CHEM 504 Name:

Exam review 2022

Limiting reactants

1. Potassium superoxide, KO_2, is used in rebreather masks to generate oxygen according to the reaction below. If the mask contains 0.150 mol KO_2 and 0.100 mol water, how many moles of oxygen can be produced? What is the limiting reagent? **(Ans: 0.113 mol oxygen, KO_2 is limiting)**

$$4\ KO_{2(s)} + 2\ H_2O_{(\ell)} \rightarrow 4\ KOH_{(s)} + 3\ O_{2(g)}$$

2. Suppose 13.7 g of C_2H_2 reacts with 18.5 g O_2 according to the reaction below. What is the mass of CO_2 produced? What is the limiting reagent? **(Ans: 20.4 g, O_2 is limiting)**

$$2\ C_2H_{2(g)} + 5\ O_{2(g)} \rightarrow 4\ CO_{2(g)} + 2\ H_2O_{(\ell)}$$

3. Nitrogen gas can react with hydrogen gas to form gaseous ammonia. If 4.7 g of nitrogen reacts with 9.8 g of hydrogen, how much ammonia is formed? What is the limiting reagent? **(Ans: 5.7 g ammonia, nitrogen is limiting)**

4. One of the most common acids found in acid rain is sulfuric acid. Sulfuric acid is formed when gaseous sulfur dioxide reacts with ozone (O_3) in the atmosphere to form gaseous sulfur trioxide and oxygen. The sulfur trioxide forms sulfuric acid when it comes in contact with water. If 5.13 g of sulfur dioxide reacts with 6.18 g of ozone, how much sulfur trioxide is formed? What is the limiting reagent? **(Ans: 6.41 g sulfur trioxide, sulfur dioxide is limiting)**

5. Another way that sulfuric acid is formed in the atmosphere is when sulfur dioxide reacts with oxygen in a reaction catalyzed by dust in the atmosphere to form sulfur trioxide. If 7.99g of sulfur dioxide reacts with 2.18 g of oxygen, how much sulfur trioxide can form? What is the limiting reagent?
(Ans: 9.99 g sulfur trioxide, sulfur dioxide is limiting)

Determining Excess Reactants

6. In the reaction in problem #5 above, how much of the excess reactant remains after all of the limiting reactant has reacted? **(Ans: 0.18 g oxygen leftover)**

7. Heating together the solids NH_4Cl and $Ca(OH)_2$ can generate ammonia. Aqueous $CaCl_2$ and liquid H_2O are also formed. If a mixture of 33.0 g each of NH_4Cl and $Ca(OH)_2$ is heated, how many grams of NH_3 will form? What is the limiting reagent? Which reactant remains in excess, and in what mass? **(Ans: 10.5 g ammonia formed, ammonium chloride is the limiting reactant, 10.2 g of calcium hydroxide remain unreacted)**

8. Nitrogen monoxide is formed primarily in car engines, and it can react with oxygen to form gaseous nitrogen dioxide. Nitrogen dioxide forms nitric acid when it comes in contact with water, another component of acid rain. If 3.13 g of nitrogen monoxide reacts with 4.16 g of oxygen, how much nitrogen dioxide will form? What is the limiting reagent? Which reactant remains in excess, and in what mass? **(Ans: 4.80 g nitrogen dioxide, nitrogen monoxide is limiting reactant, 2.49 g of oxygen not reacted)**

Simple gas laws

1. If 15.0 liters of neon at 25.0 °C is allowed to expand by 45%, what must the new temperature be to maintain constant pressure? **(Ans: 430 K)**

2. If 540.0 mL of nitrogen at 0.00 °C is heated to a temperature of 100.0 °C what the change in volume be?
(Ans: 198 mL)

3. A gas occupies 4.31 liters at a pressure of 0.755 atm. Determine the volume if the pressure is increased to 1265 mmHg. **(Ans: 1.96 L)**

4. If a gas at 25.0 °C occupies 3.60 liters at a pressure of 1.00 atm, by what percentage will its volume be reduced at a pressure of 2.50 atm? **(Ans: volume reduced by 60%)**

5. A flexible container at an initial volume of 5.120 L contains 325.00 g of gas. The mixture is 65% carbon dioxide (CO_2) and 35% neon. The next day the volume is measured as 4.89 L and neon is found to have escaped the container. Assuming the pressure and temperature of the gas remain constant, calculate the mass of neon that escaped. **(Ans: 9.48 g neon escaped)**

