNO

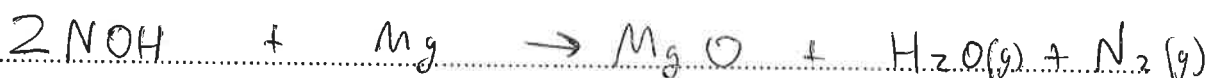
When ammonium nitrate and magnesium metal are mixed in a stoichiometric ratio, they form a pyrotechnic composition that decomposes to form magnesium oxide, water vapour and nitrogen gas.

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



0.5

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



2 × (14.0067 + 15.9994 + 1.00797) 24.312 24.312 + 15.9994

62.02814 24.312

Total Reactant Mass = 86.34014g

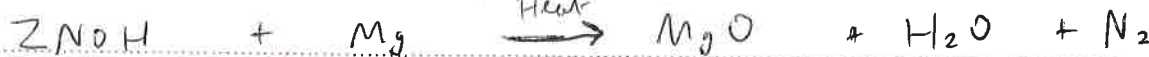
24.312 × 100 = 28.1583977% → 28.16%

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



2 × -365 kJ/mol -601 kJ/mol -242 kJ/mol

-730 kJ/mol -113 kJ/mol -843 kJ/mol

Molar Quantities values: NH₄OH: -365 kJ/mol, Mg: -113 kJ/mol

Exothermic, as heat is released during the reaction resulting in a lower energy for the products than the reactants.

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

A TNT reaction produces We must compare 'J/mol' values to 'J/g' values. The value of the reaction of NOH , -365 kJ/mol , converted to J/g, there are $\sim 31 \text{ g}$ of material in a mol of NOH , so $-365 \div 31 = -11.7741935$, so there is around -11.77 kJ/g , a lot more energy change than TNT.

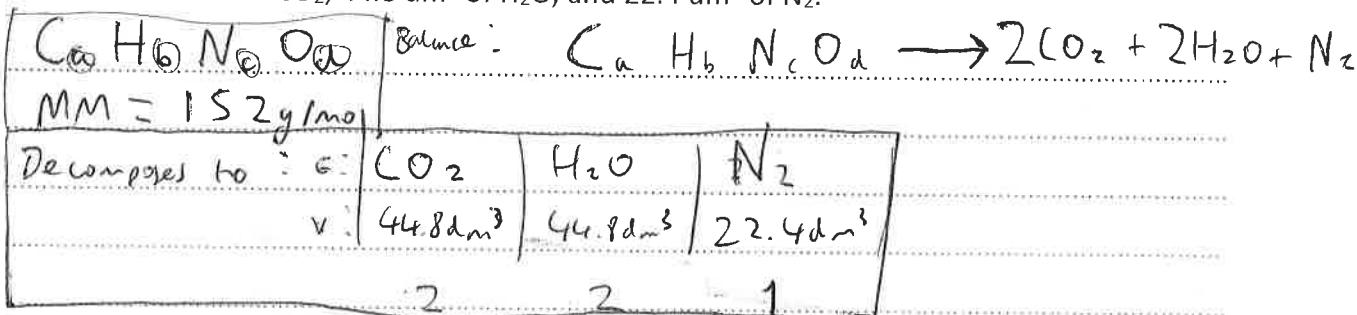
(1)

QUESTION 6: 4

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.

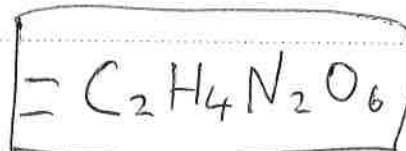
(4)

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 .



$\text{C} = 12$ $2 \times \text{C} = 24$ 2 Carbons
 $\text{H} = 1$ $2 \times \text{H}_2 = 4$ 4 Hydrogens
 $\text{N} = 14$ $\text{N}_2 = 28$ 2 Nitrogens
 $\text{O} = 16$ $2 \times \text{O}_2 + 2 \times \text{O} = 96$ 6 oxygens
 64 32

total = 152

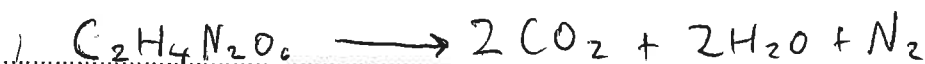


Op b) (2p) Which of the produced gases will move fastest and explain why?

