Chemistry 12
Worksheet 2-1 - Equilibrium, Enthalpy and Entropy

1. What do people mean when they say that a reaction is ***reversible?*** Having forward and reverse rxns

2. Give *four* things which are true about a system ***at equilibrium***:
   1. closed system achieved from either direction
   2. constant temperature [products] = constant = [react
   3. forward rate = reverse rate
   4. constant macroscopic properties

3. What is meant by ***macroscopic properties***? properties we can see or we can measure

4. Give some examples of macroscopic properties: colour, gas produced, mass change

5. What happens to macroscopic properties ***at equilibrium***? constant

6. How do the rates of the forward and reverse reaction compare at equilibrium? equal

7. Do the forward and reverse reactions stop at equilibrium? no

8. What can be said about the concentrations of all reactants and products ***at equilibrium***? constant

9. Why is chemical equilibrium called ***dynamic equilibrium***? molecular changes take place

A + B ⇌ C + D
I 1.0 1.0 0 0
C -0.8 -0.8 +0.8 +0.8
E 0.2 0.2 0.8 0.8
$K_{eq} = \frac{(0.8)^2}{(0.2)^2} = 16$

A + B ⇌ C + D
I 0 0 1.0 1.0
C +0.2 +0.2 ← -0.2 -0.2
E 0.2 0.2 0.8 0.8
$K_{eq} = \frac{(0.8)^2}{(0.2)^2} = 16$

10. Given the reaction: A + B ⇌ C + D

When 1.0 mole of A is combined with 1.0 mole of B, an equilibrium is established in which [A] = 0.2 M, [B] = 0.2 M , [C] = 0.8 M and [D] = 0.8 M
If, at the same temperature, 1.0 mole of C and 1.0 mole of D is combined. When equilibrium is established, determine what the following concentrations will be:

[A] = 0.2 M, [B] = 0.2 M , [C] = 0.8 M and [D] = 0.8 M

11. Given sufficient activation energy, a system ***not at equilibrium*** will eventually move toward equilibrium.

12. Systems will tend toward a position of minimum ***enthalpy.*** ΔH ↘

13. Systems will tend toward a position of maximum ***entropy.*** ΔS ↗

14. Tell whether each of the following is ***endothermic*** or ***exothermic*** and state which has ***minimum enthalpy,*** the *reactants* or the *products*:

a. $Cl_{2(g)} + PCl_{3(g)} \underset{\text{Endo}}{\overset{\text{Exo}}{\rightleftharpoons}} PCl_{5(g)}$ ΔH = -92.5 kJ

Exo thermic and the product has *minimum enthalpy.*

b. $2NH_{3(g)} \underset{\text{Exo}}{\overset{\text{Endo}}{\rightleftharpoons}} N_{2(g)} + 3H_{2(g)}$ ΔH = 92.4 kJ

Endo thermic and the reactant has *minimum enthalpy.*

c. $CH_{4(g)} + H_2O_{(g)} + 49.3\text{ kJ} \underset{\text{Exo}}{\overset{\text{Endo}}{\rightleftharpoons}} CO_{(g)} + 3H_{2(g)}$

Endo thermic and the reactants have *minimum enthalpy.*

15. If the reaction: $Cl_{2(aq)} \underset{\text{Exo}}{\overset{\text{Endo}}{\rightleftharpoons}} Cl_{2(g)}$ ΔH = +25 kJ

was proceeding to the *right*, the enthalpy would be increasing. Is this a *favourable* change? No.

16. If the reaction: $N_{2(g)} + 3H_{2(g)} \underset{\text{Endo}}{\overset{\text{Exo}}{\rightleftharpoons}} 2NH_{3(g)} + 92.4\text{ kJ}$

was proceeding to the *right*, the enthalpy would be decreasing. Is this a *favourable* change? Yes.

17. For each of the following, decide whether the ***reactants*** or the ***products*** have ***greater entropy***:

a) $I_{2(s)} \rightleftarrows I_{2(g)}$ The product have greater entropy.

b) $4PH_{3(g)} \rightleftarrows P_{4(g)} + 6H_{2(g)}$
4 mol 7 mol
The products have greater entropy.

c) $NH_{3(g)} \rightleftarrows NH_{3(aq)}$

The reactant has greater entropy.

18. When the two tendencies ***oppose each other*** (one favours reactants, the other favours products), the reaction will reach equilibrium

Processes in which ***both*** the tendency toward ***minimum enthalpy*** and toward ***maximum entropy*** favour the ***products***, will go to completion (100% product formation)

Processes in which ***both*** the tendency toward ***minimum enthalpy*** and toward ***maximum entropy*** favour the ***reactants***, will not take place (no rxn)

19. For each of the following reactions decide which has ***minimum enthalpy*** (reactants or products), which has ***maximum entropy*** (reactants or products), and if the reactants are mixed, what will happen? (go to completion/ reach a state of equilibrium/not occur at all).

a) $4HCl_{(g)} + O_{2(g)} \underset{\text{Endo}}{\overset{\text{Exo}}{\rightleftarrows}} 2H_2O_{(g)} + 2Cl_{2(g)} + 114.4\ kJ$
5 mol 4 mol
The products have minimum enthalpy.

The reactants have maximum entropy.