6. A container with a volume of 25.47 L holds 1.750 mol of oxygen gas (O_2). What is the volume if 35.46 g of sulfur dioxide (SO_2) are added to the container, assuming the pressure and temperature remain constant? **(Ans: 33.52 L)**

7. A 30.0 L sample of nitrogen inside a rigid, metal container at 20.0 °C is placed inside an oven whose temperature is 50.0 °C. The pressure inside the container at 20.0 °C was at 3.00 atm. What is the pressure of the nitrogen measured in kPa after its temperature is increased to 50.0 °C? **(Ans: 335 kPa)**

8. If a gas in a closed container is pressurized from 15.0 atmospheres to 23.0 atmospheres and its original temperature was 25.0 °C, by what factor was its Kelvin temperature increased? **(Ans: Kelvin temperature increased by a factor of 1.53)**

9. The initial temperature of a sample of argon is 20.0° C. The pressure is decreased from 720.0 mm Hg to 360.0 mm Hg and the volume decreases to one third its original value. What was the change in temperature of the argon? **(Ans: -244 K, a decrease of 244 K)**

10. A sample of nitrogen gas occupies a volume of 2.00 L at 756 mm Hg and 0.00° C. The volume increases by 2.00 L and the temperature decreases to 137 K while one third of the molecules escape. What is the final pressure exerted on the gas? **(Ans: 126 mmHg)**

11. If equal amounts of helium and argon are placed in a porous container and allowed to escape, which gas will escape faster and how much faster? **(Ans: helium 3.16 times faster)**

12. What is the molar mass of a gas which diffuses 10 times slower than hydrogen? **(Ans: 202 g/mol)**

13. 2.278×10^{-4} mol of an unidentified diatomic gas effuses through a tiny hole in 95.70 s. Under identical conditions, 1.738×10^{-4} mol of argon gas takes 81.60 s to effuse. Identify the unknown diatomic gas. **(Ans: oxygen, O_2)**

14. A 2.40 L container of hydrogen (H_2) and a 4.80 L nitrogen (N_2) container are stored in a room under identical conditions. If 2/3 of the hydrogen escapes in 6 hours how long will it take for half the nitrogen to escape? **(Ans: 33.5 hours)**

Ideal gas law

1. How many moles of gas are contained in 890.0 mL at 21.0 °C and 750.0 mm Hg pressure? **(Ans. 0.0364 mol)**

2. 1.09 g of H_2 is contained in a 2.00 L container at 20.0 °C. What is the pressure in this container in mmHg? **(Ans. 4930 mmHg)**

3. Calculate the volume 3.00 moles of a gas will occupy at 24.0 °C and 762.4 mm Hg. **(Ans. 72.89 L)**

4. How many moles of gas would be present in a gas trapped within a 100.0 mL vessel at 25.0°C at a pressure of 2.50 atmospheres? **(Ans. 0.0102 mol)**

5. How many moles would be present in a gas trapped within a 37.0 L vessel at 80.00°C at a pressure of 2.50 atm? **(Ans. 3.17 mol)**

6. What volume will 1.27 moles of helium gas occupy at STP? **(Ans. 28.45L)**

7. At what pressure would 0.150 mole of nitrogen gas at 23.0 °C occupy 8.90 L? **(Ans. 41.47 kPa)**

8. What volume would 32.0 g of NO_2 gas occupy at 3.12 atm and 18.0 °C? **(Ans. 5.32 L)**

9. How many moles of gas are contained in a 50.0 L cylinder at a pressure of 100.0 atm and a temperature of 35.0°C? If the gas weighs 79.14 g, what is its molar mass? **(Ans. 4.00 g/mol)**

10. An amount of an ideal gas at 290.9 K has a volume of 17.05 L at a pressure of 1.40 atm. What is the pressure of this gas sample when the volume is halved and the absolute temperature is multipled by four? **(Ans. 1134 kPa)**

11. A balloon has a mass of 0.5 g when completely deflated. When it is filled with an unknown gas, the mass increases to 1.7 g. You notice on the canister of the unknown gas that it occupies a volume of 0.4478 L at a temperature of 50 °C. You note the temperature in the room is 25 °C. Identify the gas. **(Ans. Cl_2)**