CO_2 , as it is greater in ~~pressure~~ volume and will expand to fill a space faster than the other gas N_2 .



Op 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).



152g total weight, Oxygen = 96g, Oxygen Balance = $\frac{96}{152} \times 100 =$

= 63.157%

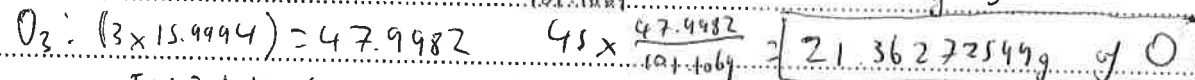
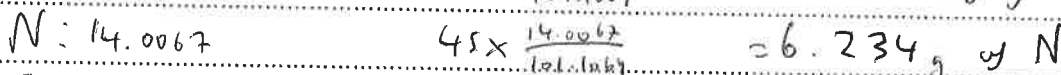
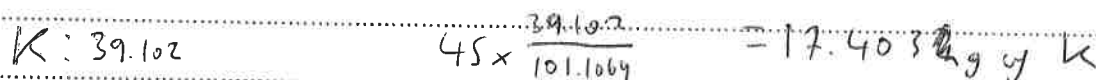
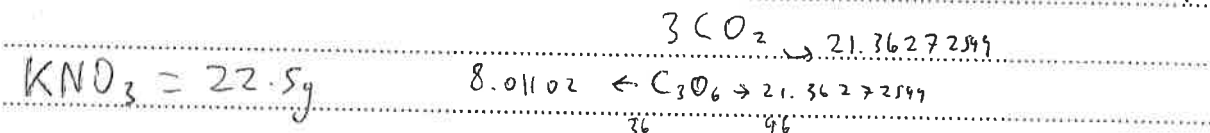
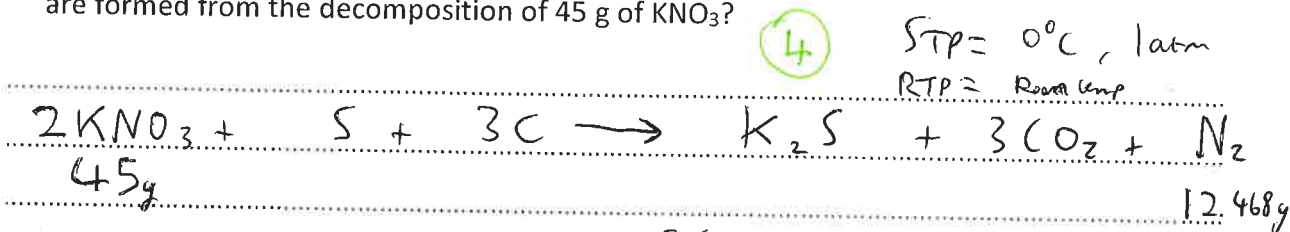


QUESTION 7: 8.5

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 ?



Total: 101.1069

C = 12
3C = 36

S = 32

and
8.01102g of C

Total: 29.3737g

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

STP

~~NR - PRT~~

The two gas products are 3CO_2 and N_2 . In the balanced equation there are 4 mol of gas products, though there will be less than this at only 45g of reactant. 1 mol of N_2 would typically be 28.0134g, but as above we have worked it out as 12.468g. Apply the ratio

$$\frac{12.468}{28.0134} = 0.4450727152$$

0.5

4 mol of gas = 4 dl of gas

$$4 \times 0.4450727152 = 1.780290861 \text{ deci-litres}$$

PTV

up

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.

KNO_3 , 45g, STP

$T: +100^\circ\text{C}$

$P: - 700\text{ mmHg}$

1.78 decil-litres

According to Charles law and Boyle's law, Temperature has a positive relationship with both pressure and volume, whilst pressure has a negative correlation with volume. As the temperature has risen, and the pressure dropped, we can expect a large increase in volume.

