

Part I
Total Value: 50%

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

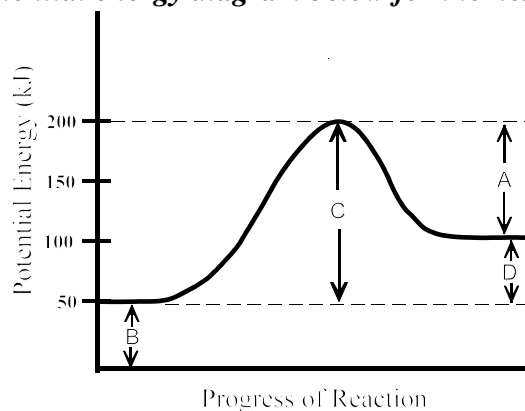
1. Which is a single step reaction in a reaction mechanism?

- (A) activated complex
- (B) catalyst
- (C) elementary process
- (D) reaction intermediate

2. What happens when a catalyst is added to a reaction?

- (A) equilibrium constant changes
- (B) heat of reaction increases
- (C) new mechanism becomes available
- (D) rate of reaction decreases

Consider the potential energy diagram below for the next two questions.



3. Which describes the forward reaction?

| | ΔH (kJ) | Reaction Type |
|-----|-----------------|---------------|
| (A) | - 50 | endothermic |
| (B) | - 50 | exothermic |
| (C) | +50 | endothermic |
| (D) | +50 | exothermic |

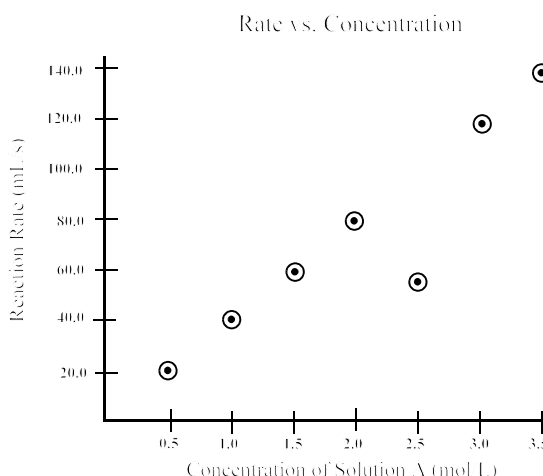
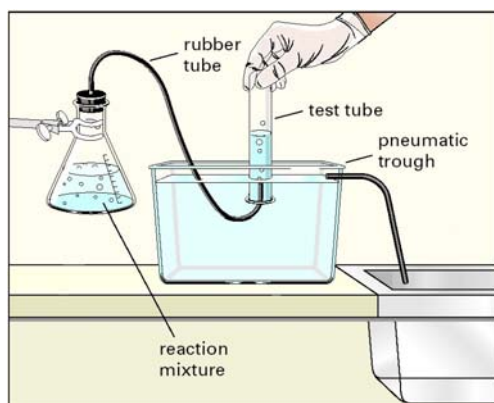
4. Which represents the activation energy for the reverse reaction?

- (A) A
- (B) B
- (C) C
- (D) D

5. Which predicts how chemical equilibria respond to changes in temperature?

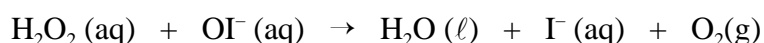
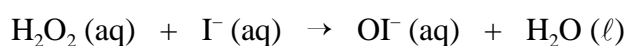
- (A) Arrhenius theory
- (B) First Law of Thermodynamics
- (C) Hess's Law
- (D) Le Châtelier's Principle

6. A student investigating the effect of concentration on a reaction rate used the apparatus below to obtain the data provided.

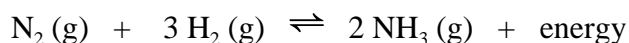


What most likely caused the result for the trial with concentration 2.5 mol/L?

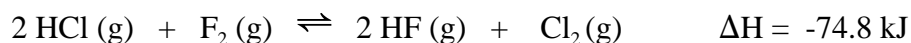
- (A) glass tubing substituted for rubber tubing
 - (B) loose stopper in reaction flask
 - (C) reaction flask is lower than pneumatic trough
 - (D) tap water used in the pneumatic trough
7. What is the catalyst in the mechanism below?



- (A) H_2O_2
 - (B) I^-
 - (C) OI^-
 - (D) O_2
8. Which would result in the highest concentration of ammonia for the equilibrium below?

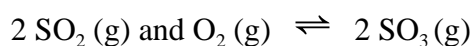


- (A) decreasing the temperature and decreasing the pressure
 - (B) decreasing the temperature and increasing the pressure
 - (C) increasing the temperature and decreasing the pressure
 - (D) increasing the temperature and increasing the pressure
9. Which would cause an increase in the value of K_{eq} for the equilibrium below?



