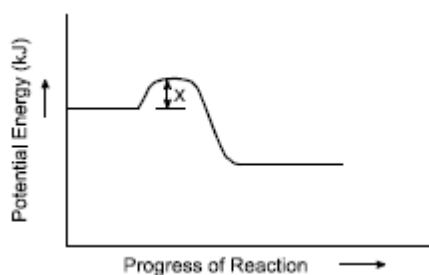


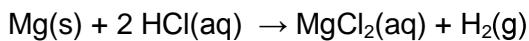
PART I
Total Value: 50%

Instructions: Shade the letter of the correct answer on the computer scorable answer sheet provided.

1. What is represented by X in the potential energy diagram below?



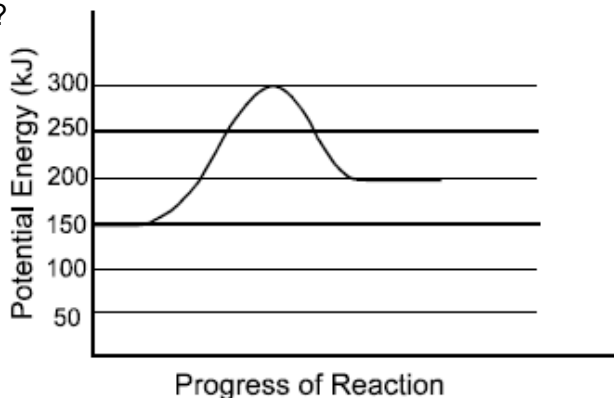
- A. activation energy of the forward reaction
B. activation energy of the reverse reaction
C. potential energy of the reactants
D. molar enthalpy of reaction
2. Why does decreasing the concentration of a reactant usually decrease the rate of reaction?
A. causes more intense collisions
B. decreases the number of collisions per second
C. lowers the activation energy
D. provides an alternate reaction mechanism
3. Which is true for an endothermic reaction?
A. forward E_a is less than reverse E_a
B. forward E_a = reverse E_a
C. forward E_a is greater than reverse E_a
D. forward E_a + reverse E_a = 0
4. A student placed 3.0 g of Mg(s) into some HCl(aq) in two different experiments giving the reaction below. It took more time for all of the Mg(s) to react in the second experiment. Which accounts for the slower rate in the second experiment?



- A. a catalyst was added
B. $[\text{H}_2]$ was decreased
C. Mg was crushed into a powder
D. temperature was decreased
5. Which substance will undergo the fastest combustion reaction?
A. $\text{C}_3\text{H}_8(\ell)$
B. $\text{C}_4\text{H}_{10}(\ell)$
C. $\text{C}_5\text{H}_{12}(\ell)$
D. $\text{C}_6\text{H}_{14}(\ell)$
6. How does adding a catalyst to a reaction affect the reaction pathway and the activation energy?

<u>Reaction Pathway Provided</u>	<u>Activation Energy</u>
A. alternate	higher
B. alternate	lower
C. same	higher
D. same	lower

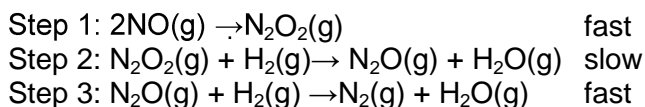
7. Which are the values for the activation energy (E_a) and change in enthalpy (ΔH) for the forward reaction?



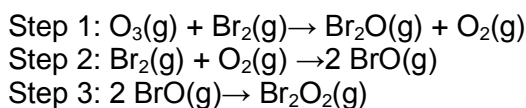
	E_a (kJ)	ΔH (kJ)
A.	150	-50
B.	300	-50
C.	150	+50
D.	300	+50

8. Which step of a reaction is the rate determining step?
- fastest
 - first
 - last
 - slowest
9. What is the purpose of a catalyst in a chemical reaction?
- decrease reaction rate
 - decrease yield
 - increase reaction rate
 - increase yield

