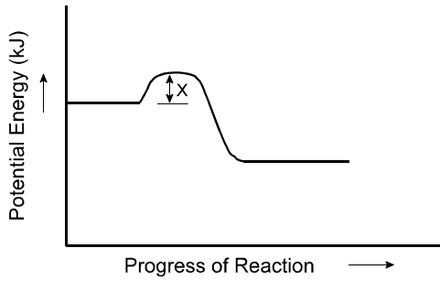
# PART I
# Total Value: 50%

**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?



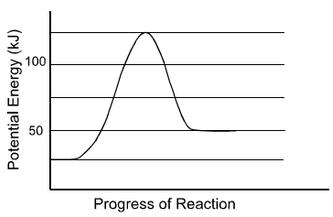

✔ (A) activation energy of the forward reaction
(B) activation energy of the reverse reaction
(C) potential energy of the reactants
(D) molar enthalpy of reaction

2. Which is true for an endothermic reaction?

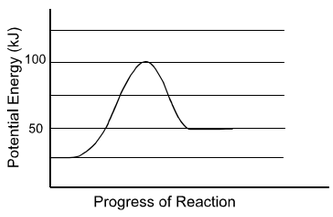
(A) forward $E_a$ is less than reverse $E_a$
(B) forward $E_a$ = reverse $E_a$
✔ (C) forward $E_a$ is greater than reverse $E_a$
(D) forward $E_a$ + reverse $E_a$ = 0

3. Which represents the slowest forward reaction?

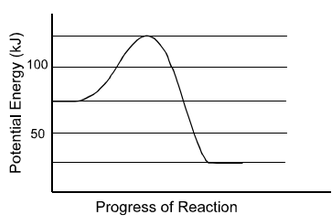
✔ (A)



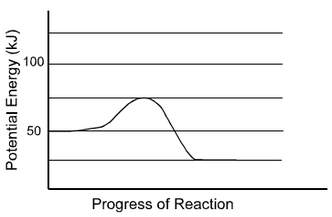

(B)




(C)



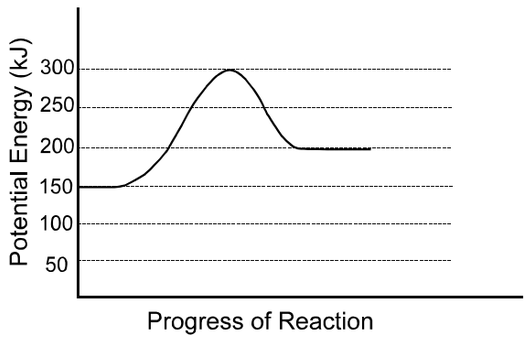

(D)



4. Which substance will undergo the fastest combustion reaction?

✔ (A) $C_3H_8(\ell)$
(B) $C_4H_{10}(\ell)$
(C) $C_5H_{12}(\ell)$
(D) $C_6H_{14}(\ell)$

5. Which are the values for the activation energy ($E_a$) and change in enthalpy ($\Delta H$) for the forward reaction?




| | $E_a$ (kJ) | $\Delta H$ (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.**

| | | | |
|---|---|---|---|
| Step 1: | $2\ NO(g)$ | $\rightarrow$ $N_2O_2(g)$ | fast |
| Step 2: | $N_2O_2(g) + H_2(g)$ | $\rightarrow$ $N_2O(g) + H_2O(g)$ | slow |
| Step 3: | $N_2O(g) + H_2(g)$ | $\rightarrow$ $N_2(g) + H_2O(g)$ | fast |

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) $H_2O$

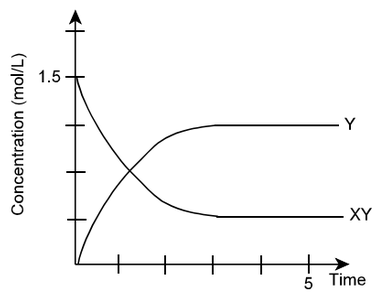
8. What are the products in the overall reaction?