12. A 10.20 g sample of a gas has a volume of 5.25 L at 23.0 °C and 751 mmHg. If 2.30 g of the same gas is added to this constant 5.25 L volume and the temperature raised to 67.0 degrees Celsius, what is the new gas pressure? **(Ans. 140.8 kPa)**

13. A gas consisting of only carbon and hydrogen has an empirical formula of CH_2. The gas has a density of 1.65 g/L at 27.0 °C and 97.86 kPa Determine the molar mass of the gas. **(Ans. 42.06 g/mol)**

14. 13.9 grams of an unknown gas is placed in a 5.00 L container. It has an initial pressure at 58.6 kPa and initial temperature at 60.0 °C. What is the name of this gas? **(Ans. Xe)**

15. A 19.5 L flask at 15 °C contains a mixture of three gases: N_2 (2.50 mol), He (0.38 mol), and Ne (1.34 mol). Calculate the partial pressure of neon gas in the mixture. **(Ans. 164.1 kPa)**

16. A 1.00 L flask is filled with 1.25 g of argon at 25.0 °C. Ethane vapor (C_2H_6) is then added to the same flask until the total pressure is 1.050 atm. What is the mass of ethane that was added to the flask? **(Ans. 0.350 g)**

Thermodynamics

(Some answers at the end of this section)

1. a) Complete the following table: ***(Answer on p.8)***

H of reactants (kJ)	H of products (kJ)	Enthalpy Change, ΔH (kJ)	Exo or Endo?
44	73		
288	88		
44	41		
555		-55	
222	444		
33		255	
	222	-88	
	55	38	

b) Draw an energy versus progress of reaction profile using the numbers from the first row of the above chart.

2. A student dissolved 1 g of each of four substances in water in a laboratory experiment.
The following table illustrates the change in temperature after the solids dissolved. ***(Answer on p.8)***

Substances	T_{intial}	T_{final}
NH_4Cl	23 °C	19 °C
NaOH	23 °C	60 °C

Which represents an exothermic reaction, and which represents an endothermic reaction? Explain.

3. Calculate ΔH for the formation of carbon dioxide gas from oxygen gas and solid carbon given the following data:
(Ans: -393.5 kJ/mol)

1) $C_{(s)} + \frac{1}{2} O_{2\,(g)} \rightarrow CO_{(g)}$ ΔH = -110.5 kJ/mol

2) $2CO_{2\,(g)} \rightarrow O_{2\,(g)} + 2CO_{(g)}$ ΔH = 566.0 kJ/mol

4. Endothermic? Or Exothermic?

a) $H_2O_{(g)} \rightarrow H_2O_{(l)}$ + energy

b) $H_2 + 0.5\ O_2 \rightarrow H_2O$ ΔH = -241.8 kJ

c) $H_2SO_{4\,(l)}$ + Heat → $H_{2\,(g)} + \frac{1}{8} S_{8\,(s)} + 2\ O_{2\,(g)}$

d) $N_{2\,(g)} + O_{2\,(g)} \rightarrow 2\ NO_{(g)}$ ΔH = 180.8 kJ

e) $C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$ + 394 kJ

Ans: a) Exo b) Exo c) Endo d) Endo e) Exo

5. Which of the following are ***endothermic*** changes?

a. Melting ice
b. A burning candle
c. Dew forming on a lawn
d. Moth balls undergoing sublimation
e. Iron rusting
f. Water decomposing by electrolysis

Ans: A, D, F

4. Carbon disulfide is a very flammable solvent. It **burns** according to the following equation:

$CS_{2\,(l)} + 3\ O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2\ SO_{2\,(g)}$

Calculate ΔH for the above reaction using the following data **(Ans: -1076 kJ)**

1) $C_{(s)} + 2\ S_{(s)} \rightarrow CS_{2\,(l)}$ ΔH = 88 kJ

2) $C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$ ΔH = -394 kJ

3) $S_{(s)} + O_{2\,(g)} \rightarrow SO_{2\,(g)}$ ΔH = -297 kJ

5. Calculate the heat of combustion for ammonia, $NH_{3\,(g)}$. **(Ans: 3348 kJ)**

$12\ NH_{3\,(g)} + 21\ O_{2\,(g)} \rightarrow 8\ HNO_{3\,(aq)} + 14\ H_2O_{(l)} + 4\ NO_{(g)}$

