

ACDA5014 ADVANCED CHEMISTRY OME 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.

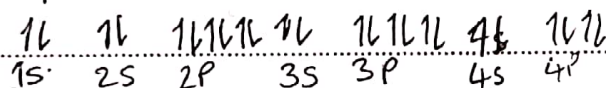
PERIODIC TABLE AND REFERENCE DATA CAN BE TORN OFF OF THE EXAM

THERE ARE 11 QUESTIONS, 100 POINTS TOTAL (PLUS 1 EXTRA CREDIT). TIME 120 min

QUESTION 1:

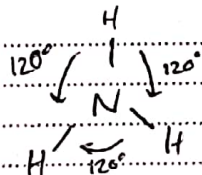
For each of the following statements determine if it is true or false. Justify your answer.

- 0p 1. (2p) Chromium metal (atomic number 24) produces silver-white colour in a standard flame test as a result of the excitation of valence electrons. Chromium atom has 4 unpaired electrons in the outermost shells that can be excited in such test.



True

- 0p 2. (2p) In ammonia, NH_3 , which is used in the industrial production of ammonium nitrate, the bond angle between a nitrogen atom and two hydrogen atoms is 120° .



True

- 0p 3. (2p) In 1 L of 1.5 M solution of NaCl there is 87.8 g of table salt.

$$\text{number of moles (n)} = \frac{87.8 \text{ g}}{58.44 \text{ g/mol}} \Rightarrow 1.5 \text{ mol}$$

$$\text{moles of Solute} \Rightarrow 1.5$$

$$\text{total moles of Solution}$$

1 litre Solution =

false.

- 1p 4. (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.

False

$$PV = nRT \text{ when atm is 1 and 273 K}$$

5. (2p) Activation energy of nitrocellulose and RDX is 86 kJ/mol and 199 kJ/mol, respectively. RDX is less stable than nitrocellulose.

0p

RDX requires less energy $(199 - 86) = 113 \text{ kJ/mol}$ than nitrocellulose to reach the transition state and begin producing products

TRUE

6. (2p) Hess's Law states that the enthalpy change for a chemical reaction is independent of the route taken.

0p

False

Hess's cycle

$$\Delta H_{\text{total}} = \Delta H_1 - \Delta H_2$$

REACTANTS

PRODUCTS

 ΔH_1

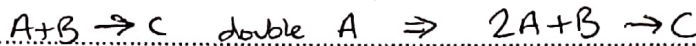
ELEMENTS

 ΔH_2

7. (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.

0p

True



more A means that B can be interacted with quicker to produce C.

8. (2p) All combustion reactions are exothermic.

2p

exothermic reaction = $\Delta H < 0$ giving a negative number/value this is the energy given away by the reaction

True ✓

9. (2p) According to the kinetic theory of gases which leads to the ideal gas law, one of the assumptions is that when the gas particles collide, they lose their kinetic energy.

1p

False ✓ - Energy can not just disappear it has to be transferred.

10. (2p) The rate of decomposition of the explosive material decreases when the temperature increases.

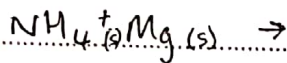
2p

False ✓ rate of decomposition is directly proportional to the increase of temperature.

QUESTION 2:

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.

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



- Op b) (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

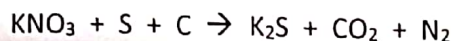
Magnesium oxide (solid) -601 kJ/mol

Water (gas) - 242 kJ/mol

- Op c) (3p) How does the heat of reaction from this reaction compare with 2.8 kJ⁻¹ provided by one gram of TNT.

QUESTION 3:

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



- a) (1p) Balance this equation using the smallest integer coefficients. Include all coefficients even if the value is 1.

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- b) (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 ?

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

1 mol of potassium nitrate will give 22.4L @ STP

KNO_3 mm = 90 ~~g~~ 1 mole

$\therefore \frac{1}{2}$ mol = 11.2L @ STP

- d) (3p) 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?