✔ (A) $N_2$ and $H_2O$
(B) $N_2$ and $N_2O_2$
(C) $N_2O$ and $H_2O$
(D) $N_2O_2$ and $N_2O$

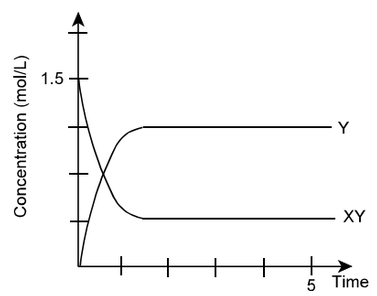
9. For the equilibrium below, 1.50 mol XY(g) is placed in a 1.0 L flask and sealed. Which graph best illustrates what happens if a catalyst is added to the reaction?

$$XY(g) \rightleftharpoons X(g) + Y(g)$$

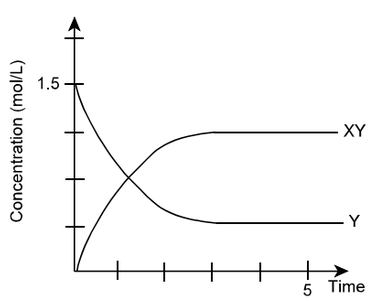
(A)



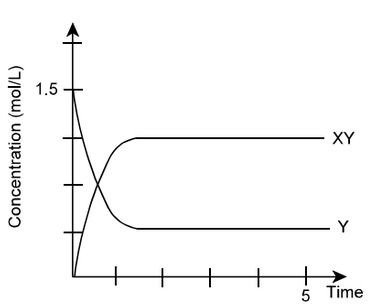

✔ (B)




(C)




(D)




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

$$\underset{\text{Red}}{HMo(aq)} + CH_3COO^-(aq) \rightleftharpoons \underset{\text{Yellow}}{Mo^-(aq)} + CH_3COOH(aq)$$

(A) add $CH_3COOH(aq)$ to the system
✔ (B) add $NaCH_3COO(aq)$ to the system
(C) remove $CH_3COO^-(aq)$ by precipitation
(D) remove HMo(aq) by precipitation

11. In the equilibrium below, a solution of $Fe(NO_3)_3(aq)$ is added and a precipitate is formed. What is observed for the equilibrium shift and the final colour of the reaction mixture?

$$H^+(aq) + 2\,CrO_4^{2-}(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + OH^-(aq)$$
Yellow — Orange

| | 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?

$$C(s) + H_2O(\ell) \rightleftharpoons CO(g) + H_2(g)$$

(A) $[C][H_2O]$

✔ (B) $[CO][H_2]$

(C) $\dfrac{[CO][H_2]}{[H_2O][C]}$

(D) $\dfrac{[H_2O][C]}{[CO][H_2]}$

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

(A) $H_2SO_4(aq)$
(B) $H_3O^+(aq)$
✔ (C) $NH_3(aq)$
(D) $NH_4^+(aq)$

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?

$$HCOOH(aq) + CN^-(aq) \rightleftharpoons HCOO^-(aq) + HCN(aq)$$

| | Acid | Base |
|---|---|---|
| (A) | $CN^-(aq)$ | $HCN(aq)$ |
| (B) | $HCN(aq)$ | $HCOO^-(aq)$ |
| (C) | $HCOOH(aq)$ | $CN^-(aq)$ |
| ✔ (D) | $HCOOH(aq)$ | $HCOO^-(aq)$ |

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) $CO_3^{2-}(aq)$
(B) $HS^-(aq)$
(C) $OCl^-(aq)$
✔ (D) $S^{2-}(aq)$

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) HCN(aq)
✔ (B) HF(aq)
(C) $H_2CO_3(aq)$
(D) $H_3BO_3(aq)$

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

(A) $9.2 \times 10^{-13}$ mol/L
(B) $4.7 \times 10^{-8}$ mol/L
(C) $6.3 \times 10^{-6}$ mol/L
✔ (D) $1.6 \times 10^{-3}$ 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 $4.2 \times 10^{-6}$ mol/L HCl?

(A) 4.37
(B) 5.38
✔ (C) 8.62
(D) 9.63

22. 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 |

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 $HNO_2(aq)$
(B) 0.100 mol/L $HNO_3(aq)$
✔ (C) 10.0 mol/L $HNO_2(aq)$
(D) 10.0 mol/L $HNO_3(aq)$

26. Which acid has the lowest conductivity?

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

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) $HNO_2$
✔ (B) $H_2S$
(C) $NO_2$
(D) $S^{2-}$

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) $q_{system} = -q_{surroundings}$
(B) $q_{system} = q_{surroundings}$
(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 $H_2O$ in a calorimeter. What is the enthalpy change of Ag if the temperature change of $H_2O$ is −3.50 °C?