Use the mechanism below to answer the next two questions

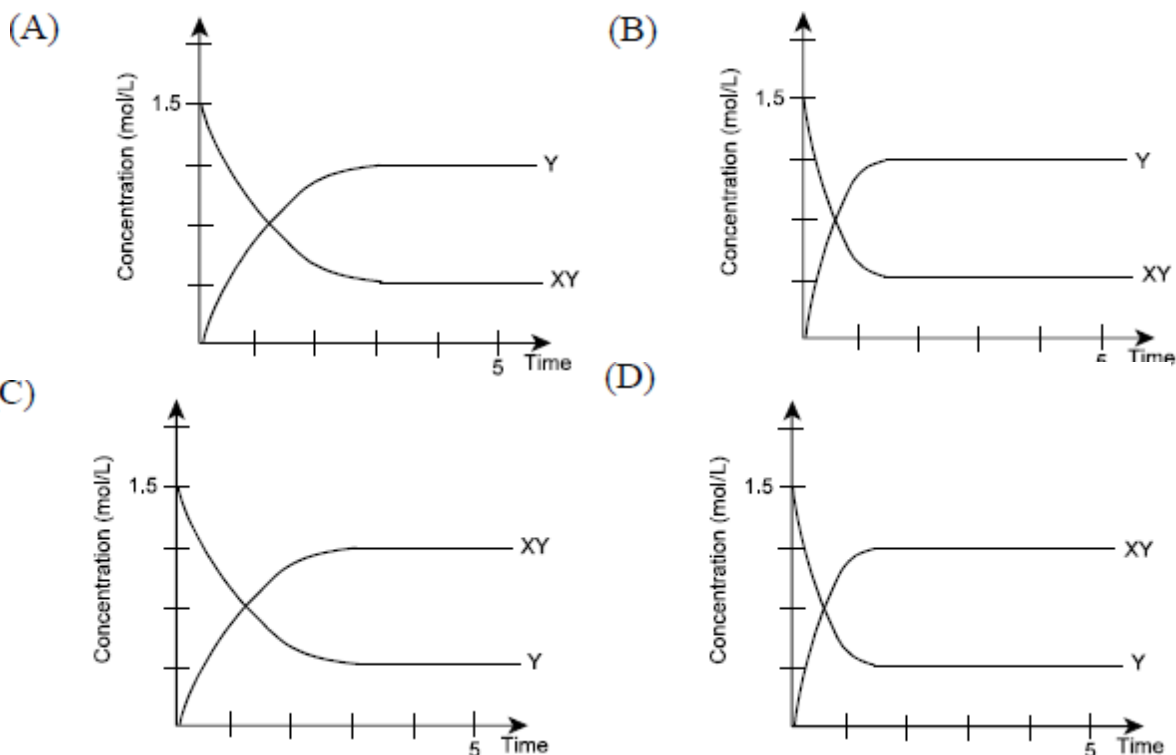
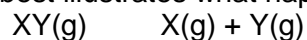


10. Increasing the concentration of which substance will cause the greatest increase in the reaction rate?
- H_2
 - NO
 - N_2O
 - H_2O
11. What are the products in the overall reaction?
- N_2 and H_2O
 - N_2 and N_2O_2
 - N_2O and H_2O
 - N_2O_2 and N_2O
12. What is the role of $\text{O}_2(\text{g})$ in the mechanism below?

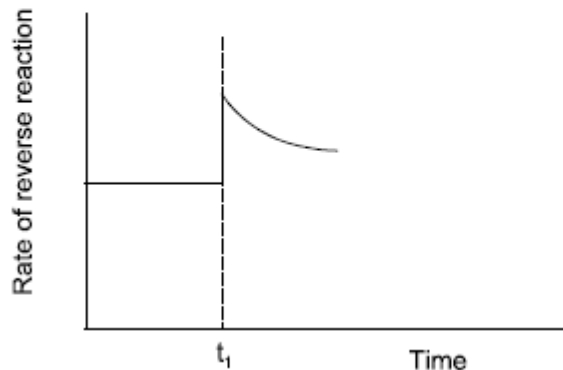
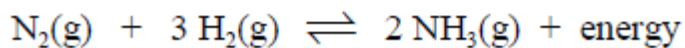


- catalyst
 - intermediate
 - product
 - reactant
13. Which is necessary for equilibrium to occur?
- closed system
 - open system
 - rate of the forward reaction is zero
 - rate of the reverse reaction is zero

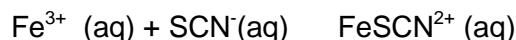
14. For the equilibrium below, 1.50 mol XY(g) is placed in a 1.0 L flask and sealed. Which graph best illustrates what happens if a catalyst is added to the reaction?



