

NORGES TEKNISK-  
NATURVITENSKAPELIGE UNIVERSITET  
INSTITUTT FOR KJEMI

**EKSAMEN I GENERELL KJEMI (KJ1000)**

Fredag 5. juni 2009

Tid: 09.00-13.00

Oppgavesettet består av: Oppgavetekst (4 sider), vedlegg (4 sider)

Hjelpebidrifter: Kalkulator

Faglig kontakt under eksamen: Professor Lise Kvittingen: 73 59 66 22, 48 29 97 06 (mobil)

Sensur: 17. juni 2009

I vedleggene er periodesystemet, tabell over standard reduksjonspotensialer, tabell over protolysekonstanter for en del syrer (syrekonstanten) og en oversikt over diverse ligninger.

Gasskonstanten ( $R$ ): 0,0821  $\frac{L \cdot atm}{mol \cdot K}$

Faraday's konstant ( $F$ ):  $9,648 \times 10^4 \frac{C}{mol \cdot e^-}$

**1) (1 p)**

Bestem antall protoner, nøytroner og elektroner i det følgende:



**2) (1 p)**

Hva er den korresponderende basen til  $\text{HCO}_3^-$ ?

**3) (1 p)**

Hva er elektronkonfigurasjonen for grunntilstanden av  $\text{F}^-$ ?

**4) (2 p)**

Gitt en reaksjon der  $\Delta H$  er negativ og  $\Delta S$  er positiv. Ved hvilke(n) temperatur(er) er denne reaksjonen spontan. Forklar kort hvorfor.

**5) (1 p)**

I vedlegget bak er det oppgitt syrekonstanten (protolysekonstanter) for flere syrer. Hvilken syre i tabellen er den sterkeste?

**6) (2 p)**

Hvis du studerer trender i periodesystemet, vil du oppdage at atomradien forandrer seg nedover grupper og langs perioder. Hvilke trender gjør seg gjeldende og hvordan forklarer du disse?

**7) (2 p)**

Gi to eksempler på ioniske forbindelser og to eksempler på molekylære forbindelser.

**8) (2 p)**

Nevn to grunnstoff som forekommer som molekyler i vanlig tilstand og to som forekommer som enkelt-atomer?

**9) (1 p)**

Atomorbitalene kan beskrives med kvantetall.

Gitt at hovedkvantetallet (n) er 3, og bikvantetallet (l) (asimutale kvantetallet) er 2. Hvilke(n) verdi(er) kan da det magnetiske kvantetallet ( $m_l$ ) ha?

**10) (1 p)**

I hvilket pH område vil vi finne ekvivalenspunktet når en svak base blir titrert med HCl ved 25°C.

**11) (2 p)**

Tegn Lewis strukturen av C<sub>2</sub>H<sub>2</sub>. Hvor mange sigma og pi bindinger er det i denne forbindelsen.

**12) (2 p)**

Skriv en balansert reaksjonsligning for reaksjonen som skjer når en vannløsning av blynitrat (to-verdig bly) helles i en vannløsning av kaliumiodid.

**13) (3 p)**

Fullfør og balanser hver av ligningene:

- a) Na (s) + O<sub>2</sub> (g)
- b) C<sub>3</sub>H<sub>8</sub> (g) + O<sub>2</sub> (g)
- c) Zn (s) + H<sub>2</sub>SO<sub>4</sub> (aq)

**14) (2 p)**

Når ammoniumkarbamat NH<sub>2</sub>CO<sub>2</sub>NH<sub>4</sub> dekomponerer dannes ammoniakk og karbondioksid.



Vi starter med bare det faste stoffet og finner at totaltrykket ved en gitt temp er 0,363 atm

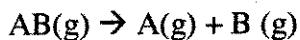
Beregn likevektskonstanten K<sub>p</sub>.

**15) (2 p)**

En varm sommerdag tar du ut en flaske kullsyreholdig drikke fra kjøleskapet og en annen som har stått på kjøkkenbenken hele dagen og åpner dem. Hva vil du observere når du åpner (og heller fra) disse flaskene. Hvordan forklarer du dette?

