

Institutt for kjemi/Department of chemistry

Eksamensoppgave/ Examination paper

KJ1000 Generell kjemi

Kandidat/candidate no.: _____

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Eksamensdato/Date of exam: 18. desember 2013/December 18, 2013

Eksamensstid/ Examination time (from-to): Kl 09.00-14.00

Hjelpemiddelkode/Tillatte hjelpemidler/ Permitted examination support material: Hjelpemidler/code C. Enkel kalkulator/simple calculator. Citizen SR-270X/College og/and HP30S

Anden informasjon/information: Svar på oppgavearket. Svar kort. Vis utregning der det er mulig og begrunn svarene ellers.

Answer on the given paper, answer briefly, show your calculations.

Sensurfrist/Examination censorship date: 22. januar 2014/January 22, 2014

Målform/språk: Norsk bokmål/ English

Antall sider/Pages: 19 (uten vedlegg)

Antall sider vedlegg/attachments: 4

Kontrollert av:

Dato

Sign

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Del 1. Flervalgsspørsmål, marker riktig svar. Vis utregning hvis mulig. Svar kort og på arket. 20 oppgaver, hver oppgave gir 2,5 poeng inkl. deloppgaver, totalt 50 poeng.

Part 1. Multiple choice. Circle the right answer, show your calculations on the paper. 20 exercises give 2.5 points each, 50 points total.

1a. (0,5p)

Det riktige navnet for NH_4NO_3 er
The correct name for NH_4NO_3 is

- A) ammonium nitrat/ammonium nitrate
- B) ammonium nitrogenetriksid/ammonium nitrogen trioxide
- C) ammoniakk nitrogenoksid/ammonia nitrogen oxide
- D) hydrogen nitrogenoksid/hydrogen nitrogen oxide
- E) hydrogennitrat/hydrogen nitrate

1b. (1p)

Hvor mange nøytroner og protoner totalt har et atom med symbolet $^{33}_{16}\text{S}$?

How many neutrons and protons does an atom with the symbol $^{33}_{16}\text{S}$ have totally?

- A) 33
- B) 16
- C) 49
- D) 17

1c. (1p)

Hvilket av disse parene av grunnstoffer vil danne en ionisk forbindelse? Hvorfor?

Which of these pairs of elements would be most likely to form an ionic compound? Why?

- A) P & Br
- B) Cu & K
- C) C & O
- D) O & Zn
- E) Al & Rb

2.

Mineralet orpiment, med empirisk formel As_2S_3 , ble i oldtiden brukt som kosmetikk. Hva er massen av arsen i 5,0 g av orpiment? [Gitt: Alt naturlig forekommende arsen er arsen-75; anta at alt naturlig forekommende svovel er svovel-32 (omtrent)]

The mineral orpiment, having the empirical formula As_2S_3 , was used in ancient times as a cosmetic. What mass of arsenic is present in 5.0 g of orpiment?

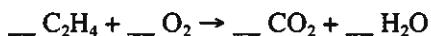
[Given: naturally occurring arsenic is all arsenic-75; assume that all naturally occurring sulfur is sulfur-32 (only approximately true)]

- A) 0,61 g
- B) 3,1 g
- C) 1,5 g
- D) 2,0 g
- E) 3,5 g

3a. (1,5p)

Hva er koeffisienten til O₂ i reaksjonslikninga under når den er balansert med laveste hele tall?

When balanced with the smallest set of whole numbers, the coefficient of O₂ in the following equation is:



- A) 1
- B) 2
- C) 3
- D) 4
- E) 6

3b. (1p)

Hva er massen i gram til ett arsenatom?

What is the mass, in grams, of one arsenic atom?

- A) $5,48 \times 10^{-23}$ g
- B) 33,0 g
- C) 74,9 g
- D) $1,24 \times 10^{-22}$ g
- E) $8,04 \times 10^{21}$ g

4.

Cola light og annen lettbrus har en pH på ca 3,0, mens melk har en pH på ca 7,0. Hvor mange ganger høyere er H₃O⁺-konsentrasjonen i cola light enn i melk?