15. The diagram below illustrates the reverse reaction rate for the equilibrium shown. Which explains what happens at t_1 ?

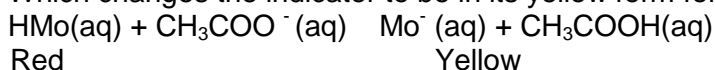


- A. $[\text{NH}_3]$ decreased
 B. $[\text{NH}_3]$ increased
 C. pressure is increased
 D. temperature is decreased
16. Some $\text{Fe}(\text{NO}_3)_3(\text{aq})$ and $\text{NaSCN}(\text{aq})$ are added to a sealed flask and allowed to reach equilibrium. What happens to the reverse reaction rate and $[\text{Fe}^{3+}]$ as equilibrium is being established?



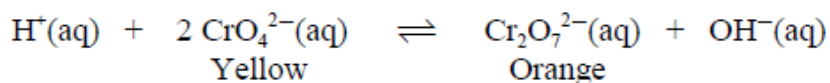
- | | <u>Reverse Rate</u> | <u>[Fe³⁺]</u> |
|----|---------------------|--------------------------|
| A. | decreased | decreased |
| B. | decreased | increased |
| C. | increased | decreased |
| D. | increased | increased |

17. Which changes the indicator to be in its yellow form for the equilibrium below?



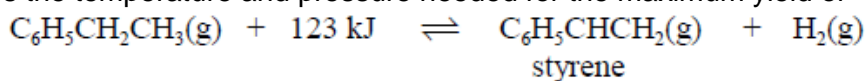
- A. add $\text{CH}_3\text{COOH(aq)}$ to the system
- B. add $\text{NaCH}_3\text{COO(aq)}$ to the system
- C. remove $\text{CH}_3\text{COO}^-(\text{aq})$ by precipitation
- D. remove HMo(aq) by precipitation

18. In the equilibrium below, a solution of $\text{Fe(NO}_3)_3(\text{aq})$ is added and a precipitate is formed. What is observed for the equilibrium shift and the final colour of the reaction mixture?



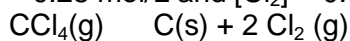
	Shift	Colour
(A)	left	orange
(B)	left	yellow
(C)	right	orange
(D)	right	yellow

19. Which describes the temperature and pressure needed for the maximum yield of styrene?



	Temperature	Pressure
(A)	high	high
(B)	high	low
(C)	low	high
(D)	low	low

20. At equilibrium, $[\text{CCl}_4] = 0.28 \text{ mol/L}$ and $[\text{Cl}_2] = 0.060 \text{ mol/L}$. What is the value of K_{eq} ?



- A. 3.9×10^{-4}
- B. 1.3×10^{-2}
- C. 2.1×10^{-1}
- D. 7.8×10^1

21. Which chemical equation corresponds to the equilibrium constant expression shown below?

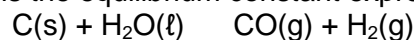
$$K_{\text{eq}} = \frac{[\text{A}]^2 [\text{B}]^3}{[\text{C}]}$$

- (A) $2\text{A} + 3\text{B} \rightleftharpoons \text{C}$
- (B) $\text{A} + \text{B} \rightleftharpoons \text{C}$
- (C) $\text{C} \rightleftharpoons \text{A} + \text{B}$
- (D) $\text{C} \rightleftharpoons 2\text{A} + 3\text{B}$

22. Which would **not** be included in an equilibrium expression?

- A. $\text{CO}_2(\text{g})$
- B. $\text{Fe}^{2+}(\text{aq})$
- C. HCl(aq)
- D. Zn(s)

23. What is the equilibrium constant expression for the reaction below?



- (A) $[\text{C}][\text{H}_2\text{O}]$
(B) $[\text{CO}][\text{H}_2]$
(C) $\frac{[\text{CO}][\text{H}_2]}{[\text{H}_2\text{O}][\text{C}]}$
(D) $\frac{[\text{H}_2\text{O}][\text{C}]}{[\text{CO}][\text{H}_2]}$

24. Which corresponds to an equilibrium in which the products are favoured?

- A. $K = 0$
B. $K = 1 \times 10^{-5}$
C. $K = 1$
D. $K = 1 \times 10^5$

25. A sample of an unknown colourless liquid conducts electricity; however, the liquid does not react with Mg(s) to form small bubbles and it does not feel slippery. What is true of the liquid?