$$t_1 = 0^\circ\text{C}$$

$$P_1 = 760\text{ mmHg}$$

$$V_1 = 1.78\text{ dl}$$

$$t_2 = 100^\circ\text{C}$$

$$P_2 = 700\text{ mmHg}$$

$$V_2 = ?$$

$$K_1 = 274$$

$$K_2 = 374$$

$$1.78 \times \frac{374}{274} \times \frac{760}{700} = 2.237821744$$

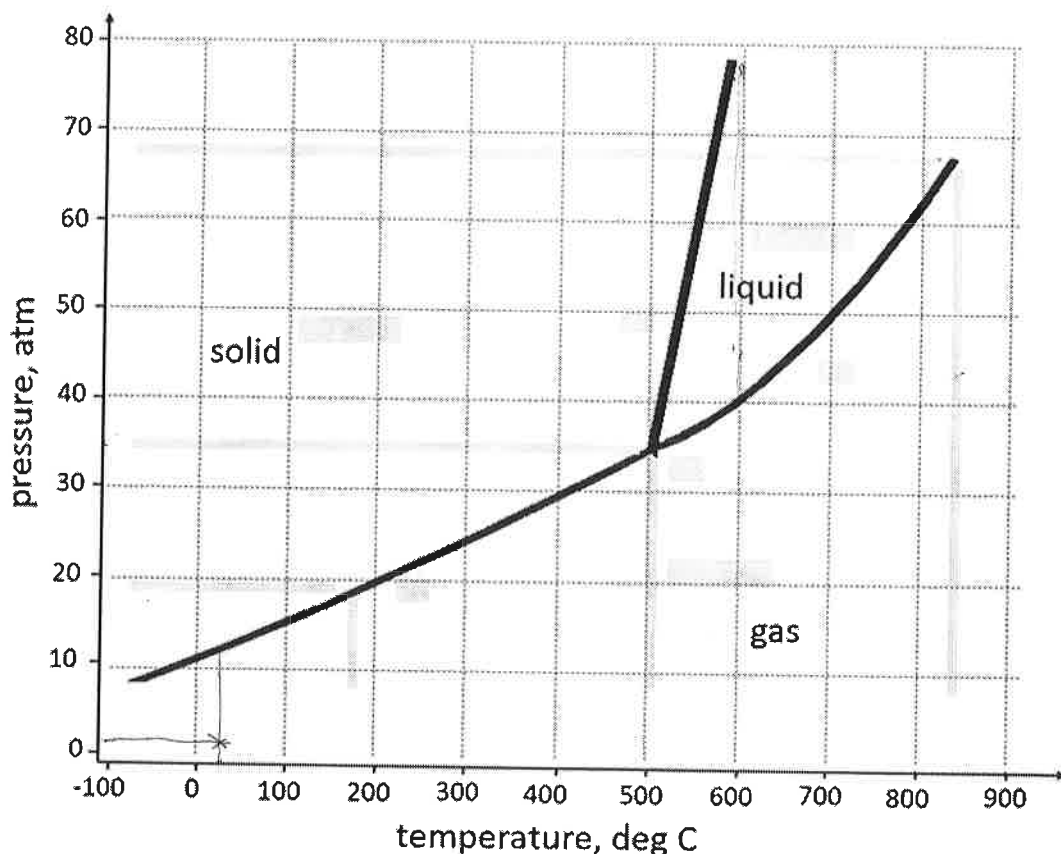
New volume: 2.23 decilitres

4

QUESTION 8:

12

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?

58 atm, 840°C, above this point it is a liquid ✓

Super-critical liquid ✓ (2)

- 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 RTP ($\sim 27^\circ\text{C}$, 1 atm) it would 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.

500°C, 35 atm are the lowest individual values.

If pressure is lowered here, the solid of X becomes a gas (vaporisation)

If temperature is lowered here, X will become solid (Freezing/Solidification)

As a mix, around 590°C minimum and 40 atm pressure.

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

'Boiled' being a transition between liquid and gas, this cannot be done at 200°C. The solid can be vapourised, but not boiled.

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

50 atm

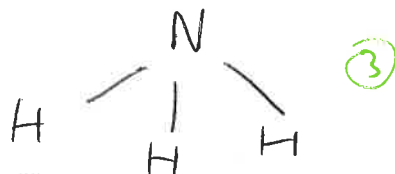
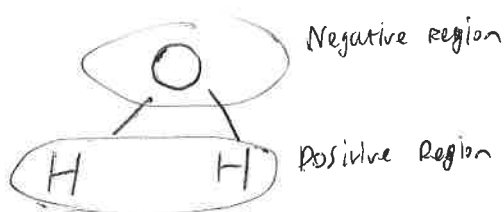
- 2p f) Does the melting point of X increase, decrease or stay the same as the pressure is increased?