Diet cola drinks have a pH of about 3.0, while milk has a pH of about 7.0. How many times greater is the H₃O⁺ concentration in diet cola than in milk?

- A) 2,3 ganger høyere i cola light enn i melk /times higher in diet cola than in milk
- B) 400 ganger høyere i cola light enn i melk /times higher in diet cola than in milk
- C) 0,43 ganger høyere i cola light enn i melk /times higher in diet cola than in milk
- D) 1000 ganger høyere i cola light enn i melk /times higher in diet cola than in milk
- E) 10000 ganger høyere i cola light enn i melk /times higher in diet cola than in milk

5.

Løsningsvarme er ...

- A) ... aldri positiv ($\Delta H^\circ_{\text{soln}} \leq 0$) fordi intermolekylære krefter mellom løst stoff og løsningsmiddel i løsning aldri er svakere enn tilsvarende krefter i rent løsningsmiddel og i rent løst stoff.
- B) ... alltid positiv ($\Delta H^\circ_{\text{soln}} > 0$) fordi intermolekylære krefter mellom løst stoff og løsningsmiddel i løsning alltid er svakere enn tilsvarende krefter i rent løsningsmiddel og i rent løst stoff.
- C) ... alltid null ($\Delta H^\circ_{\text{soln}} = 0$) fordi intermolekylære krefter mellom løst stoff og løsningsmiddel i løsning er definert som gjennomsnittet av tilsvarende krefter i rent løsningsmiddel og i rent løst stoff.
- D) ... alltid negativ ($\Delta H^\circ_{\text{soln}} < 0$) fordi intermolekylære krefter mellom løst stoff og løsningsmiddel i løsning alltid er sterkere enn tilsvarende krefter i rent løsningsmiddel og i rent løst stoff.
- E) ... positiv, null eller negativ, avhengig av det relative styrkeforholdet for intermolekylære krefter mellom løst stoff og løsningsmiddel i løsning, tilsvarende i rent løsningsmiddel, og i rent løst stoff.

Heat of solution

- A) ...is never positive ($\Delta H^\circ_{\text{soln}} \leq 0$), because the solute-solvent attraction is never weaker than the combination of the solute-solute attraction and solvent-solvent attraction.
- B) ...is always positive ($\Delta H^\circ_{\text{soln}} > 0$), because the solute-solvent attraction is always weaker than the combination of the solute-solute attraction and solvent-solvent attraction.
- C) ...is always zero ($\Delta H^\circ_{\text{soln}} = 0$), because the solute-solvent attraction is defined as the average of the solute-solute attraction and solvent-solvent attraction.
- D) ...is always negative ($\Delta H^\circ_{\text{soln}} < 0$), because the solute-solvent attraction is always stronger than the combination of the solute-solute attraction and solvent-solvent attraction.
- E) ...may be positive, zero, or negative, depending on the relative strength of the solute-solvent, solute-solute, and solvent-solvent attractive forces.

6.

Arrhenius' likning er $k = Ae^{-E_a/RT}$. Stigningstallet i en graf som viser $\ln k$ mot $1/T$ er lik ...
The Arrhenius equation is $k = Ae^{-E_a/RT}$. The slope of a plot of $\ln k$ vs. $1/T$ is equal to...

- A) $-k$
 B) k
 C) E_a
 D) $-E_a/R$
 E) A

7a. (1,5 p)

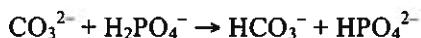
Hvilken av disse kjemiske forbindelsene er ikke en elektrolytt? Hvorfor?

Which of these compounds is a nonelectrolyte? Why?

- A) NaOH
 B) HNO₃
 C) C₂H₆O (etanol/ethanol)
 D) KF
 E) CH₃COOH (eddiksyre/acetic acid)

7b. (1p)

Hva er den konjugerte syra til CO_3^{2-} i følgende reaksjon?
Identify the conjugate acid of CO_3^{2-} in the reaction



- A) H_2CO_3
- B) HCO_3^-
- C) H_2O
- D) HPO_4^{2-}
- E) H_2PO_4^-

8.

