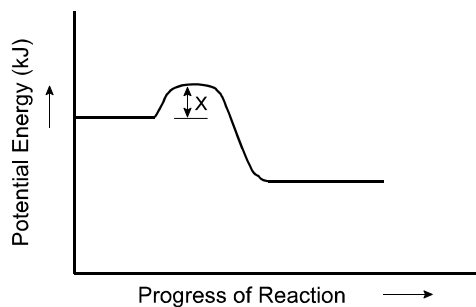


PART I
Total Value: 50%

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?

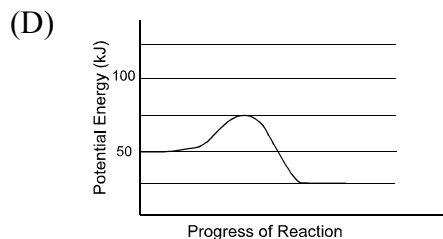
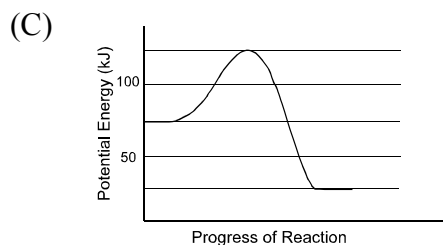
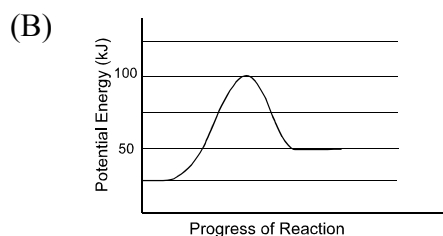
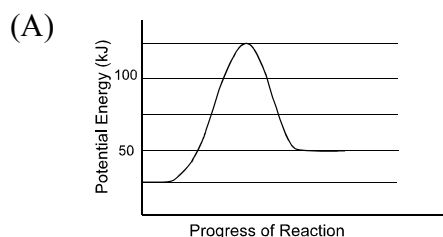


- (A) activation energy of the forward reaction
(B) activation energy of the reverse reaction
(C) potential energy of the reactants
(D) molar enthalpy of reaction

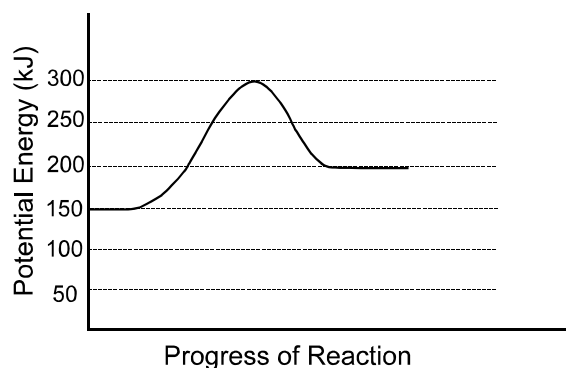
2. Which is true for an endothermic reaction?

- (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

3. Which represents the slowest forward reaction?



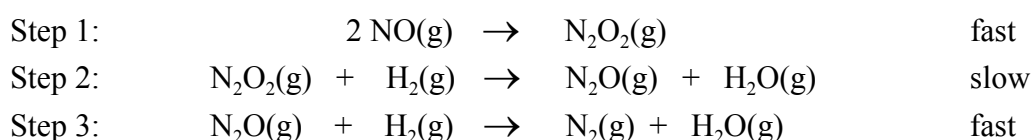
4. Which substance will undergo the fastest combustion reaction?
- (A) $\text{C}_3\text{H}_8(\ell)$
 (B) $\text{C}_4\text{H}_{10}(\ell)$
 (C) $\text{C}_5\text{H}_{12}(\ell)$
 (D) $\text{C}_6\text{H}_{14}(\ell)$
5. Which are the values for the activation energy (E_a) and change in enthalpy (ΔH) for the forward reaction?