(A) −3.84 kJ
(B) −3.68 kJ
✔ (C) +3.68 kJ
(D) +3.84 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 °C to 31.0 °C?

(A) 0.084 J/g·°C
✔ (B) 0.33 J/g·°C
(C) 3.0 J/g·°C
(D) 12 J/g·°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? ($\Delta H_{vap}(NH_3) = 23.30$ 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 $H_2O(\ell)$?

$$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(\ell) + 571.6\ kJ$$

(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 °C to −100 °C
(B) molten aluminum solidifying at 660 °C
(C) steam condensing at 100 °C
(D) water decomposing above $1.0 \times 10^7$ °C

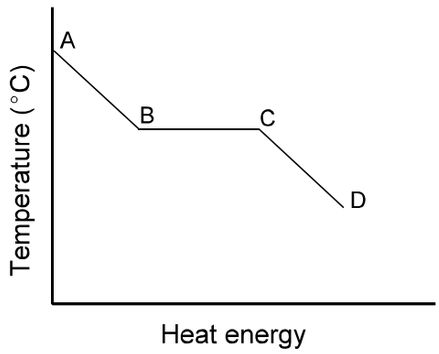
37. Which fuel releases the most energy per gram when burned?

| | Fuel | Molar Mass (g/mol) | $\Delta H^\circ_{comb}$ (kJ/mol) |
|---|---|---|---|
| (A) | $C_2H_5OH(\ell)$ | 46.08 | −1407 |
| (B) | $C_4H_9OH(\ell)$ | 74.14 | −2713 |
| ✔ (C) | $C_4H_{10}(\ell)$ | 58.14 | −2882 |
| (D) | $C_8H_{18}(\ell)$ | 114.26 | −5509 |

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

(A) J/g·°C
✔ (B) kJ/°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?

$$H_2(g) + Br_2(g) \rightarrow 2\ HBr(aq)$$

| 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 $F_2(g)$?

(A) −1
✔ (B) 0
(C) 1
(D) 2

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

$$CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(\ell)$$

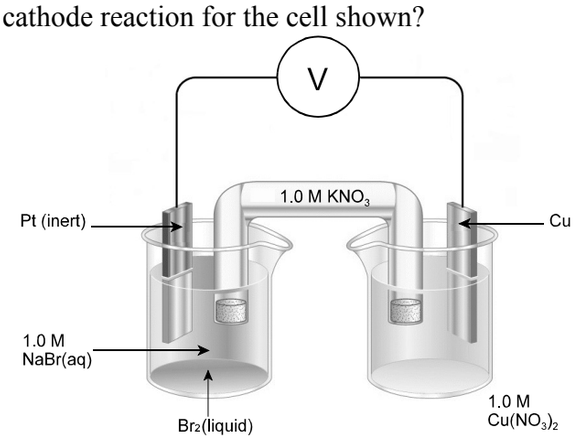
(A) Cu
(B) CuO
✔ (C) $H_2$
(D) $H_2O$

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

$$Zn(s)|Zn^{2+}(aq) \,||\, Sn^{2+}(aq)|Sn(s)$$

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

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




(A) $2\ Br^-(aq) \rightarrow Br_2(\ell) + 2\ e^-$
✔ (B) $Br_2(\ell) + 2\ e^- \rightarrow 2\ Br^-(aq)$
(C) $Cu(s) \rightarrow Cu^{2+}(aq) + 2\ e^-$
(D) $Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$

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) $Ca|Ca^{2+}||Ni^{2+}|Ni$
✔ (B) $Ca|Ca^{2+}||Pb^{2+}|Pb$
(C) $Ni|Ni^{2+}||Ca^{2+}|Ca$
(D) $Pb|Pb^{2+}||Ca^{2+}|Ca$

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) $3.33 \times 10^{-4}$ mol
(B) $1.20 \times 10^{-3}$ 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) $N_2O_4(g)$ 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.

$$N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$$

**Initially - large amount of reactant particles and small amount of product particles means forward rate is fast and reverse rate is slow. [1 mark]**

**Proceeding - as reactant particles are consumed the forward rate slows down; since more product particles are being formed the reverse rate increases. [1 mark]**

**When the forward rate and the reverse rates becomes equal, equilibrium is established. [1 mark]**

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.