**16) (4 p)**

Under er data som ble samlet for følgende reaksjon:



Tid (s)	[AB] (M)
0	0,950
50	0,459
100	0,302
150	0,225
200	0,180
250	0,149
300	0,128
350	0,112
400	0,0994
450	0,0894
500	0,0812

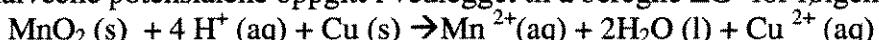
- a) Bestem reaksjonsordenen og verdien av hastighetskonstanten.  
b) Hva er konsentrasjonen av AB ved 25 sekunder?

**17) (2 p)**

Bestem prosent ionisering av en 0,124 M HCN løsning når ved 298°C.

**18) (3 p)**

Bruk halvcelle potensialene oppgitt i vedlegget til å beregne  $\Delta G^0$  for følgende reaksjon



**19) (3 p)**

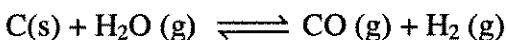
Natriumhydrogenkarbonat blir ofte brukt for å redusere overskudd av saltsyre i magen for folk med halsbrann.

- a) Skriv en balansert reaksjonsligning for reaksjonen mellom saltsyre og natriumhydrogenkarbonat

b) Hvor mye (i gram) saltsyre kan nøytraliseres med 2,5 g natriumhydrogenkarbonat?

**20) (6 p)**

Kull kan bli brukt til å lage hydrogengass i følge reaksjonen under som er endoterm.



Denne reaksjonen er i utgangspunktet ved likevekt ved en gitt temperatur.

Forutsi og forklar kort om endringene som blir gjort under vil øke eller minske utbyttet av hydrogengass hvis

- a) mer C tilsettes reaksjonsblandingen
- b) mer  $\text{H}_2\text{O}$  (gass) tilsettes reaksjonsblandingen
- c) temperaturen økes i reaksjonsblandingen
- d) volumet av reaksjonskaret øker
- e) en katalysator tilsettes
- f) en ureaktiv gass tilsettes

**21) (3 p)**

Skisser en titrerkurve (der y-aksen tilsvarer pH og x-aksen volum av tilsatt base) når en monoprotisk svak syre titreres med en sterk base.

Angi bufferområdet og ekvivalenspunktet.

**22) (2 p)**

$\text{K}_2\text{Cr}_2\text{O}_7$  (i syre),  $\text{HNO}_3$  og  $\text{KMnO}_4$  (i syre) er alle oksidasjonsmidler. Hvilke(n) av disse vil oksidere  $\text{Br}^-$  med ikke  $\text{Cl}^-$ ? Begrunn svaret.

**23) (2 p)**

I et eksperiment viser det seg at en gassprøve på 0,433 g har et volum på 248 mL ved 745 mmHg og 28°C. Hva er molmassen av gassen?

Main groups		Main groups																											
		1A <sup>a</sup>		2A		Transition metals												3A		4A		5A		6A		7A		8A	
		1	H	2	Be	Metals						Metalloids						Nonmetals			Nonmetals			Nonmetals			He		
		1	1.008	2	9.012																						18		
1	Li	3	4	2	Be	3	4B	5B	6B	7B	8	8B	9	10	1B	2B	13	14	6	7	8	9	10	17	18				
2	Mg	3	4	5	Ti	21	22	23	24	25	26	27	28	29	30	31	32	14	15	16	17	18	19	20	21	20.18			
3	Na	22.99	24.31	Sc	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	10.81	12.01	14.01	16.00	19.00	20.00	21.00	22.00	23.00	4.003				
4	K	39.10	40.08	Ca	Y	Zr	Nb	Tc	Ru	Pd	Ag	Cd	In	Sn	Sb	Te	11.01	12.01	13.01	14.01	15.01	16.01	17.01	18.01	19.01	39.95			
5	Rb	37.38	39.49	Sr	Y	Zr	Nb	Mo	Tc	Ru	Pd	Ag	49	50	51	52	53	54	55	56	57	58	59	60	61	62	36		
6	Cs	85.47	87.62	Ba	Lu	Hf	Ta	W	Re	Os	Pt	Au	Hg	Tl	Pb	Bi	12.01	13.01	14.01	15.01	16.01	17.01	18.01	19.01	20.01	Xe			
7	Fr	87.88	88.103	Ra	Lr	Rf	D <sub>b</sub>	S <sub>g</sub>	B <sub>h</sub>	H <sub>s</sub>	M <sub>t</sub>	D <sub>s</sub>	R <sub>g</sub>	12.01	13.01	14.01	15.01	16.01	17.01	18.01	19.01	20.01	21.01	22.01	23.01	24.01	131.29		
8	Lanthanide series		57	58	59	60	61	62	63	64	65	66	67	68	69	70	138.91	140.12	144.24	145.16	150.36	151.96	157.25	164.93	167.76	168.93	173.04		
9	Actinide series		89	90	91	92	93	94	95	96	97	98	99	100	101	102	127.03	128.04	129.05	129.06	129.07	129.08	129.09	129.10	129.11	129.12			