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

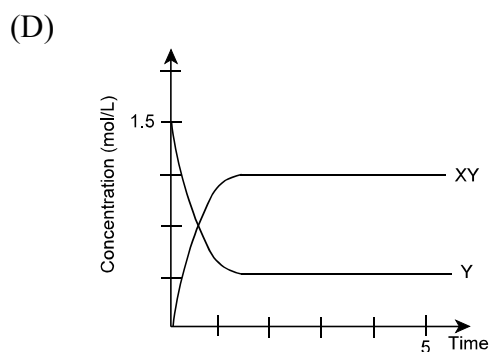
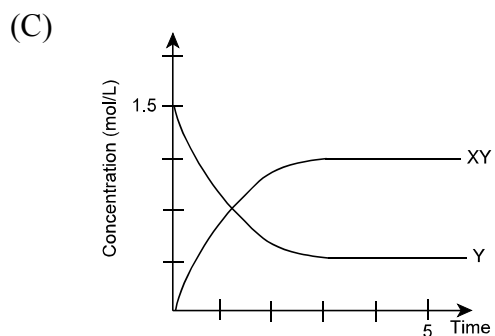
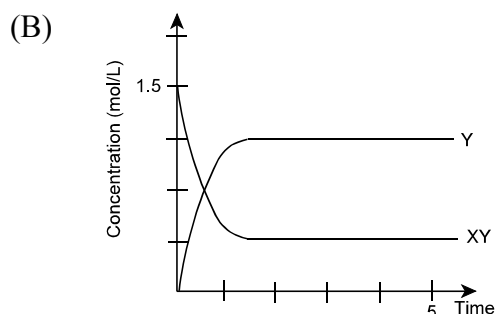
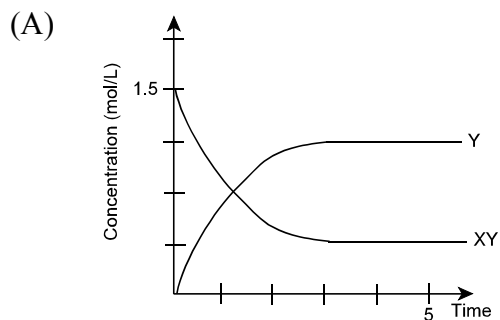
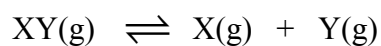
6. What is the purpose of a catalyst in a chemical reaction?
- (A) decrease reaction rate
 (B) decrease yield
 (C) increase reaction rate
 (D) increase yield

Use the mechanism below to answer questions 7 and 8.

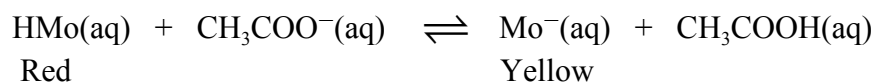


7. Increasing the concentration of which substance will cause the greatest increase in the reaction rate?
- (A) H_2
 (B) NO
 (C) N_2O
 (D) H_2O
8. What are the products in the overall reaction?
- (A) N_2 and H_2O
 (B) N_2 and N_2O_2
 (C) N_2O and H_2O
 (D) N_2O_2 and N_2O

9. 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?

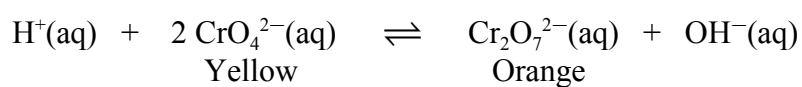


10. Which changes the indicator to be in its yellow form for the equilibrium below?



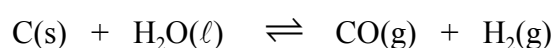
- (A) add $\text{CH}_3\text{COOH(aq)}$ to the system
- (B) add $\text{NaCH}_3\text{COO(aq)}$ to the system
- (C) remove $\text{CH}_3\text{COO}^-(\text{aq})$ by precipitation
- (D) remove HMo(aq) by precipitation

11. In the equilibrium below, a solution of $\text{Fe}(\text{NO}_3)_3(\text{aq})$ 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

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



- $$\begin{array}{ll} \text{(A)} & [\text{C}][\text{H}_2\text{O}] \\ \text{(B)} & [\text{CO}][\text{H}_2] \\ \text{(C)} & \frac{[\text{CO}][\text{H}_2]}{[\text{H}_2\text{O}][\text{C}]} \\ \text{(D)} & \frac{[\text{H}_2\text{O}][\text{C}]}{[\text{CO}][\text{H}_2]} \end{array}$$

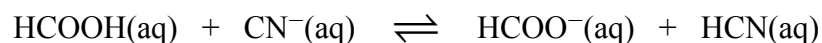
13. Which substance will cause red litmus to change to blue?