- (A) decreasing temperature
- (B) increasing temperature
- (C) decreasing volume
- (D) increasing volume

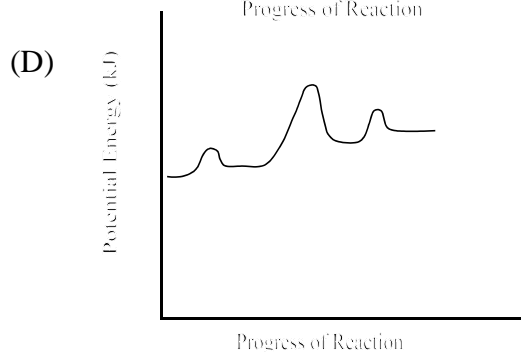
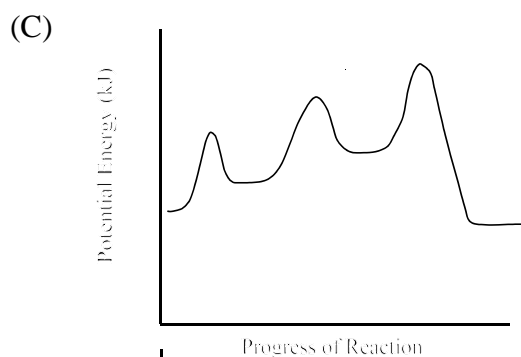
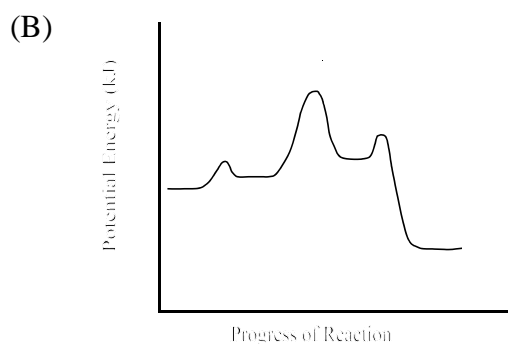
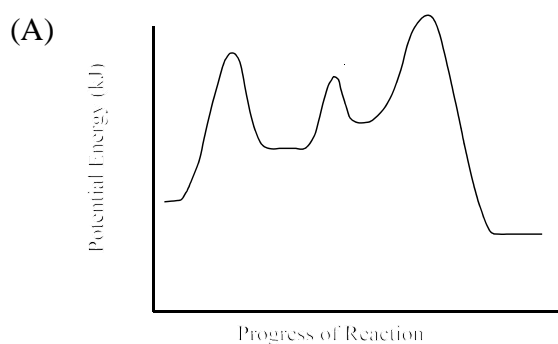
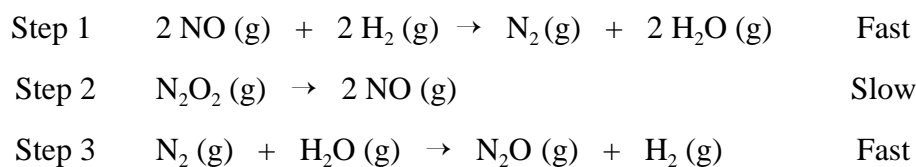
10. $\text{SO}_2(\text{g})$ and $\text{O}_2(\text{g})$ are introduced into an evacuated flask and an equilibrium is established.



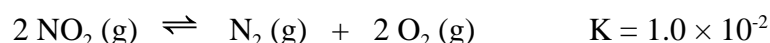
What is true given the equilibrium concentrations below?

$$[\text{SO}_2] = 1.5 \text{ mol/L} \quad [\text{O}_2] = 3.00 \text{ mol/L} \quad [\text{SO}_3] = 4.50 \text{ mol/L}$$

- (A) $K_{\text{eq}} > 1$
 (B) $K_{\text{eq}} < 1$
 (C) K_{eq} decreases when $\text{SO}_2(\text{g})$ is added to the equilibrium mixture.
 (D) K_{eq} increases when $\text{SO}_2(\text{g})$ is added to the equilibrium mixture.
11. Which graph best corresponds to the mechanism below, if the overall reaction is exothermic?