<sup>14</sup>The labels on top (1A, 2A, etc.) are common American usage. The labels below these (1, 2, etc.) are those recommended

**TABLE 18.1** Standard Reduction Potentials at 25 °C

	Reduction Half-Reaction	$E^\circ$ (V)
Stronger oxidizing agent		
$\text{F}_2(g) + 2 e^-$	$\longrightarrow 2 \text{F}^-(aq)$	2.87
$\text{H}_2\text{O}_2(aq) + 2 \text{H}^+(aq) + 2 e^-$	$\longrightarrow 2 \text{H}_2\text{O}(l)$	1.78
$\text{PbO}_2(s) + 4 \text{H}^+(aq) + \text{SO}_4^{2-}(aq) + 2 e^-$	$\longrightarrow \text{PbSO}_4(s) + 2 \text{H}_2\text{O}(l)$	1.69
$\text{MnO}_4^-(aq) + 4 \text{H}^+(aq) + 3 e^-$	$\longrightarrow \text{MnO}_2(s) + 2 \text{H}_2\text{O}(l)$	1.68
$\text{MnO}_4^-(aq) + 8 \text{H}^+(aq) + 5 e^-$	$\longrightarrow \text{Mn}^{2+}(aq) + 4 \text{H}_2\text{O}(l)$	1.51
$\text{Au}^{3+}(aq) + 3 e^-$	$\longrightarrow \text{Au}(s)$	1.50
$\text{PbO}_2(s) + 4 \text{H}^+(aq) + 2 e^-$	$\longrightarrow \text{Pb}^{2+}(aq) + 2 \text{H}_2\text{O}(l)$	1.46
$\text{Cl}_2(g) + 2 e^-$	$\longrightarrow 2 \text{Cl}^-(aq)$	1.36
$\text{Cr}_2\text{O}_7^{2-}(aq) + 14 \text{H}^+(aq) + 6 e^-$	$\longrightarrow 2 \text{Cr}^{3+}(aq) + 7 \text{H}_2\text{O}(l)$	1.33
$\text{O}_2(g) + 4 \text{H}^+(aq) + 4 e^-$	$\longrightarrow 2 \text{H}_2\text{O}(l)$	1.23
$\text{MnO}_2(s) + 4 \text{H}^+(aq) + 2 e^-$	$\longrightarrow \text{Mn}^{2+}(aq) + 2 \text{H}_2\text{O}(l)$	1.21
$\text{IO}_3^-(aq) + 6 \text{H}^+(aq) + 5 e^-$	$\longrightarrow \frac{1}{2} \text{I}_2(aq) + 3 \text{H}_2\text{O}(l)$	1.20
$\text{VO}_2^+(aq) + 2 \text{H}^+(aq) + e^-$	$\longrightarrow \text{VO}^{2+}(aq) + \text{H}_2\text{O}(l)$	1.00
$\text{Br}_2(l) + 2 e^-$	$\longrightarrow 2 \text{Br}^-(aq)$	1.09
$\text{NO}_3^-(aq) + 4 \text{H}^+(aq) + 3 e^-$	$\longrightarrow \text{NO}(s) + 2 \text{H}_2\text{O}(l)$	0.96
$\text{ClO}_2(g) + e^-$	$\longrightarrow \text{ClO}_2^-(aq)$	0.95
$\text{Ag}^+(aq) + e^-$	$\longrightarrow \text{Ag}(s)$	0.80
$\text{Fe}^{3+}(aq) + e^-$	$\longrightarrow \text{Fe}^{2+}(aq)$	0.77