Given:

$NH_{3(g)} + 1.25\ O_{2(g)} \rightarrow NO_{(g)} + 1.5\ H_2O_{(l)}$ ΔH = -293 kJ

$NO_{2(g)} + (1/3)\ H_2O_{(l)} \rightarrow (2/3)\ HNO_{3(aq)} + (1/3)\ NO_{(g)}$ ΔH = -45 kJ

$NO_{(g)} + 0.5\ O_{2(g)} + 59\ kJ \rightarrow NO_{2(g)}$

6. An unknown metal with a mass of 150 g and a temperature of 95 °C is placed into a Styrofoam cup containing 65 g of water at a temperature of 14 °C. When the system reaches equilibrium, the resulting temperature is 26 °C. What is the specific heat capacity of the unknown metal? (Assume no loss of heat energy to the surroundings.) **(Ans: 0.32 J/g °C)**

7. Diborane, B_2H_6, is highly reactive and was once considered as a possible rocket fuel for the U.S. space program. Calculate ΔH for the synthesis of diborane from its constituent elements: **(Ans: -288 kJ)**

$2\ B_{(s)} + 3\ H_{2\,(g)} \rightarrow B_2H_{6\,(l)}$

Reaction	ΔH (kJ)
$2\ B_{(s)} + 1.5\ O_{2(g)} \rightarrow B_2O_{3(s)}$	-1273
$B_2H_{6(l)} + 3\ O_{2(g)} \rightarrow B_2O_{3(s)} + 3\ H_2O_{(g)}$	-2035
$H_{2(g)} + 0.5\ O_{2(g)} \rightarrow H_2O_{(l)}$	-286
$H_2O_{(g)} \rightarrow H_2O_{(l)}$	-44

8. Barbeque propane gas, C_3H_8, burns according to the following equation:

$$C_3H_{8\,(g)} + 5\ O_{2\,(g)} \rightarrow 3\ CO_{2\,(g)} + 4\ H_2O_{\,(g)}$$

How many grams of propane are needed to provide the 980 kJ required to cook a salmon steak? **(Ans: A)**

	ΔH_f (kJ/mol)
$3\ C_{(s)} + 4\ H_{2(g)} \rightarrow C_3H_{8(g)}$	-103.8
$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$	-394.0
$H_{2(g)} + ½\ O_{2(g)} \rightarrow H_2O_{(g)}$	-241.8

A) 21.1 g
B) 19.1 g
C) 9.6 g
D) 10.6 g

9. A calorimeter is filled with 50.0 mL of 1.0 mol/L $NaOH_{(aq)}$ at an initial temperature of 22.3 °C and 20.0 mL of 2.5 mol/L $HCl_{(aq)}$ is added at this same temperature. After the neutralization reaction comes to completion, the final temperature of the resulting solution is found to be 29.8 °C.

Determine the ΔH (kJ/mol) for the neutralization for the reaction with respect to the $NaOH_{(aq)}$ solution. (Assume the density and specific heat for all solutions to be equal to that of water) **(Ans: -44000 J or -44 kJ/mol NaOH)**

10. A bomb calorimeter contains a 150.0 g of water at an initial temperature of 22.0 °C. When 1.00 g of diamond is burned in the calorimeter to produce CO_2, the final temperature of the water reaches 74.5 °C.

$$C_{(diamond)} + O_{2(g)} \rightarrow CO_{2(g)} \qquad \Delta H = ?$$

What is the ΔH (kJ/mol) for the combustion of carbon in the form of diamond?
(Ans: ΔH is -396 kJ/mol or -396 000 J/mol.)

11. Use the table of **bond energies** to estimate ΔH for the following reactions:

a. $2H_2 + O_2 \rightarrow 2\ H_2O$ **(Ans: -470 kJ/mol)**
b. $2NH_3 \rightarrow N_2 + 3H_2$ **(Ans: -219 kJ/mol)**
c. $2CO + O_2 \rightarrow 2CO_2$ **(Ans: -328 kJ/mol)**
d. $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ **(Ans: -173 kJ/mol)**