If HCl + O_2 are put together, what should happen?(go to completion/ reach a state of equilibrium/not occur at all)
state of eqm

b) $CO_{2(g)} + H_{2(g)} \underset{\text{Exo}}{\overset{\text{Endo}}{\rightleftarrows}} CO_{(g)} + H_2O_{(g)}$; $\Delta H = 42.6\ kJ$
2 mol 2 mol
The reactants have minimum enthalpy.

How does the entropy of the reactants and products compare? no change
If $CO_{2(g)}$ + $H_{2(g)}$ were put in a flask, what should happen?(go to completion/ reach a state of equilibrium/not occur at all)
not occur at all

c) $4PH_{3(g)} \rightleftharpoons P_{4(s)} + 6H_{2(g)} + 37\ kJ$ (Exo / Endo; 4 mog / 6 mog)

The products has/have minimum enthalpy.

The products has/have maximum entropy.

If $PH_{3(g)}$ was put in a flask what should happen? (go to completion/ reach a state of equilibrium/not occur at all)

go to completion

20. Do systems always reach ***minimum enthalpy*** at equilibrium? No

Explain. $\Delta S > \Delta H$ Entropy may be higher than enthalpy

21. Do systems always reach ***maximum entropy*** at equilibrium? No

Explain. $\Delta H > \Delta S$ Enthalpy may be higher than entropy

22. A "heat term" in a chemical equation shows what is happening to the enthalpy and really has nothing to do with the entropy
(Answers are either entropy or enthalpy)

23. As a reaction approaches equilibrium, the rate of the forward reaction decreases, while the rate of the reverse reaction increases. Once equilibrium is reached, the rates become equal

24. Consider the reaction: $BaCO_{3(s)} + \text{heat} \rightleftharpoons BaO_{(s)} + CO_{2(g)}$

Which one of the following observations will indicate that the reaction has most likely achieved ***equilibrium***?

a) The mass of the system becomes constant
b) The concentration of $BaO_{(s)}$ becomes constant
c) All the $BaCO_3$ is consumed.
(d) The gas pressure of the system becomes constant

Your answer is D. Explain why. solids don't affect the equilibrium

25. Consider the following reaction: $Fe^{3+}_{(aq)} + SCN^{-}_{(aq)} \rightleftharpoons FeSCN^{2+}_{(aq)}$

A solution of $Fe(NO_3)_3$ is added to a solution of KSCN. As equilibrium is being established, the $[Fe^{3+}]$ is decreased and the $[FeSCN^{2+}]$ increased

26. A system has reached equilibrium when:

a) maximum entropy has been achieved > any system
b) minimum enthalpy has been achieved
c) the rate of the forward reaction and reverse reaction is ~~zero~~ constant
d) the concentrations of reactants and products have stopped changing

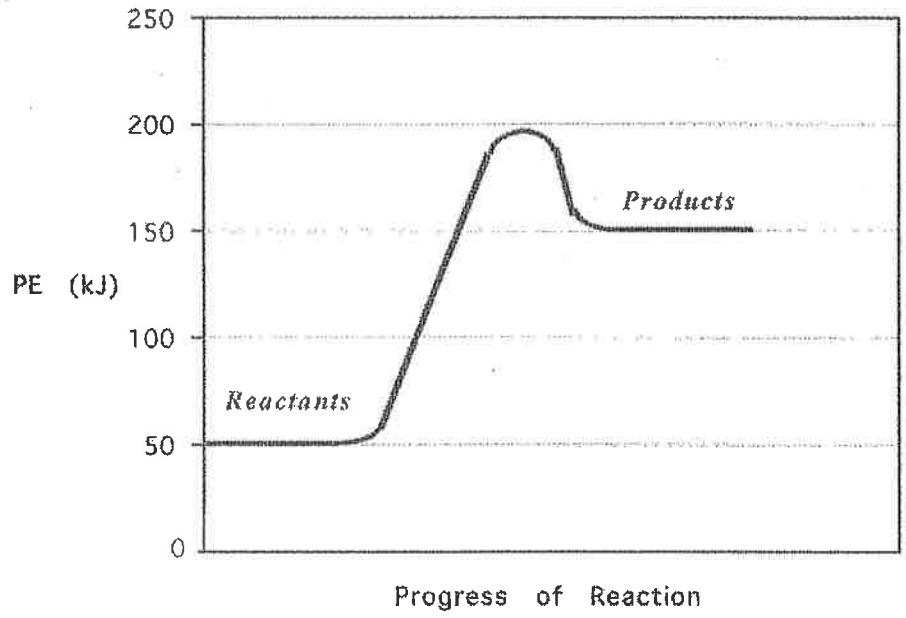
Your answer is D. Explain why At eqm [reactants] = constant = [products]

27. Equilibrium is achieved when reactant and product concentrations are (equal/constant/zero) constant

28. In a particular chemical reaction, ΔH = +100 kJ. When equilibrium has been established, it is found that a significant amount of product has formed, even though there is still some reactants left. ΔH : ← ΔS →

What has happened to ***entropy*** as this reaction was taking place? increasing
Explain how you arrived at your answer If minimum enthalpy favours the reactants, a system at eqm would have maximum entropy favouring products

29. Given the following potential energy diagram for a reaction:



Explain in terms of enthalpy and entropy, how you could end up with a fairly high ratio of products to reactants.

ΔH ↘ : products favoured + ΔS ↘ : reactants favoured
ΔH ↗ : reactants favoured + ΔS ↗ : products favoured