$\text{O}_2(g) + 2 \text{H}^+(aq) + 2 e^-$	$\longrightarrow \text{H}_2\text{O}_2(aq)$	0.70
$\text{MnO}_4^-(aq) + e^-$	$\longrightarrow \text{MnO}_4^{2-}(aq)$	0.56
$\text{I}_2(s) + 2 e^-$	$\longrightarrow 2 \text{I}^-(aq)$	0.54
$\text{Cu}^+(aq) + e^-$	$\longrightarrow \text{Cu}(s)$	0.52
$\text{O}_2(g) + 2 \text{H}_2\text{O}(l) + 4 e^-$	$\longrightarrow 4 \text{OH}^-(aq)$	0.40
$\text{Cu}^{2+}(aq) + 2 e^-$	$\longrightarrow \text{Cu}(s)$	0.34
$\text{SO}_4^{2-}(aq) + 4 \text{H}^+(aq) + 2 e^-$	$\longrightarrow \text{H}_2\text{SO}_3(aq) + \text{H}_2\text{O}(l)$	0.20
$\text{Cu}^{2+}(aq) + e^-$	$\longrightarrow \text{Cu}^+(aq)$	0.16
$\text{Sn}^{4+}(aq) + 2 e^-$	$\longrightarrow \text{Sn}^{2+}(aq)$	0.15
$2 \text{H}^+(aq) + 2 e^-$	$\longrightarrow \text{H}_2(s)$	0
$\text{Fe}^{3+}(aq) + 3 e^-$	$\longrightarrow \text{Fe}(s)$	-0.036
$\text{Pb}^{2+}(aq) + 2 e^-$	$\longrightarrow \text{Pb}(s)$	-0.13
$\text{Sn}^{2+}(aq) + 2 e^-$	$\longrightarrow \text{Sn}(s)$	-0.14
$\text{Ni}^{2+}(aq) + 2 e^-$	$\longrightarrow \text{Ni}(s)$	-0.23
$\text{Cd}^{2+}(aq) + 2 e^-$	$\longrightarrow \text{Cd}(s)$	-0.40
$\text{Fe}^{2+}(aq) + 2 e^-$	$\longrightarrow \text{Fe}(s)$	-0.45
$\text{Cr}^{3+}(aq) + e^-$	$\longrightarrow \text{Cr}^{2+}(aq)$	-0.50
$\text{Zn}^{2+}(aq) + 2 e^-$	$\longrightarrow \text{Zn}(s)$	-0.76
$\text{Cr}^{3+}(aq) + 3 e^-$	$\longrightarrow \text{Cr}(s)$	-0.73
$2 \text{H}_2\text{O}(l) + 2 e^-$	$\longrightarrow \text{H}_2(g) + 2 \text{OH}^-(aq)$	-0.83
$\text{Mn}^{2+}(aq) + 2 e^-$	$\longrightarrow \text{Mn}(s)$	-1.18
$\text{Al}^{3+}(aq) + 3 e^-$	$\longrightarrow \text{Al}(s)$	-1.66
$\text{Mg}^{2+}(aq) + 2 e^-$	$\longrightarrow \text{Mg}(s)$	-2.37
$\text{Na}^+(aq) + e^-$	$\longrightarrow \text{Na}(s)$	-2.71
$\text{Ca}^{2+}(aq) + 2 e^-$	$\longrightarrow \text{Ca}(s)$	-2.76
$\text{Ba}^{2+}(aq) + 2 e^-$	$\longrightarrow \text{Ba}(s)$	-2.90
$\text{K}^+(aq) + e^-$	$\longrightarrow \text{K}(s)$	-2.92
$\text{Li}^+(aq) + e^-$	$\longrightarrow \text{Li}(s)$	-3.04