- A. acid
B. amphoteric
C. base
D. ionic

26. Which substance will cause red litmus to change to blue?

- A. $\text{H}_2\text{SO}_4\text{(aq)}$
B. $\text{H}_3\text{O}^+\text{(aq)}$
C. $\text{NH}_3\text{(aq)}$
D. $\text{NH}_4^+\text{(aq)}$

27. What is the conjugate base of $\text{H}_2\text{PO}_4^- \text{(aq)}$?

- A. HPO_4^{3-}
B. HPO_4^{2-}
C. H_3PO_4
D. PO_3^{3-}

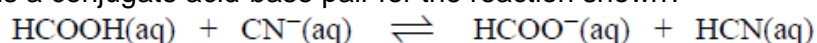
28. Which represents the reaction of a Bronsted-Lowry base?

- (A) $\text{NaOH(aq)} \rightarrow \text{Na}^+\text{(aq)} + \text{OH}^-\text{(aq)}$
(B) $\text{HNO}_3\text{(aq)} \rightarrow \text{H}^+\text{(aq)} + \text{NO}_3^-\text{(aq)}$
(C) $\text{CH}_3\text{COOH(aq)} + \text{C}_2\text{H}_5\text{OH(l)} \rightleftharpoons \text{CH}_3\text{COOCH}_2\text{CH}_3\text{(l)} + \text{H}_2\text{O(l)}$
(D) $\text{H}_2\text{C}_2\text{O}_4\text{(aq)} + \text{H}_2\text{O(l)} \rightleftharpoons \text{H}_3\text{O}^+\text{(aq)} + \text{HC}_2\text{O}_4^-\text{(aq)}$

29. Which species is amphoteric?

- (A) $\text{HNO}_3\text{(aq)}$
(B) $\text{H}_2\text{BO}_3^-\text{(aq)}$
(C) $\text{H}_3\text{BO}_3\text{(aq)}$
(D) $\text{NO}_3^-\text{(aq)}$

30. Which is a conjugate acid-base pair for the reaction shown?



	Acid	Base
(A)	$\text{CN}^-\text{(aq)}$	HCN(aq)
(B)	HCN(aq)	$\text{HCOO}^-\text{(aq)}$
(C)	HCOOH(aq)	$\text{CN}^-\text{(aq)}$
(D)	HCOOH(aq)	$\text{HCOO}^-\text{(aq)}$

31. Which is the strongest acid?

- A. $\text{CH}_3\text{COOH}(\text{aq})$
- B. $\text{HF}(\text{aq})$
- C. $\text{H}_2\text{CO}_3(\text{aq})$
- D. $\text{H}_2\text{SO}_4(\text{aq})$

32. In which acid-base equilibrium are the products favoured?

- (A) $\text{HS}^-(\text{aq}) + \text{HCN}(\text{aq}) \rightleftharpoons \text{H}_2\text{S}(\text{aq}) + \text{CN}^-(\text{aq})$
- (B) $\text{F}^-(\text{aq}) + \text{H}_2\text{SO}_3(\text{aq}) \rightleftharpoons \text{HSO}_3^-(\text{aq}) + \text{HF}(\text{aq})$
- (C) $\text{NO}_2^-(\text{aq}) + \text{HCN}(\text{aq}) \rightleftharpoons \text{HNO}_2(\text{aq}) + \text{CN}^-(\text{aq})$
- (D) $\text{SO}_4^{2-}(\text{aq}) + \text{HF}(\text{aq}) \rightleftharpoons \text{HSO}_4^-(\text{aq}) + \text{F}^-(\text{aq})$

33. Which is an amphoteric substance?

- (A) HCl
- (B) HSO_4^-
- (C) H_3PO_4
- (D) SO_4^{2-}

34. Which species will react when solutions of HF and Na_2CO_3 are added together?

- (A) $\text{HF}(\text{aq})$ and $\text{CO}_3^{2-}(\text{aq})$
- (B) $\text{HF}(\text{aq})$ and $\text{Na}^+(\text{aq})$
- (C) $\text{H}_3\text{O}^+(\text{aq})$ and $\text{CO}_3^{2-}(\text{aq})$
- (D) $\text{H}_3\text{O}^+(\text{aq})$ and $\text{F}^-(\text{aq})$

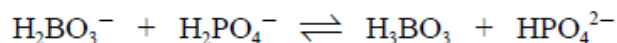
35. Which species is the strongest base?