12. Without consulting a table of bond energies, find the bond energy of H-Cl on a per mole basis if H_2's and Cl_2's bond energies are 436 kJ/mol and 243 kJ/mol respectively, and the ΔH for the following reaction is -185 kJ/mol of H_2.
$H_2\ (g) + Cl_2\ (g) \rightarrow 2\ HCl\ (g)$ **(Ans: 432 kJ/mol HCl)**

13. The heat of fusion of water is 334 J/g. How much energy is required to melt 50.0 g of ice into liquid water?
(Ans: 16700 J = 16.7 kJ)

14. How much heat is needed to transform 2.0 kg of ice at -20.0 °C to liquid water at 100°C? Sketch the graph. **(Ans: 1585 kJ)**

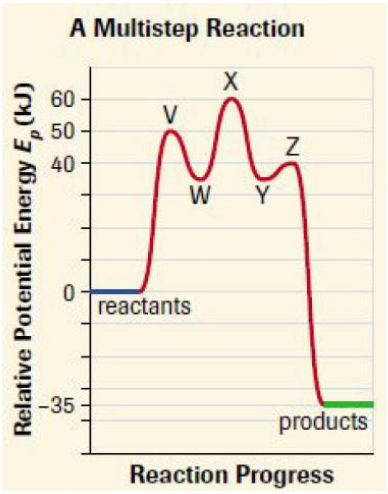
15. Calculate the heat released by cooling 54.0 g H_2O from 57.0 °C to -3.0 °C. **(Ans: 31.1 kJ)**

16. Bromine melts at −7.25 °C and boils at 58.8 °C. The enthalpy of fusion of bromine is 10.57 kJ/mol and the enthalpy of vaporization of bromine is 29.96 kJ/mol. The specific heat capacity of liquid bromine is 0.474 J/g·°C. How much heat, in kJ, is required to convert 25.0 g of solid bromine at −7.25 °C to the gas phase at 58.8 °C? **(Ans: 7.12 kJ)**

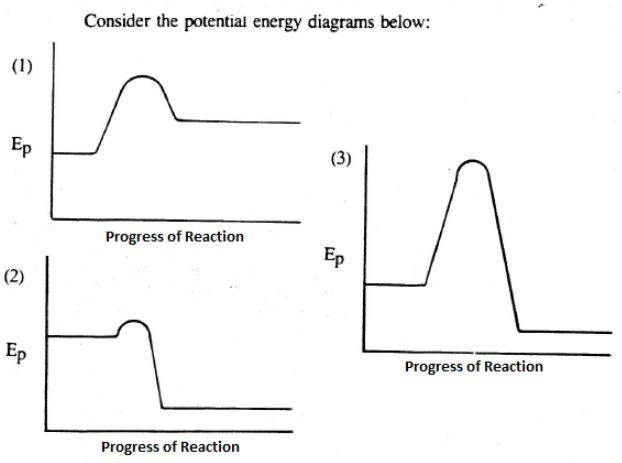
17. What amount of heat (in kJ) is required to convert 10.1 g of an unknown solid (molar mass = 67.44 g/mol) at −15.4 °C to a liquid at 42.7 °C? (heat capacity of solid = 1.95 $J\ g^{-1}\ °C^{-1}$; specific heat capacity of liquid = 1.18 $Jg^{-1}\ °C^{-1}$; ΔH_{fus} = 5.72 kJ/mol; T_{fus} = 28.3 °C) **(Ans: 1.89 kJ)**

18. In the following reaction, A + B → C, the enthalpy change of the forward reaction is ΔH = -36 kJ/mol and the activation energy for the forward reaction is 73 kJ/mol.
    - **a.** Draw a potential energy diagram for the reaction. **(*Answer on p.8*)**
    - **b.** What is the activation energy the reverse reaction? **(Ans: 109 kJ/mol)**

19. Use the multi-step reaction shown to answer the following:
    a. What is the reaction enthalpy (ΔH) for the forward reaction? **(Ans: ΔH = -35 kJ)**
    b. Overall, is the forward reaction exothermic or endothermic? **(Ans: Exo)**
    c. Which letters represent activated complexes? **(Ans: V, X, Z)**
    d. Which letters represent intermediates? **(Ans: W and Y)**
    e. What is the activation energy for the first step of the forward reaction? **(Ans: 50 kJ)**
    f. What is the activation energy for the first step of the reverse reaction? **(Ans: 75 kJ)**