**The unsanded cube has a larger surface area, thus more exposed particles. [1 mark] This means more reactant collisions therefore more successful collisions (those with proper orientation and the $E_a$). [1 mark]**

**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 $H_2$ at equilibrium.

| | **2 HI(g) ⇌** | **$H_2$(g) +** | **$I_2$(g)** | **$K_{eq} = 2.6 \times 10^{-3}$** |
|---|---|---|---|---|
| I | | 0 | 0 | |
| C | - 2 x | + x | + x | |
| E | 0.80 | x | x | **[½ mark]** |

$$K = \frac{[H_2][I_2]}{[HI]^2}$$ **[½ mark]**

$$2.6 \times 10^{-3} = \frac{x^2}{(0.80)^2}$$ **[½ mark]**

$x = 0.041\ M = [H_2]$ **[½ mark]**

| **Science Communication** | **½ mark units**<br>**½ mark significant figures** |
|---|---|

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 $NH_3(\ell)$ in the system has changed over time as given in the table below.

$$NH_3(g) \rightleftharpoons NH_3(\ell) + \text{energy}$$

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

**From Day 1 to Day 4, the temperature of the refrigerator decreased, this indicates that the ammonia equilibrium is absorbing energy. [1 mark]**

**ie: Shifting left, therefore $NH_{3\ (liquid)}$ decreases. [1 mark]**

**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: $[N_2] = 0.85$ mol/L, $[H_2] = 1.1$ mol/L, and $[NH_3] = 0.67$ mol/L. In what direction is the reaction moving to gain equilibrium? Show your workings.

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g) \qquad K_{eq} = 0.017$$

$$\mathbf{Q = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(0.67)^2}{(0.85)(1.1)^3} = 0.39(7)} \qquad \textbf{[1½ marks]}$$

**Since 0.39(7) is larger than K = 0.017, the reaction is shifting left to establish equilibrium.**

**[1½ marks]**

2% 52.(a) Predict the Brønsted-Lowry acid-base neutralization reaction that occurs when $(NH_4)_2S$ is added to $NaHSO_3$.

| Species: | $NH_4^+$ | $S^{2-}$ | $Na^+$ | $HSO_3^-$ | $H_2O$ |
|---|---|---|---|---|---|
| | A | B | neutral | A/B | A/B |
| | | SB | | SA | |

$$\mathbf{S^{2-} + HSO_3^- \rightleftharpoons HS^- + SO_3^{2-}}$$

**[½ mark] [½ mark] [½ mark] [½ mark]**

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.

$$CH_3NH_2(aq) + H_2O(\ell) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$$

| | $CH_3NH_2$ | + $H_2O$ ⇌ | $CH_3NH_3^+(aq)$ | + $OH^-$ | |
|---|---|---|---|---|---|
| **I** | **2.97** | | **0** | **0** | |
| **C** | **$-x$** | | **$+x$** | **$+x$** | |
| **E** | **$2.97 - x$** | | ***x*** | ***x*** | **[½ mark]** |

**pOH = 14.000 - 11.930 = 2.070** **[½ mark]**

**$[OH^-]_{eq} = 10^{-pOH} = 10^{-2.070} = 0.00851(1)$ mol/L = *x*** **[1 mark]**

**$[CH_3NH_3^+]_{eq} = x = 0.00851(1)$ mol/L** **[½ mark]**

**$[CH_3NH_2]_{eq} = 0.200 - x = 0.200 - 0.00851(1) = 0.191(5)$ mol/L** **[½ mark]**

$$\mathbf{K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]} = \frac{[0.00851(1)]^2}{0.191(5)} = 3.78 \times 10^{-4}}$$

**[½ mark] [½ mark]**

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.