Weaker reducing agent

Stronger reducing agent

Substance	$\Delta H_f^\circ$ (kJ/mol)	$\Delta G_f^\circ$ (kJ/mol)	$S^\circ$ (J/mol · K)	Substance	$\Delta H_f^\circ$ (kJ/mol)	$\Delta G_f^\circ$ (kJ/mol)	$S^\circ$ (J/mol · K)
<b>Uranium</b>							
U(s)	0	0	50.2	Zn(s)	0	0	41.6
U(g)	533.0	488.4	199.8	Zn(g)	130.4	94.8	161.0
UF <sub>6</sub> (s)	-2197.0	-2068.5	227.6	Zn <sup>2+</sup> (aq)	-153.39	-147.1	-109.8
UF <sub>6</sub> (g)	-2147.4	-2063.7	377.9	ZnCl <sub>2</sub> (s)	-415.1	-369.4	111.5
UO <sub>2</sub> (s)	-1085.0	-1031.8	77.0	ZnO(s)	-350.5	-320.5	43.7
<b>Vanadium</b>							
V(s)	0	0	28.9	ZnS(s, zinc blende)	-206.0	-201.3	57.7
V(g)	514.2	754.4	182.3	ZnSO <sub>4</sub> (s)	-982.8	-871.5	110.5

## C. Aqueous Equilibrium Constants

### 1. Dissociation Constants for Acids at 25 °C

Name	Formula	$K_{a_1}$	$K_{a_2}$	$K_{a_3}$
Acetic	HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>	$1.8 \times 10^{-5}$		
Acetylsalicylic	HC <sub>9</sub> H <sub>7</sub> O <sub>4</sub>	$3.3 \times 10^{-4}$		
Adipic	H <sub>2</sub> C <sub>6</sub> H <sub>8</sub> O <sub>4</sub>	$3.9 \times 10^{-5}$	$3.9 \times 10^{-6}$	
Arsenic	H <sub>3</sub> AsO <sub>4</sub>	$5.5 \times 10^{-3}$	$1.7 \times 10^{-7}$	$5.1 \times 10^{-12}$
Arsenous	H <sub>3</sub> AsO <sub>3</sub>	$5.1 \times 10^{-10}$		
Ascorbic	H <sub>2</sub> C <sub>6</sub> H <sub>6</sub> O <sub>6</sub>	$8.0 \times 10^{-5}$	$1.6 \times 10^{-12}$	
Benzoic	HC <sub>7</sub> H <sub>5</sub> O <sub>2</sub>	$6.5 \times 10^{-5}$		
Boric	H <sub>3</sub> BO <sub>3</sub>	$5.4 \times 10^{-10}$		
Butanoic	HC <sub>4</sub> H <sub>7</sub> O <sub>2</sub>	$1.5 \times 10^{-5}$		
Carbonic	H <sub>2</sub> CO <sub>3</sub>	$4.3 \times 10^{-7}$	$5.6 \times 10^{-11}$	
Chloroacetic	HC <sub>2</sub> H <sub>2</sub> O <sub>2</sub> Cl	$1.4 \times 10^{-3}$		
Chlorous	HClO <sub>2</sub>	$1.1 \times 10^{-2}$		
Citric	H <sub>3</sub> C <sub>6</sub> H <sub>5</sub> O <sub>7</sub>	$7.4 \times 10^{-4}$	$1.7 \times 10^{-5}$	$4.0 \times 10^{-7}$
Cyanic	HCNO	$2 \times 10^{-4}$		
Formic	HCHO <sub>2</sub>	$1.8 \times 10^{-4}$		
Hydrazoic	HN <sub>3</sub>	$2.5 \times 10^{-5}$		
Hydrocyanic	HCN	$4.9 \times 10^{-10}$		
Hydrofluoric	HF	$3.5 \times 10^{-4}$		
Hydrogen chromate ion	HCrO <sub>4</sub> <sup>-</sup>	$3.0 \times 10^{-7}$		
Hydrogen peroxide	H <sub>2</sub> O <sub>2</sub>	$2.4 \times 10^{-12}$		
Hydrogen selenate ion	HSeO <sub>4</sub> <sup>-</sup>	$2.2 \times 10^{-2}$		
Hydrosulfuric	H <sub>2</sub> S	$8.9 \times 10^{-8}$	$1 \times 10^{-19}$	
Hydrotelluric	H <sub>2</sub> Te	$2.3 \times 10^{-3}$	$1.6 \times 10^{-11}$	