- (A) $\text{CO}_3^{2-}(\text{aq})$
- (B) $\text{HS}^-(\text{aq})$
- (C) $\text{OCl}^-(\text{aq})$
- (D) $\text{S}^{2-}(\text{aq})$

36. A chemist needs to quickly and completely neutralize a solution of NaOH . Which is best to use if the concentration is the same for all acids?

- A. $\text{HCN}(\text{aq})$
- B. $\text{HF}(\text{aq})$
- C. $\text{H}_2\text{CO}_3(\text{aq})$
- D. $\text{H}_3\text{BO}_3(\text{aq})$

37. Which are the acids in the equilibrium below?



- (A) HPO_4^{2-} and H_3BO_3
- (B) H_2BO_3^- and HPO_4^{2-}
- (C) H_2BO_3^- and H_2PO_4^-
- (D) H_2PO_4^- and H_3BO_3

38. Which theory states that an acid is a proton donor?

- A. Arrhenius
- B. Brønsted-Lowry
- C. modified Arrhenius
- D. operational

39. What is true of a substance having a pH of 8?

- (A) $[\text{H}_3\text{O}^+]$ is greater than $[\text{OH}^-]$
- (B) $[\text{H}_3\text{O}^+]$ is less than $[\text{OH}^-]$
- (C) $[\text{H}_3\text{O}^+] = [\text{OH}^-]$
- (D) $[\text{H}_3\text{O}^+] = 0$

40. What is the $[H_3O^+]$ in a substance with a pH of 2.80?

- (A) 9.2×10^{-13} mol/L
- (B) 4.7×10^{-8} mol/L
- (C) 6.3×10^{-6} mol/L
- (D) 1.6×10^{-3} mol/L

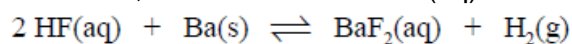
41. Which theory states that a base is a proton acceptor?

- A. Arrhenius
- B. Brønsted-Lowry
- C. modified Arrhenius
- D. operational

42. What is the pH of a solution with $[OH^-] = 3.58 \times 10^{-4}$?

- A. 3.446
- B. 3.580
- C. 10.420
- D. 10.554

43. In the equilibrium below, which is true if NaOH(aq) is added to the system?



	Equilibrium Shift	pH
(A)	left	decrease
(B)	left	increase
(C)	right	decrease
(D)	right	increase

44. A 1.0×10^{-4} mol/L solution of KOH(aq) is diluted from 50.0 mL to 500.0 mL. What is the pOH of the final solution?

- A. 3.00
- B. 5.00
- C. 9.00
- D. 11.00

45. What is the pOH of a solution of 4.2×10^{-6} mol/L HCl?

- A. 4.37
- B. 5.38
- C. 8.62
- D. 9.63

46. What happens to the pH and $[H_3O^+]$ when 0.10 mol/L NaOH is added to water?

	pH	$[H_3O^+]$
(A)	decreases	decreases
(B)	decreases	remains the same
(C)	increases	decreases
(D)	increases	remains the same

47. What is the final pH when 125.0 mL of 0.150 mol/L stock HCl(aq) solution is diluted to 3.75 L?

- A. 0.824
- B. 2.301
- C. 11.699
- D. 13.176

48. Which is a concentrated weak acid?

- A. 0.100 mol/L $\text{HNO}_2(\text{aq})$
- B. 0.100 mol/L $\text{HNO}_3(\text{aq})$
- C. 10.0 mol/L $\text{HNO}_2(\text{aq})$
- D. 10.0 mol/L $\text{HNO}_3(\text{aq})$

49. Which acid has the lowest conductivity?

	Acid	K_a
(A)	0.5 mol/L	1.0×10^3
(B)	1.0 mol/L	1.0×10^{-6}
(C)	1.5 mol/L	1.0×10^{-2}
(D)	2.0 mol/L	1.0×10^9

50. Solution A has a pH of 2.50. Solution B has a pH of 5.50. How does the hydrogen ion concentration differ between the two solutions?

- (A) Solution A has one thousand times less H^+ than B.
- (B) Solution A has one thousand times more H^+ than B.
- (C) Solution A has three times less H^+ than B.
- (D) Solution A has three times more H^+ than B.