Sink løses i saltsyre og gir hydrogengass:
Zinc dissolves in hydrochloric acid to yield hydrogen gas:



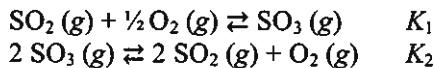
Hva er massen av hydrogengass som produseres når 7,35 g sink løses i 500 mL 1,200 M HCl?

What mass of hydrogen gas is produced when a 7.35 g piece of zinc dissolves in 500 mL of 1.200 M HCl?

- A) 0,605 g
- B) 0,113 g
- C) 0,302 g
- D) 0,453 g
- E) 0,227 g

9.

Betrakt følgende to beskrivelser av en gasslikevekt:
Consider the two gaseous equilibria:



Verdiene av likevektskonstantene K_1 og K_2 har følgende relasjon:
The values of the equilibrium constants K_1 and K_2 are related by

- A) $K_2 = K_1^2$
- B) $K_2^2 = K_1$
- C) $K_2 = 1/K_1^2$
- D) $K_2 = 1/K_1$
- E) ingen av disse

10a. (1,5p)

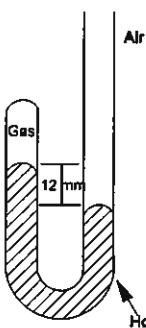
En vårmorgen (20°C) fyller du opp dekkene på bilen din til et trykk på 2,25 atmosfærer. Etterhvert som du kjører, varmes dekkene opp til 45°C pga friksjonen fra veibanen. Hva er trykket i dekkene dine nå? (Anta at det ikke er skjedd noen volumendring i dekkene.)
On a spring morning (20°C) you fill your tires to a pressure of 2.25 atmospheres. As you ride along, the tire heats up to 45°C from the friction on the road. What is the pressure in your tires now? (No change in volume of the tires.)

- A) 2,84 atm
- B) 2,44 atm
- C) 3,44 atm
- D) 2,14 atm

10b. (1p)

Hva er trykket av gassen som er inne i apparatet som vist under hvis atmosfæretrykket er 720 mmHg?

What is the pressure of the gas trapped in the apparatus shown below when the atmospheric pressure is 720 mmHg?

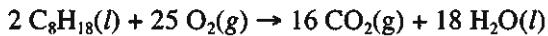


- A) 12 mmHg
- B) 708 mmHg
- C) 720 mmHg
- D) 732 mmHg
- E) 760 mmHg

11.

Forbrenning av oktan produserer varme i henhold til reaksjonslikninga under:

The combustion of octane produces heat according to the equation



$$\Delta H = -11020 \text{ kJ/mol}$$

Hva er forbrenningsvarmen per gram oktan?

What is the heat of combustion per gram of octane?

- A) -5510 kJ/g
- B) -96,5 kJ/g
- C) -48,2 kJ/g
- D) -193 kJ/g
- E) $-6,292 \times 10^5 \text{ kJ}/$

12a. (1,5p)

Elektronkonfigurasjonen for atomer av alle grunnstoffer i gruppe 5A i periodiske system er:
The general electron configuration for atoms of all elements in Group 5A is:

- A) ns^2np^6
- B) ns^2np^5
- C) ns^2np^4
- D) ns^2np^3
- E) ns^2np^1

12b. (1p)

Hvor mange elektroner er det i 4p orbitalen i selen?
How many electrons are in the 4p orbitals of selenium?

- A) 0
- B) 2
- C) 4
- D) 5
- E) 6

13.

En negativ verdi av en reaksjons ΔG indikerer at, ved konstant T og P ,
A negative sign for a reaction's ΔG indicates that, at constant T and P ,

- A) reaksjonen er eksoterm/ *the reaction is exothermic*
- B) reaksjonen er endoterm/ *the reaction is endothermic*
- C) reaksjonen er rask/*the reaction is fast*
- D) reaksjonen er spontan/*the reaction is spontaneous*
- E) ΔS_{system} må være > 0 / *ΔS_{system} must be > 0*

14.