20. Which diagram is described by each of these statements?
    a. An exothermic reaction that is unlikely to occur at room temperature. **(Ans: diagram 3; high E_a)**
    b. An endothermic reaction. **(Ans: diagram 1)**
    c. The activation energy (E_a) is greater than the energy released (ΔH). **(Ans: diagram 3)**
    d. A reaction that may occur spontaneously **(Ans: diagram 2; very tiny E_a)**



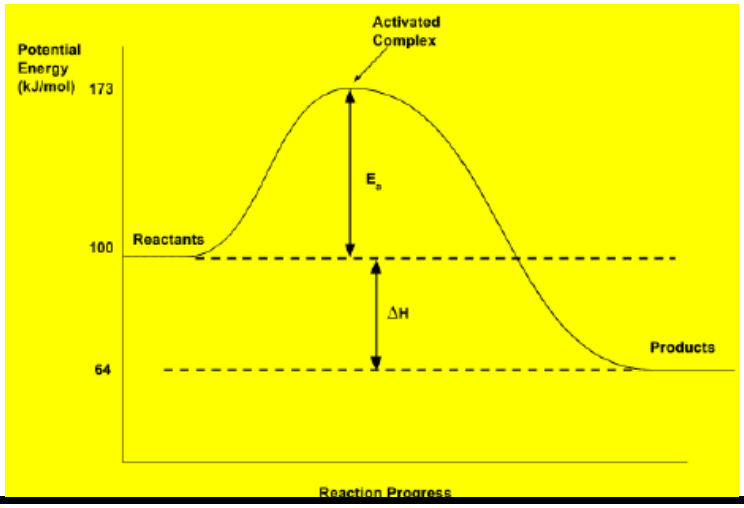
Thermodynamics – Selected Answers:

1.

H of reactants (kJ)	H of products (kJ)	Enthalpy Change, ΔH (kJ)	Exo or Endo?
44	73	**29**	**Endo**
288	88	**-200**	**Exo**
44	41	**-3**	**Exo**
555	**500**	-55	**Exo**
222	444	**222**	**Endo**
33	**288**	255	**Endo**
310	222	-88	**Exo**
17	55	38	**Endo**

2. NH_4Cl: Endo since temperature of solution decreased and thus energy was absorbed by reaction
   NaOH: Exo since temperature of solution increased and thus energy was released by reaction

18a.



Rates of reaction

1. Pick the fastest and slowest reactions from the list below. All are at room temperature. Explain your choices.
   (Ans. (a) is the fastest since it is an ionic reaction – specifically an acid-base neutralization reaction which is very fast; (b) is the slowest because it involves breaking and forming many covalent bonds)

a. $2\ H_3PO_4\ (aq) + 3\ Ca(OH)_2\ (aq) \rightarrow 6H_2O\ (l) + Ca_3(PO_4)_2\ (s)$

b. $C_4H_{10}\ (g) + 6.5\ O_2\ (g) \rightarrow 5\ H_2O\ (g) + 4CO_2\ (g)$

c. $O_{2(g)}\ (g) + 2\ Cl_{2(g)}\ (g) \rightarrow 2\ OCl_{2(g)}\ (g)$

2. A cube of calcium is added to water. A second cube is first sliced parallel to one of its bases and then added to water. Which will react faster, and how much faster will it react, if all other conditions remain the same?
   (Ans. The second cube is 1.33 times faster than the first)

3. If the rate of the reaction $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2\,(g)}$ is described by the formula:

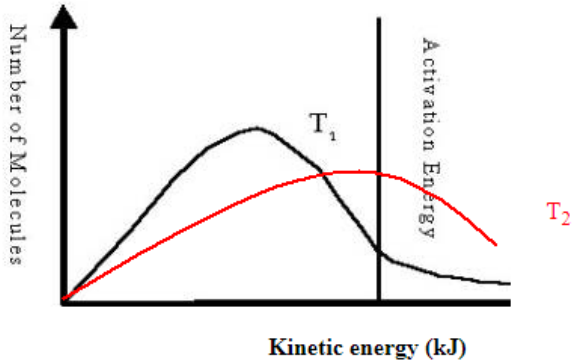
$$\text{Rate} = k[NO]^2[O_2]$$

what will happen if you triple the concentration of NO gas? **(Ans. New rate = 9 times faster)**