The melting point temperature increases as the pressure is increased.

QUESTION 9: 6

3p

- 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 molecules are 'dipolar', meaning the electrons in the molecule are biased in their distribution, in this case to the oxygen atom within the water molecule. As a result, there is a 'positive' and a 'negative' region. This allows for the positive region of one water molecule to attract to the negative region of another molecule, and form a hydrogen bond. This is why H_2O requires more energy than the 'less dipolar' NH_3 to boil.

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.

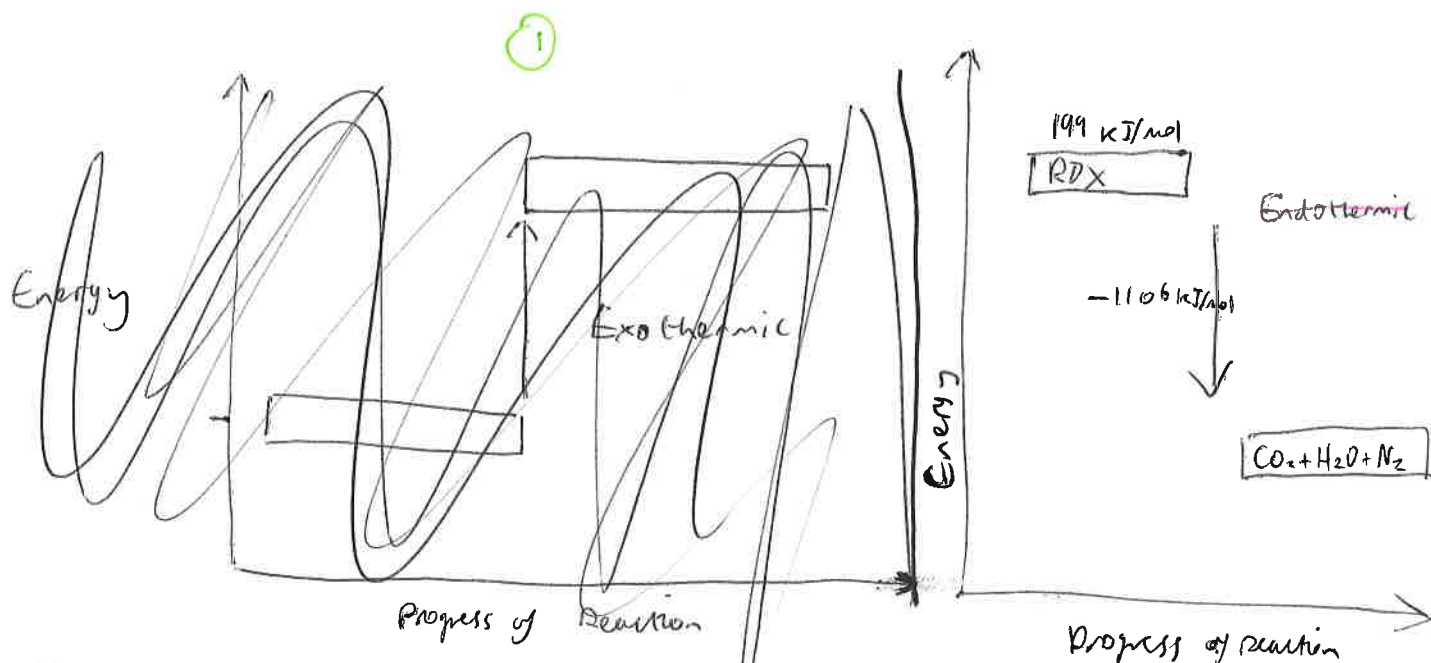
Water reacts with certain materials, notably iron, by speeding up the oxidation process that occurs turning 'Fe' into 'FeO' (ferric oxide), which is also known as rust. OME devices that use iron, or certain types of steel (which contain iron), will become structurally compromised if enough 'Fe' becomes oxidised.

(3)

QUESTION 10:

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

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



- 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.

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EXTRA CREDIT (if earned in class): 3 points