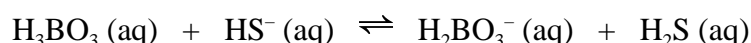


12. What is the equilibrium concentration of $\text{N}_2(\text{g})$, given the reaction and equilibrium concentrations below?



$$[\text{O}_2(\text{g})] = 10.0 \text{ mol/L} \quad [\text{NO}_2(\text{g})] = 5.0 \text{ mol/L}$$

- (A) 0.0025 mol/L
(B) 0.0050 mol/L
(C) 0.020 mol/L
(D) 0.040 mol/L
13. Which statement is part of the operational definition of an acid?
- (A) ionizes to produce H^+
(B) ionizes to produce OH^-
(C) turns litmus blue
(D) turns litmus red
14. Which defines a Brønsted-Lowry acid?
- (A) accepts OH^- (aq)
(B) accepts a proton
(C) donates OH^- (aq)
(D) donates a proton
15. Which substance is an Arrhenius acid?
- (A) CH_3CHO (aq)
(B) HBr (aq)
(C) NH_3 (aq)
(D) $\text{Mg}(\text{OH})_2$ (aq)
16. Which term describes a substance which can act as an acid or a base?
- (A) amphoteric
(B) catalytic
(C) conjugate
(D) polyprotic
17. In the equilibrium below, what are the Brønsted-Lowry acids and bases?



| | $\text{H}_3\text{BO}_3(\text{aq})$ | $\text{HS}^-(\text{aq})$ | $\text{H}_2\text{BO}_3^-(\text{aq})$ | $\text{H}_2\text{S}(\text{aq})$ |
|-----|------------------------------------|--------------------------|--------------------------------------|---------------------------------|
| (A) | acid | base | acid | base |
| (B) | acid | base | base | acid |
| (C) | base | acid | acid | base |
| (D) | base | acid | base | acid |

18. Which is the strongest acid?
- (A) CH_3COOH (aq)
(B) HNO_2 (aq)
(C) HOCl (aq)
(D) H_2CO_3 (aq)

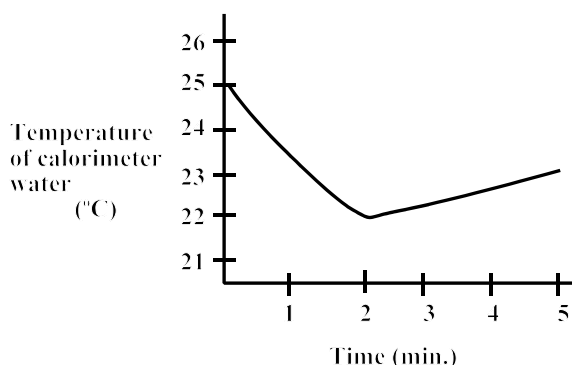
19. What is the pOH of a 0.0500 mol/L HBr solution?
- (A) 0.301
(B) 1.301
(C) 12.700
(D) 13.700
20. What is the $[\text{H}_3\text{O}^+]$ in a solution with a pH = 4.00?
- (A) 1.0×10^{-10}
(B) 1.0×10^{-4}
(C) 1.0×10^4
(D) 1.0×10^{10}
21. Which substance ionizes completely and has a pH less than 7?
- (A) CH_3COOH (aq)
(B) HClO_4 (aq)
(C) NaClO_4 (aq)
(D) NaOH (aq)
22. Why does the pH of blood in the human body remain stable?
- (A) Acids and bases are neutralized by red blood cells.
(B) Acids and bases are prevented from reaching the blood stream.
(C) Blood contains many catalysts.
(D) Blood is naturally buffered.
23. What does the expression $\frac{[\text{H}_3\text{BO}_3][\text{OH}^-]}{[\text{H}_2\text{BO}_3^-]}$ represent?
- (A) K_a for H_2BO_3^-
(B) K_a for H_3BO_3
(C) K_b for H_2BO_3^-
(D) K_b for H_3BO_3
24. What is true of the concentrations of HF, F^- , and OH^- , in a 0.10 mol/L HF(aq) solution?
- (A) $[\text{HF}] > [\text{OH}^-] > [\text{F}^-]$
(B) $[\text{HF}] > [\text{F}^-] > [\text{OH}^-]$
(C) $[\text{OH}^-] > [\text{HF}] > [\text{F}^-]$
(D) $[\text{OH}^-] > [\text{F}^-] > [\text{HF}]$
25. What is the concentration of H_2SO_4 (aq) if a 50.0 mL sample is completely neutralized by 150 mL of 0.50 M KOH(aq)?
- $$\text{H}_2\text{SO}_4 (\text{aq}) + 2 \text{KOH} (\text{aq}) \rightarrow \text{K}_2\text{SO}_4 (\text{aq}) + 2 \text{H}_2\text{O} (\ell)$$
- (A) 0.67 mol/L
(B) 0.75 mol/L
(C) 1.5 mol/L
(D) 3.0 mol/L

26. Which best describes the equivalence point for an acid-base titration?
- (A) moles of H^+ = moles of OH^-
 (B) moles of acid = moles of base
 (C) $\text{pH} = 7.0$
 (D) $\text{pH} = \text{pOH}$
27. An unmarked cleaning solution was found under a kitchen sink. The solution was tested with two indicators and their color was recorded in the table below.

| Indicator | Color |
|------------------|------------|
| bromothymol blue | blue |
| phenolphthalein | colourless |

Which is a possible pH for the solution?