4. A) What is the name of an agent which lowers the activation energy required for a reaction? **(Ans. catalyst)**
   B) What is the name of an agent which raises the activation energy required for a reaction? **(Ans. inhibitor)**

5. At 20°C, the following reaction is extremely slow: $CH_4\,(g) + 2\,O_2\,(g) \rightarrow CO_2\,(g) + 2\,H_2O\,(g)$
   Assuming that it takes 50 years for 160 g of CH_4 to disappear, at what rate is water produced? Express your answer in ml/year. **(Ans. 7.2 mL of water / year)**

6. Which is the higher temperature, T1 or T2? Why?
(T2 because more particles with higher kinetic energy)



7. Given $2\,NO\,(g) + O_2\,(g) \rightarrow 2\,NO_2\,(g)$
   Calculate the average rate of NO_2 formation for the *last 8* recorded minutes.
   (Ans. 0.250 moles of NO_2/min)

Time (minutes)	0	2	4	6	8	10	12
Amount of O_2 disappearing (moles)	0	3	4.5	5.0	5.3	5.4.	5.5

8. For a reaction where the rate law equation is $r = k[NH_4^+{}_{(aq)}][NO_2^-{}_{(aq)}]$, calculate k if the rate, r, is 2.40×10^{-7} mol/(L·s) when $[NH_4^+{}_{(aq)}]$ is 0.200 mol/L and $[NO_2^-{}_{(aq)}]$ is 0.00500 mol/L.
   (Ans. K = 0.000240 L/mol·s)

9. A series of experiments is performed for the system: $2A + 3B + C \rightarrow D + 2E$

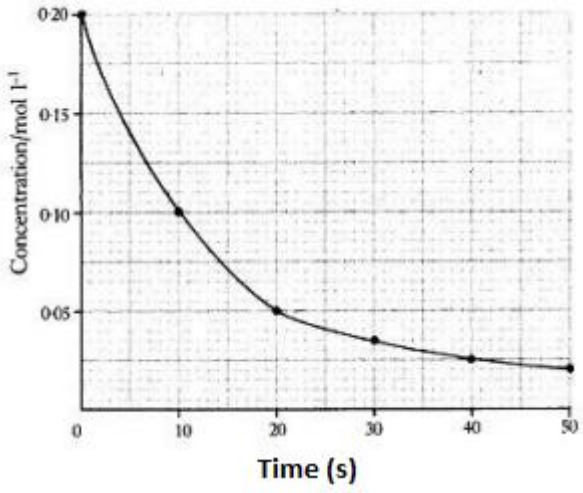
- When the initial concentration of A is doubled, the rate increases by a factor of 4.
- When the initial concentration of B is doubled, the rate is doubled.
- When the initial concentration of C is doubled, there is no effect on rate.

a. What is the order of reaction with respect to each of the reactants? **(Ans. 2nd order with respect to A; 1st order with respect to B; zero order with respect to C)**

b. Write the expression of the rate equation. **(Ans. $R=k[A]^2[B]$)**

10. Use the graph to answer the following questions:
    a) During which 10 second interval is the reaction rate the slowest? Why? **(Ans: 40-50 s; smallest slope)**
    b) What is the average rate between 10.0 s and 20.0 s? **(Ans: -0.005 mol/L·s)**
    c) If the concentration represented the remaining mol/L of H_2 in the following reaction, $H_{2\,(g)} + Br_{2\,(g)} \rightarrow 2\ HBr_{\,(g)}$

    At what rate is HBr being produced during the first 10.0 seconds? **(0.020 mol/L·s of HBr)**



11. The experimental observations in the following table are obtained for the reaction:

$$2A + B + 2C \rightarrow 3X$$

    a) Write an expression for the rate law equation. **(Ans. $R=k[A]^2[C]$)**
    b) Calculate the value for the rate constant (include units) **(Ans. 0.30 L^2/mol·s)**
    c) Calculate the rate of production of X when [A]=[B]=[C]=0.40 mol/L **(Ans. 0.019 mol/L·s)**

Table 1. Observations on the rate of production of X based on the initial concentration of each reactant.