Name	Formula	$K_{a_1}$	$K_{a_2}$	$K_{a_3}$
Hypobromous	HBrO	$2.8 \times 10^{-9}$		
Hypochlorous	HClO	$2.9 \times 10^{-8}$		
Hypoiodous	HIO	$2.3 \times 10^{-11}$		
Iodic	HIO <sub>3</sub>	$1.7 \times 10^{-1}$		
Lactic	HC <sub>3</sub> H <sub>5</sub> O <sub>3</sub>	$1.4 \times 10^{-4}$		
Maleic	H <sub>2</sub> C <sub>4</sub> H <sub>2</sub> O <sub>4</sub>	$1.2 \times 10^{-2}$	$5.9 \times 10^{-7}$	
Malonic	H <sub>2</sub> C <sub>3</sub> H <sub>2</sub> O <sub>4</sub>	$1.5 \times 10^{-3}$	$2.0 \times 10^{-6}$	
Nitrous	HNO <sub>2</sub>	$4.6 \times 10^{-4}$		
Oxalic	H <sub>2</sub> C <sub>4</sub> O <sub>4</sub>	$5.9 \times 10^{-2}$	$6.4 \times 10^{-5}$	
Paraperiodic	H <sub>5</sub> IO <sub>6</sub>	$2.8 \times 10^{-2}$	$5.3 \times 10^{-9}$	
Phenol	HC <sub>6</sub> H <sub>5</sub> O	$1.3 \times 10^{-10}$		
Phosphoric	H <sub>3</sub> PO <sub>4</sub>	$7.5 \times 10^{-3}$	$6.2 \times 10^{-8}$	$4.2 \times 10^{-13}$
Phosphorous	H <sub>3</sub> PO <sub>3</sub>	$5 \times 10^{-2}$	$2.0 \times 10^{-7}$	
Propanoic	HC <sub>3</sub> H <sub>5</sub> O <sub>2</sub>	$1.3 \times 10^{-5}$		
Pyruvic	HC <sub>3</sub> H <sub>3</sub> O <sub>3</sub>	$4.1 \times 10^{-3}$		
Pyrophosphoric	H <sub>4</sub> P <sub>2</sub> O <sub>7</sub>	$1.2 \times 10^{-1}$	$7.9 \times 10^{-3}$	$2.0 \times 10^{-7}$
Selenous	H <sub>2</sub> SeO <sub>3</sub>	$2.4 \times 10^{-3}$	$4.8 \times 10^{-9}$	
Succinic	H <sub>2</sub> C <sub>4</sub> H <sub>4</sub> O <sub>4</sub>	$6.2 \times 10^{-5}$	$2.3 \times 10^{-6}$	
Sulfuric	H <sub>2</sub> SO <sub>4</sub>	Strong acid	$1.2 \times 10^{-2}$	
Sulfurous	H <sub>2</sub> SO <sub>3</sub>	$1.7 \times 10^{-2}$	$6.4 \times 10^{-8}$	
Tartaric	H <sub>2</sub> C <sub>4</sub> H <sub>4</sub> O <sub>6</sub>	$1.0 \times 10^{-3}$	$4.6 \times 10^{-5}$	
Trichloroacetic	HC <sub>2</sub> Cl <sub>3</sub> O <sub>2</sub>	$2.2 \times 10^{-1}$		
Trifluoroacetic acid	HC <sub>2</sub> F <sub>3</sub> O <sub>2</sub>	$3.0 \times 10^{-1}$		