Hva er den kjemiske formelen for saltet som dannes i nøytralisasjonsreaksjonen mellom hydrogenbromid og magnesiumhydroksid?
What is the chemical formula of the salt produced by the neutralization of hydrobromic acid with magnesium hydroxide?

- A) MgBr
- B) Mg_2Br_3
- C) Mg_3Br_2
- D) Mg_2Br
- E) $MgBr_2$

15.

Hvilken av de følgende kjemiske stoffer forventer du har det høyeste kokepunktet, men er samtidig den svakeste syren av disse løst i vann? Forklar.

Which one of the following substances is expected to have the highest boiling point, but at the same time is the weakest acid of these four when dissolved in water? Why?

- A) HBr
- B) HCl
- C) HF
- D) HI

16.

En 0,10 M HF-løsning er 8,4% ionisert. Regn ut H^+ ion-konsentrasjonen.

A 0.10 M HF solution is 8.4% ionized. Calculate the H^+ ion concentration.

- A) 0,84 M
- B) 0,12 M
- C) 0,10 M
- D) 0,084 M
- E) $8,4 \times 10^{-3}$ M

17.

En løsning hvor 15,00 % (masseprosent) laktose ($C_{12}H_{22}O_{11}$, 342,30 g/mol) er løst i vann har en tetthet på 1,0602 g/mL ved 20°C. Hva er molariteten av løsningen?

A 15.00 % by mass solution of lactose ($C_{12}H_{22}O_{11}$, 342.30 g/mol) in water has a density of 1.0602 g/mL at 20°C. What is the molarity of this solution?

- A) 0,03097 M
- B) 0,4133 M
- C) 0,4646 M
- D) 1,590 M
- E) 3,097 M

18.

Estere kan syntetiseres fra to klasser av organiske forbindelser. Hvilke to?
Esters are synthesized from two classes of organic compounds. Those two types of compounds are

- A) syrer og baser/*acids and bases*
- B) aminer og alkoholer/*amines and alcohols*
- C) alkoholer og syrer/*alcohols and acids*
- D) aminer og alkener/*amines and alkenes*
- E) alkener og baser/*alkenes and bases*

19a. (1,5p)

Lewis-strukturen til CS_2 er:

The Lewis structure for CS_2 is:

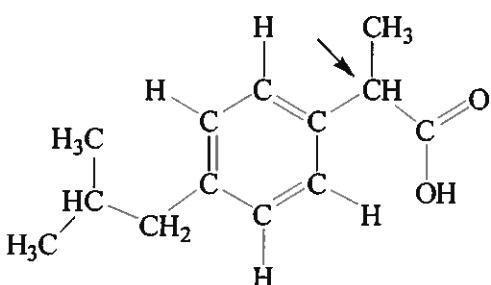
- A) $\begin{array}{c} \cdot\cdot \\ \text{C} = \text{S}-\text{S} \\ \cdot\cdot \end{array}$
- B) $\begin{array}{c} \cdot\cdot \\ :\text{S}-\text{C}-\text{S}: \\ \cdot\cdot \end{array}$
- C) $\begin{array}{c} \cdot\cdot \\ \text{S} = \text{C} = \text{S} \\ \cdot\cdot \end{array}$
- D) $\begin{array}{c} \cdot\cdot \\ \text{S} = \text{C}-\text{S}: \\ \cdot\cdot \end{array}$

19b. (1p)

Ibuprofen markedsføres som et smertestillende og febernedsættende middel. Hva er hybridiseringen til karbonatomet som indikeres med en pil i strukturen av ibuprofen under?

Ibuprofen is used as an analgesic for the relief of pain, and also to help reduce fever.

What is the hybridization state of carbon indicated by the arrow in the structure of ibuprofen shown below?



- A) sp
- B) sp^2
- C) sp^3
- D) sp^3d
- E) sp^3d^2

20.

Molekylformelen av aspirin er $C_9H_8O_4$. Hvor mange aspirinmolekyler er det i en 500-milligram aspirintablett sett bort fra hjelpestoffene?