- (A) 7.0
 (B) 8.0
 (C) 9.0
 (D) 10.0
28. Which represents the second equivalence point in a titration of H_3PO_4 with OH^- ?
- (A) $\text{H}_3\text{PO}_4(\text{aq}) + 3 \text{OH}^-(\text{aq}) \rightarrow \text{PO}_4^{3-}(\text{aq}) + 3 \text{H}_2\text{O}(\ell)$
 (B) $\text{H}_3\text{PO}_4(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{PO}_4^-(\text{aq}) + \text{H}_2\text{O}(\ell)$
 (C) $\text{H}_2\text{PO}_4^-(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\ell)$
 (D) $\text{HPO}_4^{2-}(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{PO}_4^{3-}(\text{aq}) + \text{H}_2\text{O}(\ell)$
29. Which is a measure of average kinetic energy?
- (A) calorie
 (B) enthalpy
 (C) heat
 (D) temperature
30. A piece of ice was dropped into liquid water to determine the molar heat of fusion of water. The results are given in the graph below.



What is the best reason for the change after 2 minutes?

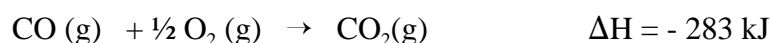
- (A) room was colder than the water; heat entered the container
 (B) room was colder than the water; heat left the container
 (C) room was warmer than the water; heat entered the container
 (D) room was warmer than the water; heat left the container

31. What is the mass of a piece of iron ($c_{\text{Fe}} = 0.444 \text{ J/g}\cdot^{\circ}\text{C}$) which requires 15.0 J of energy to raise its temperature 12.0°C ?
- (A) 0.355 g
(B) 0.555 g
(C) 1.80 g
(D) 2.82 g

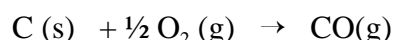
32. Which phase change is endothermic?

- (A) gas to liquid
(B) gas to solid
(C) liquid to gas
(D) liquid to solid

33. Using the following two reactions:

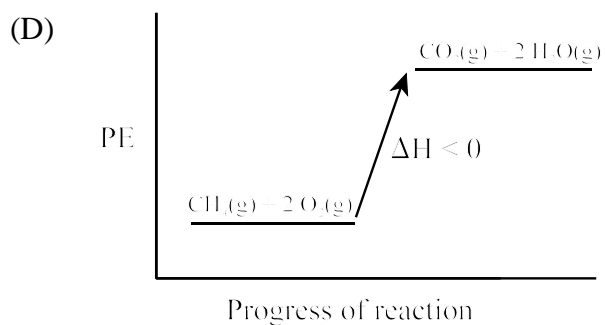
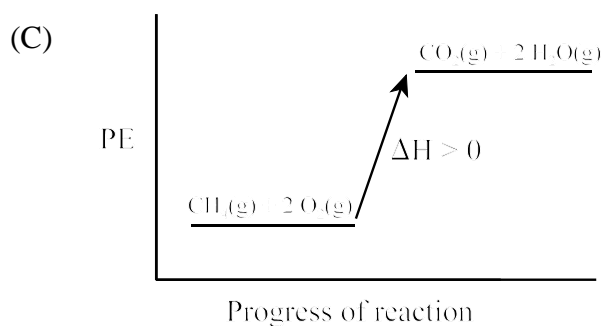
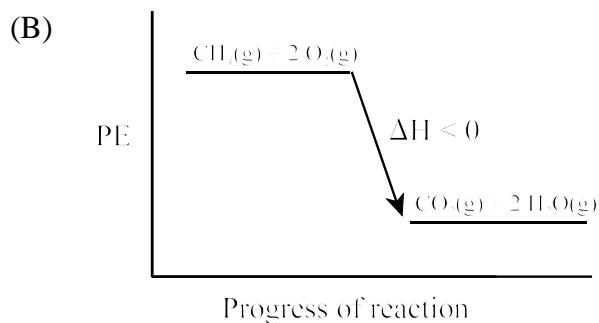
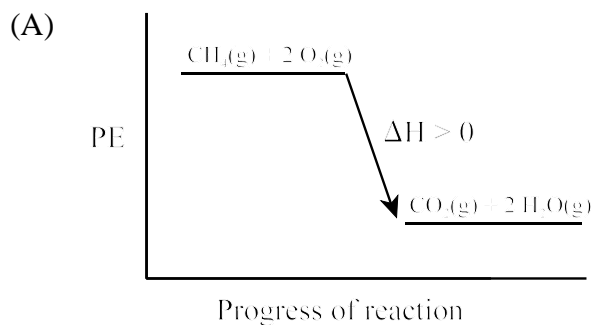
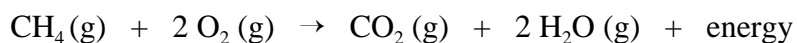


what is the ΔH for the reaction below?