### 2. Dissociation Constants for Hydrated Metal Ions at 25 °C

Cation	Hydrated Ion	$K_a$	Cation	Hydrated Ion	$K_a$
Al <sup>3+</sup>	Al(H <sub>2</sub> O) <sub>6</sub> <sup>3+</sup>	$1.4 \times 10^{-5}$	Fe <sup>3+</sup>	Fe(H <sub>2</sub> O) <sub>6</sub> <sup>3+</sup>	$6.3 \times 10^{-3}$
Be <sup>2+</sup>	Be(H <sub>2</sub> O) <sub>6</sub> <sup>2+</sup>	$3 \times 10^{-7}$	Ni <sup>2+</sup>	Ni(H <sub>2</sub> O) <sub>6</sub> <sup>2+</sup>	$2.5 \times 10^{-11}$
Co <sup>2+</sup>	Co(H <sub>2</sub> O) <sub>6</sub> <sup>2+</sup>	$1.3 \times 10^{-9}$	Pb <sup>2+</sup>	Pb(H <sub>2</sub> O) <sub>6</sub> <sup>2+</sup>	$3 \times 10^{-8}$
Cr <sup>3+</sup>	Cr(H <sub>2</sub> O) <sub>6</sub> <sup>3+</sup>	$1.6 \times 10^{-4}$	Sn <sup>2+</sup>	Sn(H <sub>2</sub> O) <sub>6</sub> <sup>2+</sup>	$4 \times 10^{-4}$
Cu <sup>2+</sup>	Cu(H <sub>2</sub> O) <sub>6</sub> <sup>2+</sup>	$3 \times 10^{-8}$	Zn <sup>2+</sup>	Zn(H <sub>2</sub> O) <sub>6</sub> <sup>2+</sup>	$2.5 \times 10^{-10}$
Fe <sup>2+</sup>	Fe(H <sub>2</sub> O) <sub>6</sub> <sup>2+</sup>	$3.2 \times 10^{-10}$			

# Selected Key Equations

**Density (1.6)**

$$d = \frac{m}{V}$$

**Solution Dilution (4.4)**

$$M_1 V_1 = M_2 V_2$$

**Ideal Gas Law (5.4)**

$$PV = nRT$$

**Dalton's Law (5.6)**

$$P_{\text{total}} = P_a + P_b + P_c + \dots$$

**Mole Fraction (5.6)**

$$\chi_a = \frac{n_a}{n_{\text{total}}}$$

**Average Kinetic Energy (5.8)**

$$KE_{\text{avg}} = \frac{3}{2} RT$$

**Root Mean Square Velocity (5.8)**

$$u_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

**Effusion (5.9)**

$$\frac{\text{rate A}}{\text{rate B}} = \sqrt{\frac{M_B}{M_A}}$$

**Van der Waals Equation (5.10)**

$$\left[ P + a \left( \frac{n}{V} \right)^2 \right] \times [V - nb] = nRT$$

**Kinetic Energy (6.1)**

$$KE = \frac{1}{2} mv^2$$

**Internal Energy (6.2)**

$$\Delta E = q + w$$

**Heat Capacity (6.3)**

$$q = m \times C_s \times \Delta T$$

**Pressure-Volume Work (6.3)**

$$w = -P \Delta V$$

**Change in Enthalpy (6.5)**

$$\Delta H = \Delta E + P \Delta V$$

**Standard Enthalpy of Reaction (6.8)**

$$\Delta H_{\text{rxn}}^{\circ} = \sum n_p \Delta H_f^{\circ} (\text{products}) - \sum n_r \Delta H_i^{\circ} (\text{reactants})$$