**$NH_4Cl$ and $NH_3$ mixture is a buffer [1 mark]**

**which resists changes in pH because the addition of a small amount of**

**base (NaOH) will react with the acid, $NH_4^+$, in the buffer. [1 mark]**

$$NH_4^+ + OH^- \rightarrow HOH + NH_3$$

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.

**$[OH^-] = [NaOH] = 10^{-pOH} = 10^{-3.25} = 5.6(2) \times 10^{-4}$ mol/L** **[½ mark]**

**$[H_3O^+] = [HCl] = 10^{-pH} = 10^{-2.87} = 1.3(5) \times 10^{-3}$ mol/L** **[½ mark]**

**$n(OH^-) = c\,v = (5.6(2) \times 10^{-4}\ mol/L)(0.0200\ L) = 1.1(2) \times 10^{-5}$ mol** **[½ mark]**

**$n(H_3O^+) = c\,v = (1.3(5) \times 10^{-3}\ mol/L)(0.0300\ L) = 4.0(5) \times 10^{-5}$ mol**

**Ratio 1 : 1** **[½ mark]**

**$n(H_3O^+)_{excess} = 4.0(5) \times 10^{-5}\ mol - 1.1(2) \times 10^{-5}\ mol = 2.9(3) \times 10^{-5}$ mol** **[½ mark]**

**$[H_3O^+] = \frac{n_{excess}}{v_{total}} = \frac{2.9(3) \times 10^{-5}\ mol}{0.0500\ L} = 5.8(6) \times 10^{-4}$ mol/L** **[1 mark]**

**$pH = -\log [H_3O^+] = -\log 5.8(6) \times 10^{-4} = 3.23$** **[½ mark]**

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.

$$HIn(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + In^-(aq)$$

red yellow

**Base reacts with $[H_3O^+]$ decreasing its concentration. [½ mark]**

**Equilibrium shifts to the right. [½ mark]**

**Equilibrium becomes more yellow. [1 mark]**

**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.

**Situation 1**

$q_{methanol} = - q_{water}$ **[½ mark]**

$= - m\ c\ \Delta T$

$= - (426\ g)\ (4.184\ J/g{\bullet}°C)\ (14.0°C)$

$= - 249(53)\ J$ **[1 mark]**

**Situation 2**

$q_{methanol} = - q_{water}$ **[½ mark]**

$- 249(53)\ J = - m\ (4.184\ J/g{\bullet}°C)\ (42.0°C)$

$m = \dfrac{- 249(53)\ J}{(4.184\ J/g{\bullet}°C)\ (42.0°C)} = 142\ g$ **[1 mark]**

| **Science Communication** | **½ mark units**<br>**½ mark significant figures** |
|---|---|

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 |

**Gold will have the higher temperature [1 mark]**

**since it has a lower specific heat capacity, it needs to absorb less**

**energy to make its temperature increase 1°C [1 mark].**

**Gold: $\Delta T = q / mc = 300\ J / (12.0\ g \times 0.129\ J/g{\cdot}°C) = 194°C$**

**Aluminum: $\Delta T = q / mc = 300\ J / (12.0\ g \times 0.902\ J/g{\cdot}°C) = 27.7°C$**

**Value**

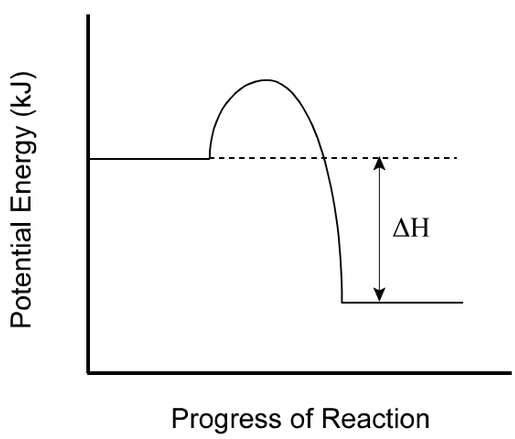
3% 53.(c) The molar enthalpy of combustion of butane ($C_4H_{10}$) is −2871 kJ/mol.

i) Write a balanced thermochemical equation to represent the reaction that occurs when two moles of butane burns in excess oxygen.

**$2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O + 5742$ kJ**

**[½ mark reactants & products]**
**[½ mark balancing]**
**[1 mark energy value in products]**

ii) Construct a potential energy diagram for the above reaction and label the heat of reaction.