- (A) - 677 kJ
(B) - 111 kJ
(C) 111 kJ
(D) 677 kJ
34. How much energy is required to vaporize completely a 25.0 g sample of acetone, $\text{C}_3\text{H}_6\text{O}$, at its boiling point? (Given: $\Delta H_{\text{vap}} = 30.25 \text{ kJ/mol}$)
- (A) 1.21 kJ
(B) 13.0 kJ
(C) 58.1 kJ
(D) 769 kJ
35. Given the standard heat of formation, ΔH_f° , for methanol, $\text{C}_2\text{H}_5\text{OH}(\ell)$ is - 278 kJ/mol, which reaction illustrates this process?
- (A) $\text{C}_2\text{H}_2 \text{ (g)} + 2 \text{H}_2\text{O (g)} \rightarrow \text{C}_2\text{H}_5\text{OH}(\ell) + 278 \text{ kJ}$
(B) $\text{C}_2\text{H}_2 \text{ (g)} + 2 \text{H}_2\text{O (g)} + 278 \text{ kJ} \rightarrow \text{C}_2\text{H}_5\text{OH}(\ell)$
(C) $2 \text{C (s)} + 3 \text{H}_2 \text{ (g)} + \frac{1}{2} \text{O}_2 \text{ (g)} \rightarrow \text{C}_2\text{H}_5\text{OH}(\ell) + 278 \text{ kJ}$
(D) $2 \text{C (s)} + 3 \text{H}_2 \text{ (g)} + \frac{1}{2} \text{O}_2 \text{ (g)} + 278 \text{ kJ} \rightarrow \text{C}_2\text{H}_5\text{OH}(\ell)$
36. Why do nuclear reactions involve greater enthalpy changes than chemical reactions?
- (A) Chemical bonds are stronger than nuclear forces.
(B) Chemical bonds are weaker than nuclear forces.
(C) Nuclear reactions involve elements with larger atomic numbers.
(D) Nuclear reactions involve elements with smaller atomic numbers.

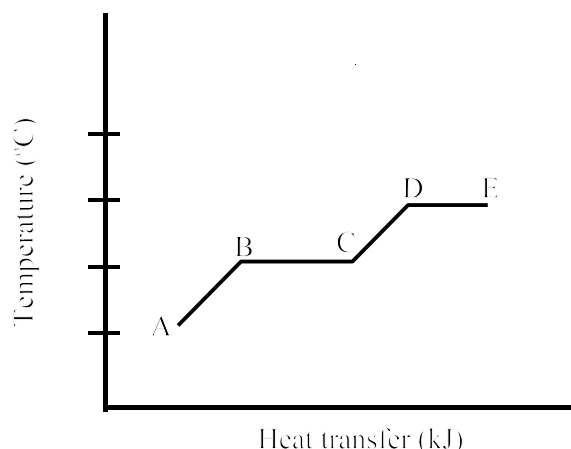
37. Which enthalpy diagram and corresponding ΔH represents the reaction below?



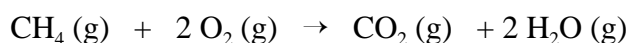
38. What is the fuel value of a 3.00 g sample of banana that produces 12 110 J of energy?

- (A) 2.48 kJ/g
- (B) 4.04 kJ/g
- (C) 16.2 kJ/g
- (D) 36.3 kJ/g

39. Which sections of the heating curve below represent a potential energy increase?



- (A) AB and CD
 (B) AB and DE
 (C) BC and CD
 (D) BC and DE
40. Use the table below to calculate the molar enthalpy of combustion for methane.