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QUESTION 4:

(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 narrative or cartoons or both.

op ~~IBF~~ inter particle forces are ~~the forces~~ the forces that hold the atoms in a molecule and are strong but stronger in metals. Intermolecular forces hold molecules in a substance and are weak, Van der Waals forces are the weakest IMF with London dispersion being one of these.

Macroscopically Solid $\rightarrow$ melts $\rightarrow$ liquid $\rightarrow$ boils $\rightarrow$ gas
for IFF's

QUESTION 5:

Mercury (II) fulminate $\text{Hg}(\text{CNO})_2$ is a primary explosive whereas mercury (II) cyanate $\text{Hg}(\text{OCN})_2$ is not explosive in nature.

- op a) (3p) Draw all resonance structures, three for each anion, fulminate (N is a central atom) and cyanate (C is a central atom).

- op b) (3p) Explain in terms of formal charges why fulminate is explosive and cyanate is not

c) (2p) What would be the other reason to explain explosive character of mercury fulminate?

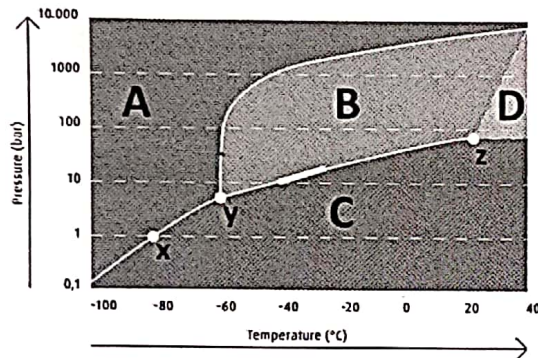
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QUESTION 6:

The phase diagram of carbon dioxide, CO_2 , is shown below:



a) (2p) Identify each area of the plot:

- 2p
- A: Solid
- B: Liquid
- C: Gas
- D: Plasma

b) (1.5p) Give the names of points x, y and z:

- 1p
- point x: Equalibrium line
- point y: Triple point
- point z: Critical point

c) (0.5p) Which phase can exist at SATP? Gas

d) (0.5p) If a sample of this substance is cooled from -45 degC to -85 degC at a pressure of 100 bar, what phase change will occur? Freeze from liquid to solid

e) (0.5p) What name is given to the change from phase C to phase B?

Condensation Gas to liquid

f) (1p) What are the boiling and freezing points of this substance at 50 bar?

freezing -60°C, boiling 0°C

g) (1p) Estimate the conditions of a critical point. 90 bar, 20°C

QUESTION 7:

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 that 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 dm³ of CO_2 , 44.8 dm³ of H_2O , and 22.4 dm³ of N_2 .

$$C_6 \quad \frac{44.8}{-p} = \frac{nRT}{-p} \quad \begin{array}{l} 1 \text{ part } CO_2 \\ 44g \end{array} \quad \begin{array}{l} 1 \text{ part } H_2O \\ 33g \end{array} \quad \begin{array}{l} 5 \text{ part } N_2 \\ 14g \end{array}$$

E

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

N_2 gasses will require a lot of energy to form and will give off a lot of energy so they will have the most excitation and will move the fastest

- c) (2p) For the explosive determined in a) calculate the per cent by mass of oxygen.

$$\Delta_{det} = \frac{\Delta H_{det} \times 1000}{\text{molar mass}}$$

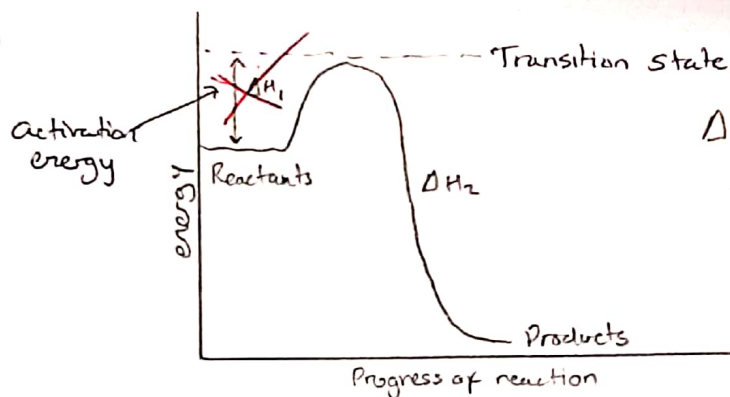
- d) (3p) The oxygen balance of an explosive is the mass of oxygen either in excess (the balance is positive) or in deficit (the balance is negative) of that required for complete oxidation of C and H. The oxygen balance is expressed as a percentage of the molar mass of the explosive. Calculate the oxygen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

