

ACDB4011 CHEMISTRY OME FINAL EXAM

40.5

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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 11 QUESTIONS, 100 POINTS TOTAL TIME 120 min

14

QUESTION 1:

For each of the following statements determine if it is **TRUE** or **FALSE**. Circle the correct answer. In each case justify your choice.

1. (2p) The elements in the periodic table are arranged in the order of increasing number of electrons.

TRUE / FALSE In order of increasing protons, but they will have equivalent numbers of protons and electrons.

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

TRUE / FALSE Shorter distance between nuclei results in greater forces of attraction.

3. (2p) In 1 mole of water there are 6.02×10^{23} atoms of oxygen.

TRUE / FALSE 1 mol = Avogadro's Constant = 6.02×10^{23} .
 $H_2O = 1 \text{ mol of } O = 6.02 \times 10^{23}$

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.

TRUE / FALSE $PV = nRT$, describes the gas behaviour irrespective of temperature and pressure equalling 0.

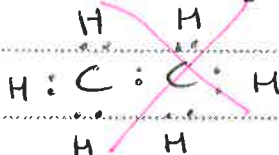
5. (2p) Activation energy of nitrocellulose and RDX is 86 kJ/mol and 199 kJ/mol, respectively. RDX is less stable than nitrocellulose.

TRUE / ~~FALSE~~ Lower activation energy = Less stable

Nitrocellulose = Less stable ✓

6. (2p) The C_2H_4 molecule has six bonding electron pairs and no lone pairs.

TRUE / ~~FALSE~~



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.

~~TRUE~~ / FALSE Doubled due to second order reaction

8. (2p) For every $10^\circ C$ increase in temperature, the rate of thermal decomposition of explosive material decreases by factor of two.

TRUE / ~~FALSE~~ Higher temperature = Higher rate of thermal decomposition ✓

9. (2p) Volume of gas produced in the detonation process decreases when the oxygen balance becomes less negative.

TRUE / ~~FALSE~~ Oxygen balance less negative = higher volume of gas produced due to less oxygen-starved reaction

10. (2p) The value of the equilibrium constant, K_{eq} , will increase when more reactants are added to the reaction system at a constant temperature.

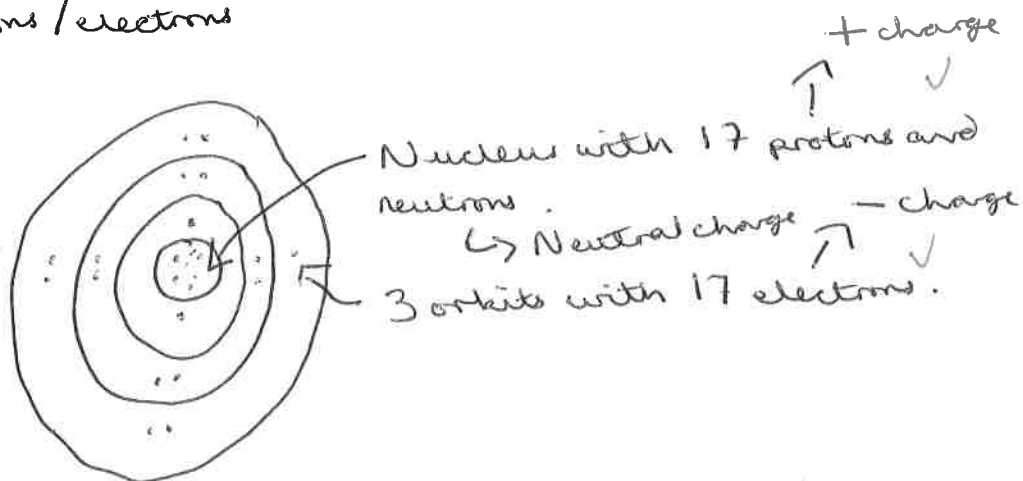
~~TRUE~~ / ~~FALSE~~ Equal temperature with more reactants will not result in a change to the constant ✓

7.5

QUESTION 2:

- a) (3p) 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.

Cl 17 protons / electrons



3 orbits ✓

3p

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

Mass number = ^{number} mass of the protons + neutrons ✓
 Average atomic mass of Cl = 35.453 due to the presence of Cl isotopes ✓ and the proportion / fraction of their abundance and number of neutrons. The average is taken from these.

3p

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

Protons = ~~35~~ 17 ✓

Neutrons = ~~35~~ 19

1p

- d) (1p) What is the charge on the chlorine atom when it achieves octet?