Trial	**Initial [A] (mol/L)**	**Initial [B] (mol/L)**	**Initial [C] (mol/L)**	**Rate of production of X (mol/Ls)**
1	0.10	0.10	0.10	3.0×10^{-4}
2	0.20	0.10	0.10	1.2×10^{-3}
3	0.10	0.30	0.10	3.0×10^{-4}
4	0.20	0.10	0.20	2.4×10^{-3}

Equilibrium

1. Predict the effects of the following changes on the system at equilibrium: ***(Answer on next page)***

$$2\ CO_{\,(g)} + O_{2\,(g)} \leftrightarrow 2\ CO_{2\,(g)} + \text{energy}$$

	[CO]	[O_2]	[CO_2]	Reaction favoured	Direction of shift
Addition CO_2					
Removal CO					
Decrease temperature					
Decrease pressure					

2. In the following system at equilibrium, what changes could be made to temperature and pressure in order to increase the concentration of carbon dioxide? **(Ans. Decrease temp, increase pressure)**

$$2\ CO_{\,(g)} + O_{2\,(g)} \leftrightarrow 2\ CO_{2\,(g)} + \text{energy}$$

3. A 5.0 L container holds 5.00 x 10^{-3} moles H_2 and 1.00 x 10^{-2} moles of I_2. At equilibrium, the concentration of HI is 1.87 x 10^{-3} mol/L. What is the value of K_{eq}? **(Ans. K= 51)**

$$H_{2\,(g)} + I_{2\,(g)} \leftrightarrow 2\,HI_{(g)}$$

4. At 25 °C the value of the equilibrium constant of the following equation is 82. If 0.83 mol of iodine and 0.83 mol of chlorine are placed in a 5.0 L container, what is the concentration of each of the gases at equilibrium? **(Ans. I_2 and Cl_2 : 0.029 mol/L, ICl 0.274 mol/L)**

$$I_{2\,(g)} + Cl_{2\,(g)} \leftrightarrow 2\,ICl_{(g)}$$

5. A chemist places 1.70 x 10^{-1} moles of sulphur dioxide and 1.10 x 10^{-1} moles of nitrogen dioxide in a 2.00 L container. The value of the equilibrium constant is 4.80 at a given temperature. What is the concentration at equilibrium of sulphur trioxide? **(Ans. 0.0447 mol/L)**

$$SO_{2\,(g)} + NO_{2\,(g)} \leftrightarrow NO_{(g)} + SO_{3\,(g)}$$

6. Complete the following table.

Acid or Base?	[H+]	pH	[OH-]	pOH
				9.86
			2.83 x 10^{-7}	
	4.25 x 10^{-2}			

7. $C_4H_4N_2O_3$ is a weak acid. A solution with an initial concentration of 0.10 mol/L is found to have a pH of 2.5 at equilibrium. What is the value of "K" and what is the percent ionization? **(Ans. K=1.0 x 10^{-4} L/mol, 3.16%)**

8. Calculate the concentration of both ions in a saturated solution of copper (II) phosphate if the K_{sp} value is 1.40x10^{37}. **(Ans. Cu^{2+} = 4.8 x 10^{-8} mol/L, PO_4^{3-} = 3.2 x 10^{-8} mol/L)**

9. Ammonium hydroxide is a base used as a cleaning product. What is the pH of a solution with an initial concentration of 0.500 mol/L if the K_b value is 1.80 x 10^{-5}? **(Ans. pH = 11.48)**

$$NH_4OH_{(aq)} \leftrightarrow NH_4^{+}{}_{(aq)} + OH^{-}{}_{(aq)}$$

10. The maximum solubility of silver sulfate is 2.98 x 10^{-2} g/250.0 mL at ambient temperature. Calculate $K_{sp.}$ **(Ans. K_{sp} = 2.23 x 10^{-4} mol^3/L^3)**

Table answers:

Question 1

	[CO]	[O_2]	[CO_2]	Reaction favoured	Direction of shift
Addition CO_2	↑	↑	↑	REVERSE	LEFT
Removal CO	↓	↑	↓	REVERSE	LEFT
Decrease temperature	↓	↓	↑	FORWARD	RIGHT
Decrease pressure	↑	↑	↓	REVERSE	LEFT

Question 6.

Acid or Base?	**[H+]**	**pH**	**[OH-]**	**pOH**
ACID	7.24×10^{-5}	4.14	1.38×10^{-10}	9.86
BASE	3.5×10^{-8}	7.45	2.83×10^{-7}	6.55
ACID	4.25×10^{-2}	1.37	2.34×10^{-13}	12.63