**[½ mark shape]**
**[½ mark for ΔH]**

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

$$C_2H_4(g) + 6\ F_2(g) \rightarrow 2\ CF_4(g) + 4\ HF(g) \qquad \Delta H = ?$$

| | | | |
|---|---|---|---|
| $H_2(g) + F_2(g)$ | $\rightarrow$ | $2\ HF(g)$ | $\Delta H = -546.6$ kJ |
| $C(s) + 2\ F_2(g)$ | $\rightarrow$ | $CF_4(g)$ | $\Delta H = -74.6$ kJ |
| $2\ C(s) + 2\ H_2(g)$ | $\rightarrow$ | $C_2H_4(g)$ | $\Delta H = +52.4$ kJ |

| | | | | |
|---|---|---|---|---|
| **$2\ H_2(g) + 2\ F_2(g)$** | **$\rightarrow$** | **$4\ HF(g)$** | **$\Delta H = -1093.(2)$ kJ** | **[1 mark]** |
| **$2\ C(s) + 4\ F_2(g)$** | **$\rightarrow$** | **$2\ CF_4(g)$** | **$\Delta H = -149.(2)$ kJ** | **[1 mark]** |
| **$C_2H_4(g)$** | **$\rightarrow$** | **$2\ C(s) + 2\ H_2(g)$** | **$\Delta H = +52.4$ kJ** | **[1 mark]** |
| **$C_2H_4(g) + 6\ F_{2\,(g)}$** | **$\rightarrow$** | **$4\ HF(g) + 2\ CF_4(g)$** | **$\Delta H = -1295$ kJ** | **[1 mark]** |

**Value**

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

i) Write the equation for the reaction.

| | | |
|---|---|---|
| **$Ni^{2+} + 2\ e^- \rightarrow Ni$** | $\xi$ = - 0.26 V | **[½ mark]** |
| **$Ag \rightarrow Ag^+ + 1\ e^-$ ] x 2** | $\xi$ = - 0.80 V | **[½ mark]** |
| **$Ni^{2+} + 2\ Ag \rightarrow Ni + 2\ Ag^+$** | | **[1 mark]** |

ii) Calculate the $E^o$ of the cell and tell whether it is spontaneous.

**$\xi^\circ_{cell}$ = (- 0.26 V ) + (- 0.80 V) = - 1.06 V** **[½ mark]**

**non - spontaneous** **[½ mark]**

3% (b) A standard cell potential of 1.71 V is measured for an electrochemical cell using a $Cr(s)|Cr^{2+}(aq)$ 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.

| | | |
|---|---|---|
| **$Cr \rightarrow Cr^{2+} + 2\ e^-$** | **$\xi^\circ_{ox}$ = 0.91 V** | **[½ mark]** |
| **??** | **$\xi^\circ_{red}$ = ??** | |
| | **$\xi^\circ_{cell}$ = 1.71 V** | |

**$\xi^\circ_{red}$ = 1.71 V - 0.91 V = 0.80 V** **[½ mark]**

**Since a precipitate forms with KCl, the cathode cell is silver.** **[1 mark]**

**Cathode half reaction: $Ag^+ + e^- \rightarrow Ag$** **[1 mark]**

**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.

$t = 35 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}} = 2100 \text{ s}$ **[½ mark]**

$Q = I\ t = (20.0 \text{ A})(2100 \text{ s}) = 42000 \text{ C}$ **[½ mark]**

$n(e^-) = \frac{Q}{F} = \frac{42000 \text{ C}}{96500 \text{ C/mol } e^-} = 0.43(5) \text{ mol } e^-$ **[½ mark]**

$Au^{3+} + 3\ e^- \rightarrow Au$ **[½ mark]**

$n_{Au} = 0.43(5) \text{ mol } e^- \times \frac{1 \text{ mol Au}}{3 \text{ mol } e^-} = 0.14(5) \text{ mol}$ **[½ mark]**

$m_{Au} = n\ M = (0.14(5) \text{ mol})(196.97 \text{ g/mol}) = 29 \text{ g}$ **[½ mark]**

| **Science Communication** | **½ mark units**<br>**½ mark significant figures** |
|---|---|