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

14. What is the conjugate base of H_2PO_4^- ?

- (A) HPO_4^{3-}
(B) HPO_4^{2-}
(C) H_3PO_4
(D) PO_4^{3-}

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



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

16. Which is an amphoteric substance?
- (A) HCl
(B) HSO_4^-
(C) H_3PO_4
(D) SO_4^-
17. Which species is the strongest base?
- (A) $\text{CO}_3^{2-}(\text{aq})$
(B) $\text{HS}^-(\text{aq})$
(C) $\text{OCl}^-(\text{aq})$
(D) $\text{S}^{2-}(\text{aq})$
18. 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) $\text{H}_3\text{BO}_3(\text{aq})$
19. What is the $[\text{H}_3\text{O}^+]$ in a substance with a pH of 2.80?
- (A) $9.2 \times 10^{-13} \text{ mol/L}$
(B) $4.7 \times 10^{-8} \text{ mol/L}$
(C) $6.3 \times 10^{-6} \text{ mol/L}$
(D) $1.6 \times 10^{-3} \text{ mol/L}$
20. Which theory states that a base is a proton acceptor?
- (A) Arrhenius
(B) Brønsted-Lowry
(C) modified Arrhenius
(D) operational
21. What is the pOH of a solution of $4.2 \times 10^{-6} \text{ mol/L}$ HCl?
- (A) 4.37
(B) 5.38
(C) 8.62
(D) 9.63
22. What happens to the pH and $[\text{H}_3\text{O}^+]$ when 0.10 mol/L NaOH is added to water?

	pH	$[\text{H}_3\text{O}^+]$
(A)	decreases	decreases
(B)	decreases	remains the same
(C)	increases	decreases
(D)	increases	remains the same

23. 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
24. Which is the best indicator for an acid-base titration having an equivalence point pH of 4.2?
- (A) bromocresol green
(B) bromothymol blue
(C) orange IV
(D) phenol red
25. Which is a concentrated weak acid?
- (A) 0.100 mol/L HNO₂(aq)
(B) 0.100 mol/L HNO₃(aq)
(C) 10.0 mol/L HNO₂(aq)
(D) 10.0 mol/L HNO₃(aq)
26. 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 |
27. What is the most likely pH at the equivalence point when equal concentrations of a weak acid and a strong base are titrated?
- (A) 4
(B) 7
(C) 10
(D) 14
28. Which substance is diprotic?
- (A) HNO₂
(B) H₂S
(C) NO₂
(D) S²⁻
29. Which is a measure of average kinetic energy?
- (A) enthalpy
(B) heat
(C) specific heat capacity
(D) temperature