$$OB = \frac{-1600 \times (2x + (\frac{y}{2}) + m - z)}{mm(152)} \quad \text{when}$$

QUESTION 8:

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



$$\Delta H_{\text{det}} = \Delta H_2 - \Delta H_1$$

$$\therefore \Delta H_2 - \Delta H_1 = -1106 \text{ kJ mol}^{-1}$$

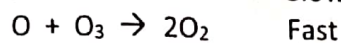
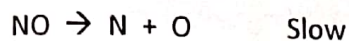
2. b) (2p) The activation energy for the explosive detonation of RDX is 199 kJ mol^{-1} whereas the activation energy for the explosive detonation of mercury fulminate is 105 kJ mol^{-1} . Define the term activation energy and hence comment on the relative stability of these two explosives.

Activation energy is the energy needed to be added for the reaction to take place. Without it or too little the transition state can not be reached and no products are produced.

As mercury fulminate needs 94 kJ mol^{-1} less than RDX to reach the transition state it is more likely to be set off than RDX. So mercury fulminate is less stable than RDX. ✓

QUESTION 9:

Nitrous oxide, NO_2 , is a common propellant for rocket motors. The proposed mechanism for the formation of NO_2 is shown below:



a) (2) Write the overall chemical equation for the reaction with the above mechanism.

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b) (4p) Three experiments were conducted to discover the initial rate of formation of NO_2 values as the concentrations of the reactants change. Use the data in the table below to determine the order of the reaction with respect to each reactant and write the rate law for the reaction

experiment	NO , mol/L	O_3 , mol/L	Initial rate, mol/L-s
1	0.012	0.020	0.102
2	0.024	0.020	0.204
3	0.024	0.040	0.204

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c) (3) Calculate the value of the rate constant. What is the unit of k?

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d) (2p) How does the rate law support the mechanism of this reaction?

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QUESTION 10:

(4p) A 500 g sample of TNT ($\text{C}_7\text{H}_5\text{N}_2\text{O}_6$) is burned in a bomb calorimeter containing 610 g of water at an initial temperature of 20.0 degC. The heat capacity of the calorimeter is 420 J/degC. Once the reaction is completed final temperature of the water and calorimeter increased to 23.0 degC. Using these data, calculate the heat of combustion of TNT in kJ/mol. The specific heat of water is 4.184 J/g-degC.

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QUESTION 11:

Many fireworks contain metal compounds that emit visible light. The colours given by barium and calcium compounds and their wavelengths are given in the table

metal	colour	Wavelength, nm
Barium	Green	554
Calcium	Orange-red	616

a) (3p) Which of these two colours has the higher energy? Show your calculations.

Green

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b) (3p) Write the full electron configuration for calcium and show the electrons in orbitals.
 For barium write the shorthand electron configuration ONLY.

1p

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ ✓

barium

~~$Ba 6s^2$~~



Ca

c) (2p) The colours seen are a result of the emission of visible light. State how these colours are produced.

op

As the electrons are emitted they have an energy this energy is equivalent to a wavelength of light if it falls within the visible spectrum of 400-700nm then a visible colour is produced with violet being the shorter wavelength and red being the longer wavelength anything above 700nm goes into the IR spectrum

- d) (2p) Two, out of six stable isotopes of barium are ^{132}Ba and ^{138}Ba . For each of these isotopes, determine the number of neutrons.

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EXTRA CREDIT (must give all three)

What are three elements predicted by Mendeleev?

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