Negative

0.5p

7.5

7.5

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QUESTION 3:

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

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

Show your calculations.

$$c = \text{wavelength} \times \text{frequency} \therefore \nu = c/\lambda$$

$$\nu = 3 \times 10^8 / 0.616 = 4870129870 \text{ s}^{-1}$$

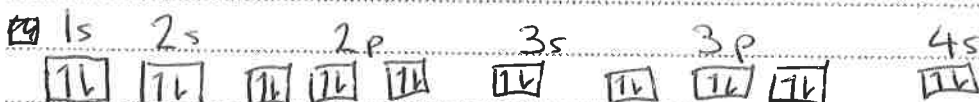
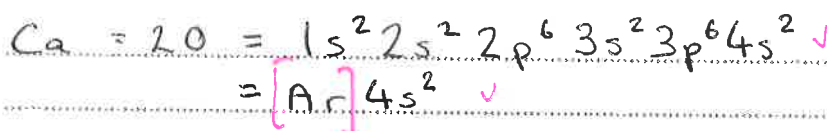
$$616 \text{ nm} = 6.16 \times 10^{-7} \text{ m}$$

$$E = h\nu = 6.6 \times 10^{-34} \times 4870129870$$

$$E = 3.21 \times 10^{-28} \text{ J}$$

$$3.21 \times 10^{-24} \text{ J}$$

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



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

Colours can be found on the electromagnetic spectrum at a certain wavelength visible to the naked eye. The colours will change as wavelength increases or decreases on the visible spectrum.

5

QUESTION 4:

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. 2p



b) (2p) What percentage of magnesium, by mass, is contained in the stoichiometric mixture? 1.5p

$$\text{Mol NH}_4\text{NO}_3 = (14.0067 \times 2) + (1.00797 \times 4) + (15.9994 \times 3) = 80.04348 \text{ g} \quad \textcircled{1} \checkmark$$

$$\text{M of Mg} = 24.312 \text{ g} \quad \textcircled{2}$$

$$\frac{\text{M of Mg}}{\text{Mol NH}_4\text{NO}_3 + \text{M Mg}} \times 100 = 30.37\%$$

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 3p

Ammonium nitrate (solid) -365 kJ/mol

Magnesium oxide (solid) -601 kJ/mol

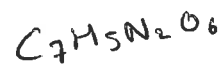
Water (gas) - 242 kJ/mol

$$(1 \times -365) = (1 \times -601) + (2 \times -242)$$

$$-365 = -1085$$

$$\text{Heat of reaction} = -720 \text{ kJ/mol} \quad \checkmark$$

reaction = exothermic as it releases net quantity of heat, signified by the negative value meaning heat was lost. ✓



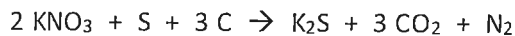
d) (3p) How does the heat of reaction from this reaction compare with 2.8 kJ g⁻¹ provided by one gram of TNT. Ⓟ

it is lower.

why?

QUESTION 5:

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



a) (4p) Assuming that the reaction above can be carried out at STP, how many grams of CO₂ are formed from the decomposition of 45 g of KNO₃? 0.5p

$$M = n \times m \quad N = n \times N_A$$

$$n \text{ of } \text{CO}_2 = \frac{M}{n}$$

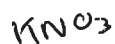
$$M \text{ of } \text{CO}_2 = 12.0112 + (2 \times 15.9994)$$

$$= 44.01 \quad \checkmark$$

$$= \frac{44.01}{3} = 14.67 \text{ g}$$

$$M \text{ of } \text{KNO}_3 = 39.102 + 14.0067 + (3 \times 15.9994) = 101.1069 \quad \checkmark$$

$$n \text{ of } \text{KNO}_3 = \frac{M}{m} = \frac{101.1069}{45} = 2.24682 \text{ mol}$$



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

$$M_r \text{ of } \text{KNO}_3 = 101.1069$$

$$n \text{ of } \text{KNO}_3 = 2.24682 \text{ mol}$$

- c) (4p) 45 g KNO_3 at STP is heated to 100°C 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. DO NOT USE THE IDEAL GAS EQUATION!