30. Which relationship illustrates the First Law of Thermodynamics?
- (A) $q_{\text{system}} = -q_{\text{surroundings}}$
(B) $q_{\text{system}} = q_{\text{surroundings}}$
(C) $q = mc\Delta T$
(D) $q = n\Delta H$
31. A sample of 0.105 mol of Ag metal is placed in 251.0 mL of H₂O in a calorimeter. What is the enthalpy change of Ag if the temperature change of H₂O is $-3.50\text{ }^{\circ}\text{C}$?
- (A) -3.84 kJ
(B) -3.68 kJ
(C) $+3.68\text{ kJ}$
(D) $+3.84\text{ kJ}$
32. What is the specific heat capacity of a metal that absorbs 4.95 J of heat when a 2.50 g sample of the metal increases in temperature from $25.0\text{ }^{\circ}\text{C}$ to $31.0\text{ }^{\circ}\text{C}$?
- (A) $0.084\text{ J/g}\cdot^{\circ}\text{C}$
(B) $0.33\text{ J/g}\cdot^{\circ}\text{C}$
(C) $3.0\text{ J/g}\cdot^{\circ}\text{C}$
(D) $12\text{ J/g}\cdot^{\circ}\text{C}$
33. Which is true for an exothermic reaction?
- (A) enthalpy difference between products and reactants (ΔH) is negative
(B) enthalpy difference between products and reactants (ΔH) is positive
(C) enthalpy of the products is higher than the enthalpy of the reactants
(D) enthalpy of the products is the same as the enthalpy of the reactants
34. What is the heat of condensation for 15.00 moles of ammonia gas that is liquifying? ($\Delta H_{\text{vap}}(\text{NH}_3) = 23.30\text{ kJ/mol}$)
- (A) -349.5 kJ
(B) -1.553 kJ
(C) 1.553 kJ
(D) 349.5 kJ
35. For the reaction below, what is the molar heat of formation of H₂O(ℓ)?
- $$2\text{ H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{ H}_2\text{O}(\ell) + 571.6\text{ kJ}$$
- (A) -571.6 kJ
(B) -285.8 kJ
(C) 285.8 kJ
(D) 571.6 kJ
36. At standard pressure, which is an example of a change in kinetic energy only?
- (A) carbon dioxide cooling from $-80\text{ }^{\circ}\text{C}$ to $-100\text{ }^{\circ}\text{C}$
(B) molten aluminum solidifying at $660\text{ }^{\circ}\text{C}$
(C) steam condensing at $100\text{ }^{\circ}\text{C}$
(D) water decomposing above $1.0 \times 10^7\text{ }^{\circ}\text{C}$

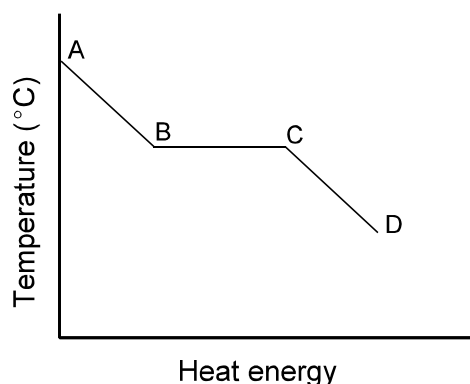
37. Which fuel releases the most energy per gram when burned?

	Fuel	Molar Mass (g/mol)	$\Delta H^\circ_{\text{comb}}$ (kJ/mol)
(A)	$\text{C}_2\text{H}_5\text{OH}(\ell)$	46.08	-1407
(B)	$\text{C}_4\text{H}_9\text{OH}(\ell)$	74.14	-2713
(C)	$\text{C}_4\text{H}_{10}(\ell)$	58.14	-2882
(D)	$\text{C}_8\text{H}_{18}(\ell)$	114.26	-5509

38. Which is the unit for the heat capacity of a bomb calorimeter?

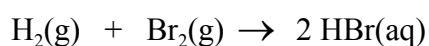
- (A) $\text{J/g}\cdot^\circ\text{C}$
 (B) $\text{kJ}/^\circ\text{C}$
 (C) kJ/g
 (D) kJ/mol

39. What is true for changes in the kinetic and potential energy for section A-B on the graph below?



	Kinetic Energy	Potential Energy
(A)	decreases	constant
(B)	decreases	increases
(C)	increases	constant
(D)	increases	decreases

40. What is the enthalpy change for the formation of HBr?



Bond	Bond Energy (kJ/mol)
H-H	436
Br-Br	193
H-Br	366

- (A) -263 kJ
 (B) -103 kJ
 (C) 103 kJ
 (D) 263 kJ

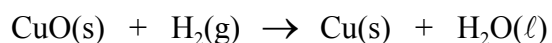
41. Which occurs in oxidation half-reactions?