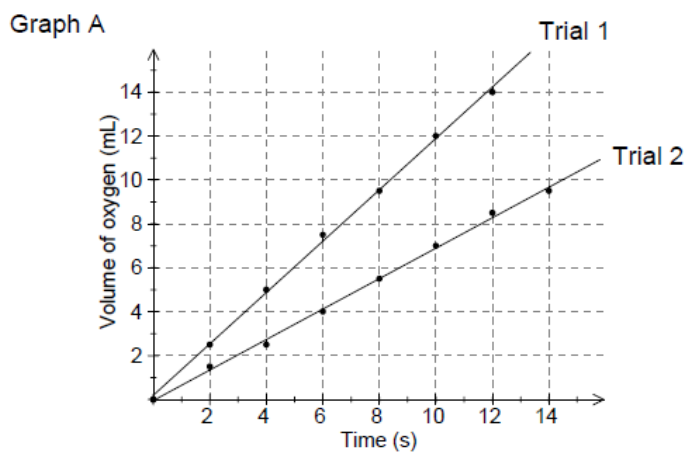
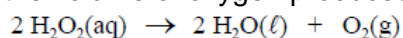
PART II

Total Value: 50%

Instructions: Complete all items in this section. Your responses should be clearly presented in a well-organized manner with proper use of units, formulae and significant figures where appropriate.

Value

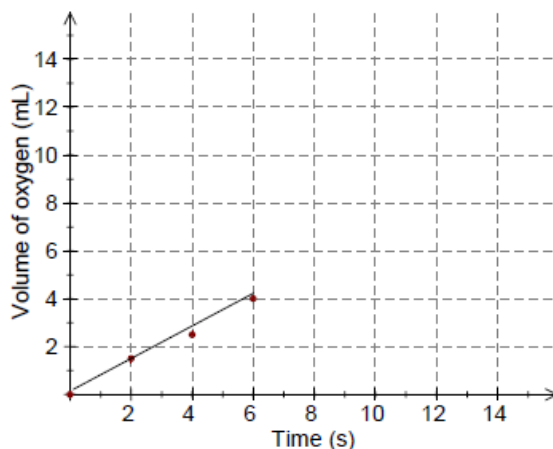
4% 51.(a) In a lab, data from two trials of the reaction below were collected. Graph A illustrates the volume of oxygen produced over time for each trial.



i. Which trial has the highest rate of O_2 production?

ii) On Graph B below, show how trial 2 will change if a catalyst is added after 6 seconds.

Graph B



iii) Explain how one factor, other than a catalyst, could cause the different rates for trials 1 and 2 shown in Graph A.

Value

4% (b) The mechanism below shows the decomposition of ozone in the upper atmosphere.

Step	Reaction Mechanism
1	$O_3(g) \rightarrow O_2(g) + O(g)$
2	$O_3(g) + NO(g) \rightarrow NO_2(g) + O_2(g)$
3	$NO_2(g) + O(g) \rightarrow NO(g) + O_2(g)$

i) What is the equation for the overall reaction?

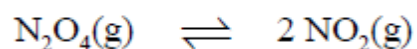
ii) Identify reaction intermediate(s) and/or catalyst(s) present.

Reaction Intermediate(s):

Catalyst(s):

iii) Step 1 of the reaction mechanism does not occur unless ultraviolet radiation is present. Describe the role that ultraviolet radiation plays in the reaction.

Value 3% (c) $N_2O_4(g)$ is placed in a sealed flask and allowed to establish the equilibrium below.

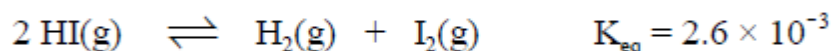


Describe the changes in both the forward and reverse reaction rates as the system moves towards and establishes equilibrium.

Value 2% (d) Two 15 g cubes of the same metal are placed outside. One of the cubes has been sanded to a very smooth surface while the other has not been sanded. Explain why the unsanded cube rusts faster than the sanded cube.

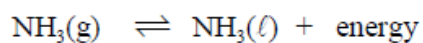
Value 3% (e)

A flask is initially filled with some HI. At equilibrium, the concentration of HI is 0.80 mol/L. Calculate the concentration of H₂ at equilibrium.



Value 2% (f)

The temperature in a closed system, such as with industrial refrigeration, is regulated by the equilibrium shown below. Explain how the amount of NH₃(l) in the system has changed over time as given in the table below.