The molecular formula of aspirin is $C_9H_8O_4$. How many aspirin molecules are present in one 500-milligram tablet if the whole tablet was aspirin?

- A) 2,77 molekyler/molecules
- B) $2,77 \times 10^{-3}$ molekyler /molecules
- C) $1,67 \times 10^{24}$ molekyler/ molecules
- D) $1,67 \times 10^{21}$ molekyler/molecules
- E) Ingen av disse er korrekt/*None of these is correct.*

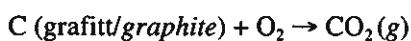
Del 2. Totalt 50 poeng. Vis utregning.

Part 2. Total 50 points. Show calculations.

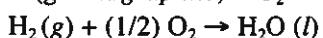
21. (5 p)

Regn ut standard dannelsesentalpi (ΔH°_f) av flytende metanol, CH₃OH (l) ved å
bruke følgende informasjon:

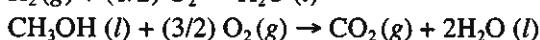
*Calculate the standard enthalpy of formation (ΔH°_f) of liquid methanol, CH₃OH (l), using the
following information:*



$$\Delta H_{rxn}^\circ = -393,5 \text{ kJ/mol}$$



$$\Delta H_{rxn}^\circ = -285,8 \text{ kJ/mol}$$



$$\Delta H_{rxn}^\circ = -726,4 \text{ kJ/mol}$$

22a. (2,5p)

En vanlig personbil produserer omrent 31 gram NO for hver 10 km den blir kjørt. Hvor mange liter NO-gass slipper en slik personbil ut ved STP for hver tur den blir kjørt mellom Oslo og Trondheim (ca 500 km)?

Many automobiles produce about 31 grams of NO for each 10 km they are driven.

How many liters of NO gas at STP would be produced by a car of this type on a trip between Oslo and Trondheim (approx. 500 km)?

22b. (2,5p)

En liten boble kommer fra bunnen av en innsjø, hvor temperaturen og trykket er 4°C og 3,0 atm, til vannets overflate hvor temperaturen er 25°C og trykket er 0,95 atm. Regn ut sluttvolumet av bobla hvis startvolumet var 2,1 mL.

A small bubble rises from the bottom of a lake, where the temperature and pressure are 4°C and 3.0 atm, to the water's surface, where the temperature is 25°C and the pressure is 0.95 atm. Calculate the final volume of the bubble if its initial volume was 2.1 mL.

23a. (5p)

Regn ut pH av 1,00 L av bufferen 0,80 M CH₃NH₂/1,00 M CH₃NH₂Cl.

Calculate pH of 1.00 L of the buffer 0.80 M CH₃NH₂/1.00 M CH₃NH₂Cl.

23b. (4p)

Regn ut pH av bufferen i a) etter tilsats av 0,070 mol NaOH, anta ingen endring i volum.

Calculate the pH of the buffer after addition of 0.070 mol NaOH, assume constant volume.

23c. (4p)

Regn ut pH av bufferen i a) etter tilsats av 0,11 mol HCl, ingen endring i volum.

Calculate the pH of the buffer after addition of 0.11 mol HCl, assume constant volume.

$$K_a \text{CH}_3\text{NH}_3^+ = 2,3 \times 10^{-11}.$$

24. (5p)

Frysepunktet for ren bensen er $5,44\text{ }^{\circ}\text{C}$. Da 6,5 gram av en ukjent forbindelse ble løst i 200 gram bensen, ble løsningens frysepunkt målt til $4,14\text{ }^{\circ}\text{C}$. Det ble også fastslått at forbindelsen ikke dissosierer eller assosierer i løsningen. Frysepunktskonstanten, K_f , for bensen er $5,12\text{ }^{\circ}\text{C}/\text{m}$, der m står for "molal". Bestem den ukjente forbindelsens molare masse.