**Frequency and Wavelength (7.2)**

$$\nu = \frac{c}{\lambda}$$

**Energy of a Photon (7.2)**

$$E = h\nu$$

$$E = \frac{hc}{\lambda}$$

**De Broglie Relation (7.4)**

$$\lambda = \frac{h}{mv}$$

**Heisenberg's Uncertainty Principle (7.4)**

$$\Delta x \times m \Delta v \geq \frac{h}{4\pi}$$

**Energy of Hydrogen Atom Levels (7.5)**

$$E_n = -2.18 \times 10^{-18} \left( \frac{1}{n^2} \right) \quad (n = 1, 2, 3, \dots)$$

**Coulomb's Law (9.2)**

$$E = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r}$$

**Dipole Moment (9.6)**

$$\mu = qr$$

**Clausius-Clapeyron Equation (11.5)**

$$\ln P_{\text{vap}} = \frac{-\Delta H_{\text{vap}}}{RT} + \ln \beta$$

$$\ln \frac{P_2}{P_1} = \frac{-\Delta H_{\text{vap}}}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

**Henry's Law (12.4)**

$$S_{\text{gas}} = k_H P_{\text{gas}}$$

**Raoult's Law (12.6)**

$$P_{\text{solution}} = \chi_{\text{solvent}} P_{\text{solvent}}^{\circ}$$

**Freezing Point Depression (12.7)**

$$\Delta T_f = m \times K_f$$

**Boiling Point Elevation Constant (12.7)**

$$\Delta T_b = m \times K_b$$

**Osmotic Pressure (12.7)**

$$\Pi = MRT$$

**The Rate Law (13.3)**

$$\text{Rate} = k[A]^n \quad (\text{single reactant})$$

$$\text{Rate} = k[A]^m[B]^n \quad (\text{multiple reactants})$$

**Integrated Rate Laws and Half-Life (13.4)**

Order	Integrated Rate Law	Half-Life Expression
0	$[A]_t = -kt + [A]_0$	$t_{1/2} = \frac{[A]_0}{2k}$
1	$\ln[A]_t = -kt + \ln[A]_0$	$t_{1/2} = \frac{0.693}{k}$
2	$\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$	$t_{1/2} = \frac{1}{k[A]_0}$

**Arrhenius Equation (13.5)**

$$k = A e^{\frac{-E_a}{RT}}$$

$$\ln k = -\frac{E_a}{R} \left( \frac{1}{T} \right) + \ln A \quad (\text{linearized form})$$

$$k = p z e^{\frac{-E_a}{RT}} \quad (\text{collision theory})$$

 **$K_c$  and  $K_p$  (14.4)**

$$K_p = K_c (RT)^{\Delta n}$$

**pH Scale (15.5)**

$$\text{pH} = -\log[H_3O^+]$$

**Entropy (17.3)**

$$S = k \ln W$$

**Change in the Entropy of the Surroundings (17.4)**

$$\Delta S_{\text{surr}} = \frac{-\Delta H_{\text{sys}}}{T}$$

**Change in Gibb's Free Energy (17.5)**

$$\Delta G = \Delta H - T \Delta S$$

**The Change in Free Energy: Nonstandard Conditions (17.8)**

$$\Delta G_{\text{rxn}} = \Delta G_{\text{rxn}}^{\circ} + RT \ln Q$$

 **$\Delta G_{\text{rxn}}^{\circ}$  and  $K$  (17.9)**

$$\Delta G_{\text{rxn}}^{\circ} = -RT \ln K$$

**Temperature Dependence of the Equilibrium Constant (17.9)**

$$\ln K = -\frac{\Delta H_{\text{rxn}}^{\circ}}{R} \left( \frac{1}{T} \right) + \frac{\Delta S_{\text{rxn}}^{\circ}}{R}$$

 **$\Delta G^{\circ}$  and  $E_{\text{cell}}^{\circ}$  (18.5)**

$$\Delta G^{\circ} = -nFE_{\text{cell}}^{\circ}$$

 **$E_{\text{cell}}^{\circ}$  and  $K$  (18.5)**

$$E_{\text{cell}}^{\circ} = \frac{0.0592 \text{ V}}{n} \log K$$

**Nerst Equation (18.6)**

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.0592 \text{ V}}{n} \log Q$$

**Einstein's Energy-Mass Equation (19.8)**

$$E = mc^2$$