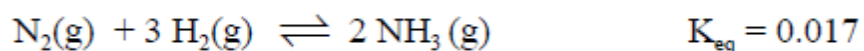


Day	Inside Temperature (°C)
1	-4.93
2	-4.97
3	-5.00
4	-5.02

Value 3%.(g)
container.

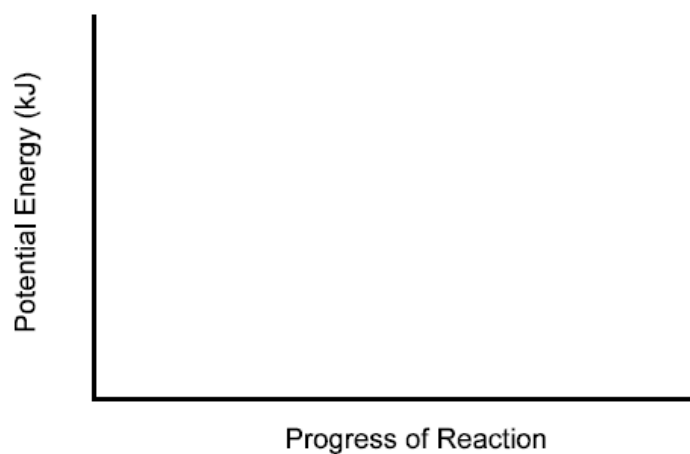
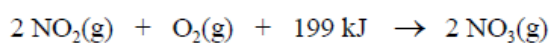
A scientist placed amounts of N₂, H₂, and NH₃ in a sealed

After thirty minutes the scientist measured the following concentrations of gases present in the container: [N₂] = 0.85 mol/L, [H₂] = 1.1 mol/L, and [NH₃] = 0.67 mol/L. In what direction is the reaction moving to gain equilibrium? Show your workings.



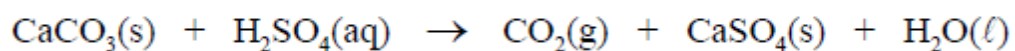
Value 2% .(h)

The reaction below has an activation energy of 209 kJ. Sketch a potential energy diagram for the reaction, and label the activation energy and heat of reaction.



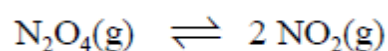
Value 2% (i)

For the reaction below, it takes longer to collect 35 mL of $\text{CO}_2(\text{g})$ using acid at room temperature compared to acid at 60.0°C . Explain why.



Value 3% (l)

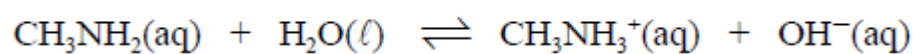
Calculate K_{eq} if 1.0 mol of N_2O_4 is initially placed into a 1.0 L vessel, and at equilibrium 0.75 mol of N_2O_4 remains in the vessel.



Value 2% 52.(a) Predict the Bronsted-Lowry acid-base neutralization reaction that occurs when $(\text{NH}_4)_2\text{S}$ is added to NaHSO_3 .

Value 2% (b) Determine the Bronsted-Lowry acid-base neutralization reaction that occurs between $\text{NaHCO}_3(\text{aq})$ and $\text{NH}_4\text{NO}_2(\text{aq})$.

Value 4% (c) Calculate the K_b value of a 0.200 mol/L solution of CH_3NH_2 if the Measured pH is 11.930.



Value 4% (d) Calculate the pH of a 0.297 mol/L solution of hypochlorous acid, $\text{HOCl}(\text{aq})$, which has $K_a = 2.9 \times 10^{-8}$

Value 2% .(e) Using the data below, determine which solution is the best conductor of electricity, and explain why.

	Solution A	Solution B	Solution C
Name	HCl(aq)	CH ₃ COOH(aq)	LiOH(aq)
Volume (mL)	45	35	35
Moles of Solute	1.10×10^{-3}	1.50×10^{-2}	1.50×10^{-2}

Value 4% (f) Calculate the pH of a 0.25 mol/L solution of NH₃ ($K_b = 1.8 \times 10^{-5}$).

Value 4% (g) A solution is prepared by dissolving a 15.00 g sample of an alkali metal hydroxide, MOH(s), in enough water to make a 5.00 L solution. If the resulting pH is 12.466, identify the metal, M.