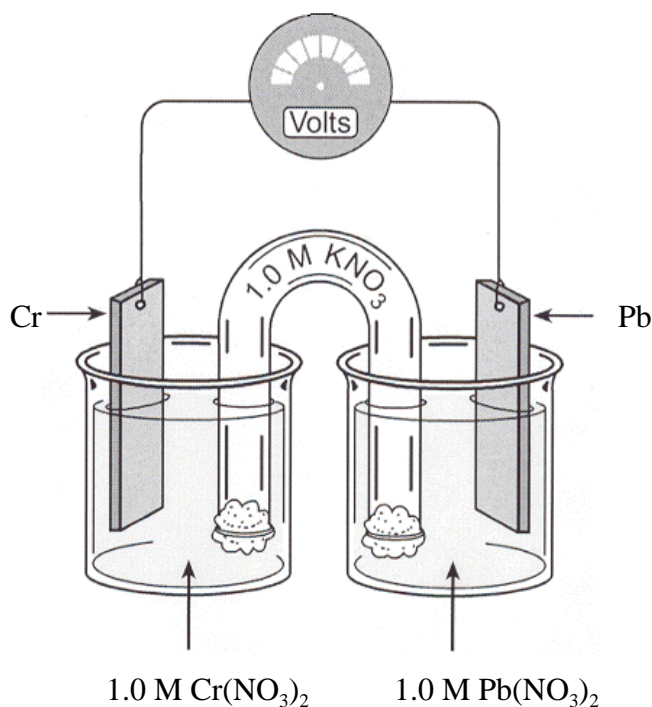


| Compound | ΔH°_f (kJ/mol) |
|--------------------------------|-----------------------------|
| $\text{CH}_4(\text{g})$ | - 75 |
| $\text{CO}_2(\text{g})$ | -394 |
| $\text{H}_2\text{O}(\text{g})$ | -242 |

- (A) - 803 kJ/mol
 (B) - 561 kJ/mol
 (C) 561 kJ/mol
 (D) 803 kJ/mol
41. Which is true for an oxidizing agent?
- (A) oxidized as it gains electrons
 (B) oxidized as it loses electrons
 (C) reduced as it gains electrons
 (D) reduced as it loses electrons
42. In which reaction is nitrogen reduced?
- (A) $\text{Cu}^{2+} + 2 \text{NO}_2 + 2 \text{H}_2\text{O} \rightarrow \text{Cu} + 4 \text{H}^+ + 2 \text{NO}_3^-$
 (B) $2 \text{NH}_3 \rightarrow \text{N}_2 + 3 \text{H}_2$
 (C) $2 \text{NO} + \text{O}_2 \rightarrow 2 \text{NO}_2$
 (D) $4 \text{Zn} + 10 \text{H}^+ + \text{NO}_3^- \rightarrow 4 \text{Zn}^{2+} + \text{NH}_4^+ + 3 \text{H}_2\text{O}$
43. What is the oxidation number of manganese in MnO_2 ?
- (A) 0
 (B) + 2
 (C) + 4
 (D) + 6

44. What is the oxidation half reaction for $2\text{K(s)} + \text{F}_2\text{(g)} \rightarrow 2\text{KF(s)}$?
- (A) $\text{K}^+ + \text{e}^- \rightarrow \text{K(s)}$
 (B) $\text{K(s)} \rightarrow \text{K}^+ + \text{e}^-$
 (C) $\text{F}_2\text{(g)} + 2\text{e}^- \rightarrow 2\text{F}^-$
 (D) $2\text{F}^- \rightarrow \text{F}_2\text{(g)} + 2\text{e}^-$
45. Which reacts spontaneously with Ag metal?
- (A) Cl_2
 (B) Cu^{2+}
 (C) Fe^{2+}
 (D) I_2
46. What is the E_{cell}° for the reaction, $\text{Sn}^{4+}\text{(aq)} + \text{Co(s)} \rightarrow \text{Co}^{2+}\text{(aq)} + \text{Sn}^{2+}\text{(aq)}$?
- (A) -0.43
 (B) -0.13
 (C) 0.13
 (D) 0.43

47. What happens to the mass of the chromium electrode in the diagram below?



- (A) decreases as it is oxidized
 (B) decreases as it is reduced
 (C) increases as it is oxidized
 (D) increases as it is reduced
48. Which is an example of a redox reaction?
- (A) $\text{CaCO}_3\text{(s)} \rightarrow \text{CaO(s)} + \text{CO}_2\text{(g)}$
 (B) $\text{Cu(s)} + 2\text{AgNO}_3\text{(aq)} \rightarrow 2\text{Ag(s)} + \text{Cu(NO}_3)_2\text{(aq)}$
 (C) $2\text{NaI(aq)} + \text{Pb(NO}_3)_2\text{(aq)} \rightarrow 2\text{NaNO}_3\text{(aq)} + \text{PbI}_2\text{(s)}$
 (D) $\text{NH}_3\text{(g)} + \text{HCl(g)} \rightarrow \text{NH}_4\text{Cl(s)}$

49. Which cell uses electrical energy to cause a non-spontaneous redox reaction?
- (A) electrochemical
 - (B) electrolytic
 - (C) galvanic
 - (D) voltaic
50. Which is an example of a secondary battery?
- (A) alkaline
 - (B) button
 - (C) dry cell
 - (D) lead storage

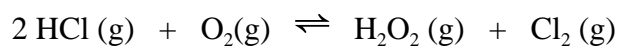
Part II
Total Value: 50%

Instructions: Complete ALL questions in the space provided. Show calculations for numerical problems.