Boyle's Law

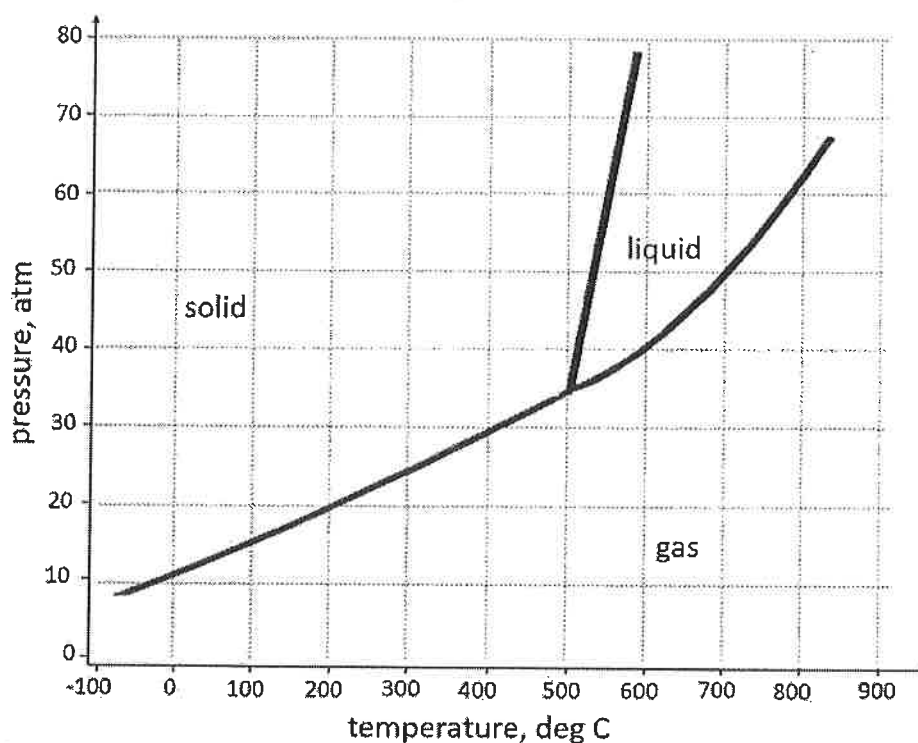
Gay-Lussac's Law

Avogadro's Law

$$= 2.67 \text{ L}$$

QUESTION 6:

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? How is substance X called above the critical point?

$T = 500^{\circ}\text{C}$, $P = 35\text{ atm}$

0p

- 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.

$T = 500^{\circ}\text{C}$ $P = 35\text{ atm}$

1p

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

50atm

2p

QUESTION 7:

(4p) The normal boiling point is 100° C for H₂O and -33.3° C for NH₃, even though the two molecules have almost identical atomic weights. Explain this difference in terms of intermolecular forces. Use an appropriate drawing to support your answer.

Op

NH₃ has weaker Van der Waals forces.

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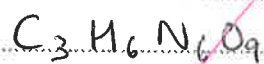
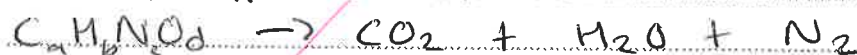
QUESTION 8:

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

$$M = 152 \quad m = 152 \quad n \Rightarrow m/M = 1 \text{ mol}$$

$$N = n \times N_A = 6.02 \times 10^{23}$$



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

H_2O will move fastest due to ^{being produced} having the same quantity of CO_2 but having the lowest molar mass of the gases produced.

2

- 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 the oxygen weight over the molar mass of the explosive. Calculate the oxygen balance for the explosive with the formula determined in part a).

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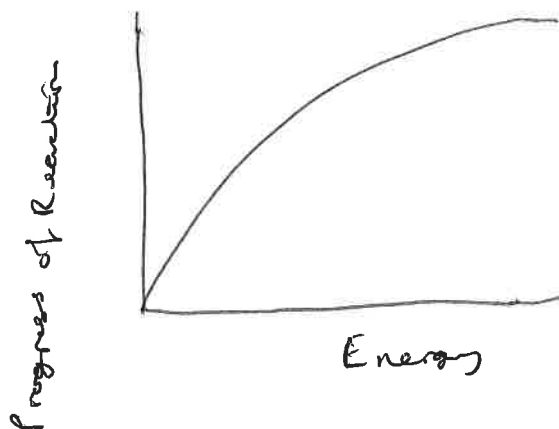
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QUESTION 9:

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.

op



o

o

- 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.

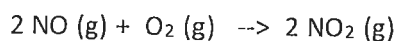
As activation energy increases, the fraction of colliding molecules that result in a reaction increases.

QUESTION 10:

(4p) A 500 g sample of TNT ($C_7H_5N_2O_6$) is burned in a bomb calorimeter containing 610 g of water at an initial temperature of $20.0^\circ C$. The heat capacity of the calorimeter is $420 J/^\circ C$. Once the reaction is completed final temperature of the water and calorimeter increased to $23.0^\circ C$. Using these data, calculate the heat of combustion of TNT in kJ/mol . The specific heat of water is $4.184 J/g \cdot ^\circ C$.

QUESTION 11:

Nitrous oxide, NO_2 , is a common propellant for rocket motors and it forms according to the following chemical equation:



- a) (4p) Three experiments were conducted to determine the values of the initial rate of formation of NO_2 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_2 , 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

Second order reaction

b) (3p) Calculate the **value** of the rate constant. What is the **unit** of k ?

Op

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c) (2p) Which direction will the equilibrium shift if the overall pressure of the system is increased?

Op

Equilibrium will shift to the left.

Diwedd/End

Op

Op