- (A) electrons are gained
- (B) electrons are lost
- (C) protons are gained
- (D) protons are lost

42. What is the oxidation number of $\text{F}_2(\text{g})$?

- (A) -1
- (B) 0
- (C) 1
- (D) 2

43. What is the reducing agent in the reaction below?



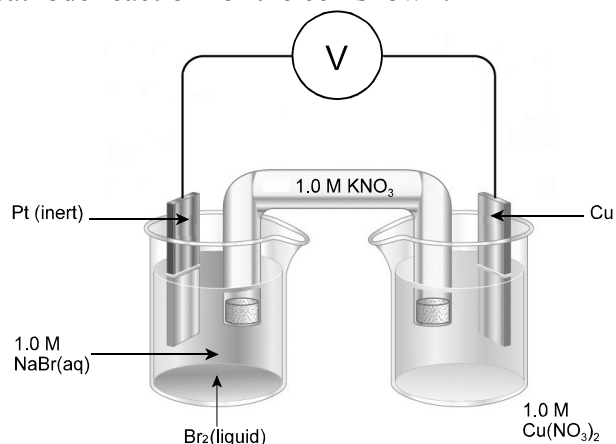
- (A) Cu
- (B) CuO
- (C) H_2
- (D) H_2O

44. Which is the cathode for the cell notation given below?



- (A) $\text{Sn}(\text{s})$
- (B) $\text{Sn}^{2+}(\text{aq})$
- (C) $\text{Zn}(\text{s})$
- (D) $\text{Zn}^{2+}(\text{aq})$

45. What is the cathode reaction for the cell shown?



- (A) $2 \text{Br}^{-}(\text{aq}) \rightarrow \text{Br}_2(\ell) + 2 \text{e}^{-}$
- (B) $\text{Br}_2(\ell) + 2 \text{e}^{-} \rightarrow 2 \text{Br}^{-}(\text{aq})$
- (C) $\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2 \text{e}^{-}$
- (D) $\text{Cu}^{2+}(\text{aq}) + 2 \text{e}^{-} \rightarrow \text{Cu}(\text{s})$

46. Which process separates water into hydrogen and oxygen?

- (A) combustion
- (B) electrolysis
- (C) electroplating
- (D) fusion

47. When connected, which pair of half cells produces the highest possible cell potential?
- (A) $\text{Ca}|\text{Ca}^{2+}||\text{Ni}^{2+}|\text{Ni}$
(B) $\text{Ca}|\text{Ca}^{2+}||\text{Pb}^{2+}|\text{Pb}$
(C) $\text{Ni}|\text{Ni}^{2+}||\text{Ca}^{2+}|\text{Ca}$
(D) $\text{Pb}|\text{Pb}^{2+}||\text{Ca}^{2+}|\text{Ca}$
48. Which is the strongest oxidizing agent?
- (A) Ag
(B) Ag^+
(C) Na
(D) Na^+
49. Calculate the number of moles of Ag metal produced when 0.919 A is passed through an electrolytic cell for 35 h.
- (A) 3.33×10^{-4} mol
(B) 1.20×10^{-3} mol
(C) 1.20 mol
(D) 129 mol
50. Which is a primary cell?
- (A) button
(B) hydrogen fuel
(C) lead-storage
(D) rechargeable

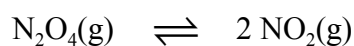
PART II

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

3% 51.(a) $\text{N}_2\text{O}_4(\text{g})$ 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.

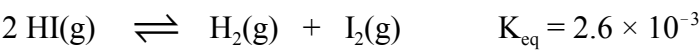
This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. There are no margins, text, or other markings on the paper.

2% (b) 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.

[illegible]

Value

3% 51.(c) 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.



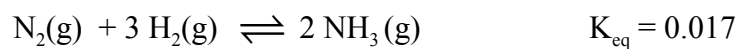
2% (d) The temperature in a closed system, such as with industrial refrigeration, is regulated by the equilibrium shown below. Explain how the amount of NH₃(ℓ) in the system has changed over time as given in the table below.



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

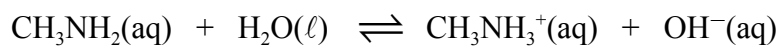
Value

- 3% 51.(e) A scientist placed amounts of N_2 , H_2 , and NH_3 in a sealed container. After thirty minutes the scientist measured the following concentrations of gases present in the container: $[\text{N}_2] = 0.85 \text{ mol/L}$, $[\text{H}_2] = 1.1 \text{ mol/L}$, and $[\text{NH}_3] = 0.67 \text{ mol/L}$. In what direction is the reaction moving to gain equilibrium? Show your workings.