Value

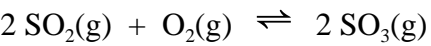
- 2% 51.(a) For faster relief, why should antacid medication be chewed rather than swallowed whole? Explain.

- 3% 51.(b) Initially 4.00 mol of HCl (g) and 4.00 mol of O₂ (g) were placed in a 2.00 L vessel and allowed to establish equilibrium. If at equilibrium, the vessel contained 0.500 mol of Cl₂(g), what is the value of K_{eq}?



Value

51(c) 1 mol each of SO₂(g) and O₂(g) are placed in a 1.0L reaction vessel and allowed to reach equilibrium. The concentrations of the reactants and products after various time periods are shown in the data table below.



| Reaction Time (min.) | [SO ₂] mol/L | [O ₂] mol/L | [SO ₃] mol/L |
|----------------------|--------------------------|-------------------------|--------------------------|
| 0.0 | 1.00 | 1.00 | 0.00 |
| 1.0 | 0.86 | 0.93 | 0.14 |
| 2.0 | 0.76 | 0.88 | 0.24 |
| 3.0 | 0.68 | 0.84 | 0.32 |
| 4.0 | 0.64 | 0.82 | 0.36 |
| 5.0 | 0.64 | 0.82 | 0.36 |
| 6.0 | 0.64 | 0.82 | 0.36 |

2%

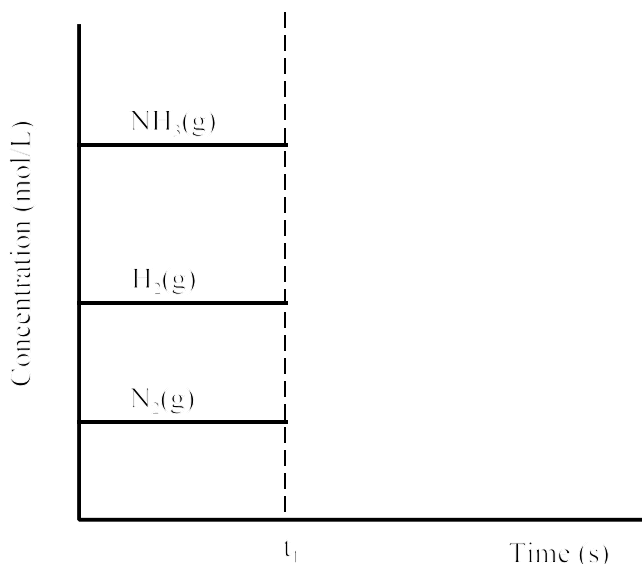
(i) When was equilibrium established? Justify your answer.

3%

(ii) Compare the forward and reverse reaction rates at 2.0 minutes? Explain your answer.

Value

- 3% 51.(d) The equilibrium concentrations for $3 \text{H}_2(\text{g}) + \text{N}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g})$ are graphed below. More $\text{H}_2(\text{g})$ is added to the system at time t_1 . Extend the graph to show how the concentrations of $\text{N}_2(\text{g})$, $\text{H}_2(\text{g})$ and $\text{NH}_3(\text{g})$ will change until a new equilibrium is established.



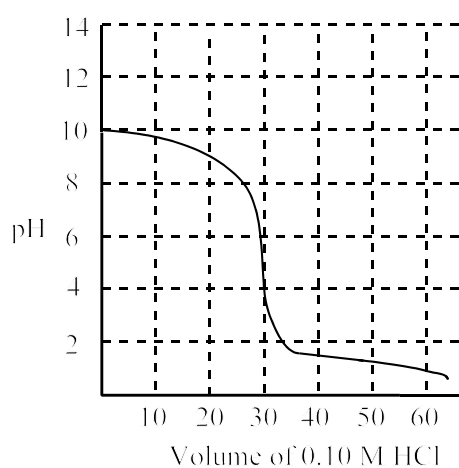
- 3% 52.(a) Aqueous solutions of lithium hydrogen sulfite (LiHSO_3) and sodium carbonate (Na_2CO_3) are mixed. Write the balanced acid-base reaction indicating which is favoured, products or reactants.

- 3% (b) What is the resulting pH when 20.0 mL of 0.33 mol/L $\text{HCl}(\text{aq})$ are mixed with 30.0 mL of 0.15 mol/L $\text{LiOH}(\text{aq})$?