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

- 4% (b) Calculate the K_{b} value of a 0.200 mol/L solution of CH_3NH_2 if the measured pH is 11.930.

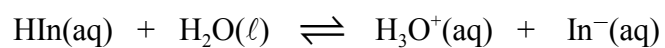


Value

- 2% 52.(c) Explain why the pH of a mixture of NH_4Cl and NH_3 does not drastically change when a small amount of NaOH is added.

- 4% (d) A 20.0 mL solution of NaOH has a pOH of 3.25. A 30.0 mL solution of HCl has a pH of 2.87. Calculate the pH of the mixture of these solutions if the NaOH solution is added to the HCl solution.

- 2% (e) Explain what happens to the equilibrium colour of the indicator in the equation shown below when it is placed in a basic solution.



red

yellow

Value

4% 53.(a) Burning 2.20 g of methanol in an alcohol burner warms 426 g of water by 14.0 °C. The experiment is repeated using the same mass of methanol but this time a different mass of water is heated and the temperature of the water increases by 42.0 °C. Calculate the new mass of water heated.

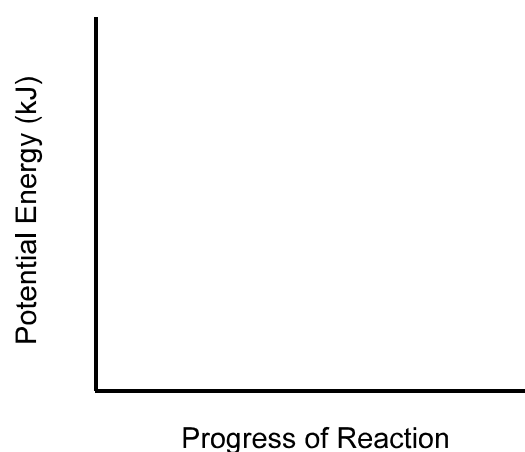
2% (b) Use the data below to explain which 12 g sample of metal will have the higher temperature when 300 J of energy is added.

	Aluminum	Gold
Specific Heat Capacity (J/g·°C)	0.902	0.129

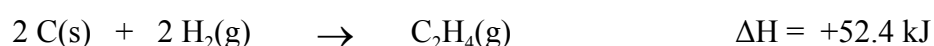
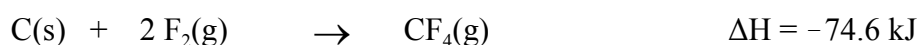
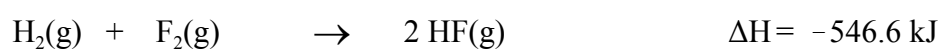
Value

3% 53.(c) The molar enthalpy of combustion of butane (C_4H_{10}) is -2871 kJ/mol .

- i) Write a balanced thermochemical equation to represent the reaction that occurs when two moles of butane burns in excess oxygen.
- ii) Construct a potential energy diagram for the above reaction and label the heat of reaction.



4% (d) Using the data below, calculate the enthalpy change for the following reaction:



Value

3% 54.(a) A redox cell reaction is attempted using $\text{Ni}^{2+}(\text{aq})$ and $\text{Ag}(\text{s})$.

i) Write the equation for the reaction.

ii) Calculate the E° of the cell and tell whether it is spontaneous.

3% (b) A standard cell potential of 1.71 V is measured for an electrochemical cell using a $\text{Cr}(\text{s})|\text{Cr}^{2+}(\text{aq})$ anode and a KNO_3 salt bridge. When the KNO_3 salt bridge is replaced with a KCl salt bridge, a white precipitate forms in the cathode compartment. What is the cathode half-cell reaction? Explain.

Value

4% 54.(c) Calculate the mass of gold plated onto a metal ring from a solution of AuCl_3 in an electrolytic cell run with a current of 20.0 A for 35 minutes.