Value

- 4% 52.(c) What is the pH of a 0.159 mol/L solution of a weak acid, HA (aq), given the K_a for the acid is 6.9×10^{-9} .

- (d) The graph below shows the titration of a 0.10 M unknown base with 0.10 M HCl.



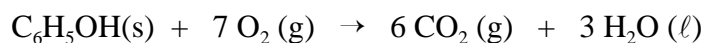
- 2% (i) What is a suitable indicator for this titration. Justify your choice.

- 2% (ii) Is the unknown base weak or strong? Explain.

Value

3% 53.(a) A 0.910g sample of sucrose, $C_{12}H_{22}O_{11}$, (Molar Mass = 342.34 g/mol) is burned in a bomb calorimeter and the temperature of the calorimeter and contents increased from 22.5 °C to 27.5°C. If the heat capacity of the calorimeter and contents was 4.50 kJ/°C, calculate the molar heat of combustion of sucrose.

(b) When a 2.00 g sample of pure phenol, $C_6H_5OH(s)$, is burned according to the equation below, 65.0 kJ of heat is released.



2% (i) Calculate the molar heat of combustion for phenol.

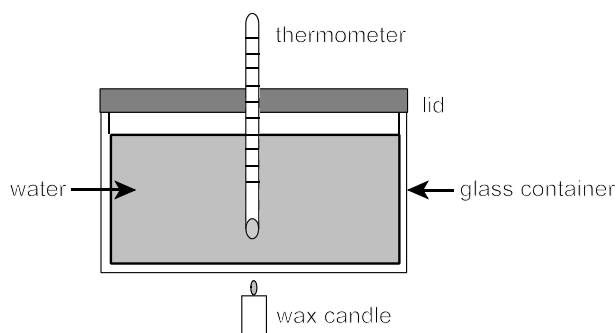
.

2% (ii) Using the data below, calculate the standard heat of formation, ΔH_f° , of phenol.

| Substance | Standard heat of Formation, ΔH_f° (kJ/mol) |
|---------------|---|
| $C_6H_5OH(s)$ | ? |
| $CO_2(g)$ | - 394 |
| $H_2O(l)$ | - 286 |

Value

- 53.(c) The molar enthalpy of combustion of candle wax, $\text{C}_{25}\text{H}_{52}(\text{s})$, was determined in an experiment using the apparatus shown in the diagram below.



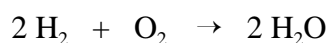
The following two quantities were measured:

- mass of water in glass container = 200 g
- initial temperature of water = 25.4°C

- 2% (i) State two other quantities that would also have to be measured in order to determine the molar enthalpy of combustion of the candle wax.

- 2% (ii) Suggest one improvement that could be made to the experimental apparatus, and briefly state how this would help to increase the accuracy of the result.

- 2% (d) Using the bond energies given, determine the enthalpy of reaction for:

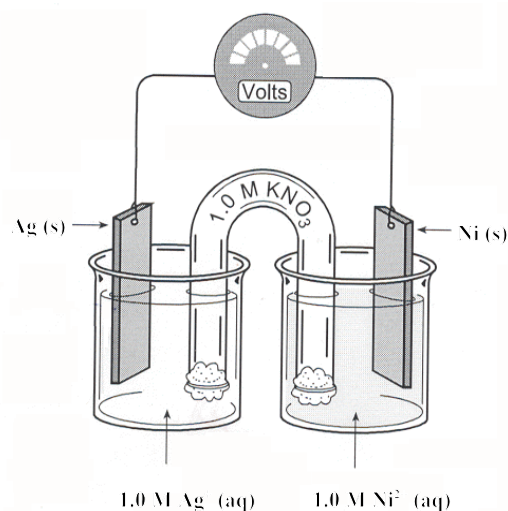


| Bond | Bond Energy (kJ) |
|-------|------------------|
| H - H | 436 |
| O = O | 498 |
| H - O | 464 |

Value

- 3% 54.(a) A stainless steel spoon is put into an electrolytic cell that has 3.10 amps of electricity passing through it for 2.50 h. What mass of silver will be produced?

- 54.(b) Refer to the diagram below to answer questions (i) and (ii).



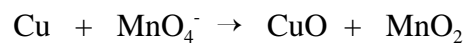
- 2% (i) What is the balanced equation for the overall reaction and the maximum possible voltage for the cell?
- 1% (ii) Explain what would happen to the voltage if the salt bridge was removed.

Value

54.(c) Copper metal will undergo a redox reaction with permanganate ions.

3%

(i) Balance the redox reaction below under acidic conditions.



1%

(ii) What mass of copper is required to completely react with 1.0 mol of permanganate ions?