When 6.5 grams of an unknown compound are dissolved in 200 grams of benzene, the freezing point of the resulting solution is $4.14\text{ }^{\circ}\text{C}$. It has been determined that the compound does not dissociate or associate in solution. The freezing point of pure benzene is $5.44\text{ }^{\circ}\text{C}$, and the freezing-point depression constant, K_f , for benzene is $5.12\text{ }^{\circ}\text{C}/\text{m}$, where m represents "molal". What is the molar mass of the unknown compound?

25.

Ved en viss temperatur ble data gitt i tabellen nedenfor målt for følgende reaksjon:
At a certain temperature, the data below were collected for the following reaction:



Startkonsentrasjon, mol L ⁻¹ <i>Initial concentrations, mol L⁻¹</i>		Reaksjonshastighet for dannelse av I ₂ , mol L ⁻¹ s ⁻¹ <i>Initial Rate of Formation of I₂, mol L⁻¹ s⁻¹</i>
[ICl]	[H ₂]	
0,10	0,10	0,00150
0,20	0,10	0,00300
0,10	0,05	0,00075

25a. (5p)

Bestem hastighetsloven for reaksjonen.

Determine the rate law for the reaction.

25b. (3p)

Bestem hastighetskonstanten for reaksjonen.

Determine the rate constant for the reaction.

26. (5p)

Ved 340 K er likevektskonstanten $K_P = 69$ for reaksjonen

At 340 K, $K_P = 69$ for the reaction



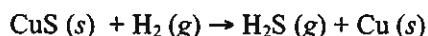
50,0 g HI injiseres i en tom beholder med volum 5,00 L ved 340 K. Hva er det totale trykket i beholderen når reaksjonsblandingen har kommet til likevekt?

50.0 g of HI is injected into an evacuated 5.00-L rigid cylinder at 340 K. What is the total pressure inside the cylinder when the system comes to equilibrium?

27. (4p)

Betrakt reaksjonen

Consider the reaction



Følgende data er gitt ved 298 K:

The following data are given at 298 K:

$$\Delta G_f^\circ (\text{CuS}) = -53,6 \text{ kJ/mol}$$

$$\Delta G_f^\circ (\text{H}_2\text{S}) = -33,6 \text{ kJ/mol}$$

$$\Delta H_f^\circ (\text{CuS}) = -53,1 \text{ kJ/mol}$$

$$\Delta H_f^\circ (\text{H}_2\text{S}) = -20,6 \text{ kJ/mol}$$

Beregn verdien av likevektskonstanten K_P , for reaksjonen ved 298 K.

Calculate the value of the equilibrium constant, K_P , for this reaction at 298 K.

28. (5p)

For en galvanisk Zn–Cu celle er cellespenningen målt til 0,80 V når konsentrasjonen av Zn^{2+} er 2,0 M og $T = 298$ K. Hva er konsentrasjonen av Cu^{2+} ?

If the cell emf of a galvanic Zn–Cu cell is 0.80 V when the concentration of Zn^{2+} is 2.0 M and $T = 298$ K, what is the concentration of Cu^{2+} ?

Vedlegg 1

Tall og fakta/*Numbers and facts*

Avogadros tall/*number* $6,02 \cdot 10^{23}$

Gasskonstanten/*gas constant*

$$R = 0,082057 \text{ L} \cdot \text{atm} / \text{K} \cdot \text{mol}$$

$$R = 8,314 \text{ J} \cdot \text{K}^{-1} \text{ mol}^{-1}$$

Varmekapasitet/*heat capacity* C = ms, m = masse i gram/*mass in grams*

s = spesifikk varme/*specific heat*, J/g • °C.

F = Faradays konstant/*constant*: 96500 J/V• mol

Vedlegg 2

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Table 19.1 Standard Reduction Potentials at 25°C*

Half-Reaction	E° (V)
$\text{F}_2(g) + 2e^- \longrightarrow 2\text{F}^-(aq)$	+2.87
$\text{O}_3(g) + 2\text{H}^+(aq) + 2e^- \longrightarrow \text{O}_2(g) + \text{H}_2\text{O}$	+2.07
$\text{Co}^{3+}(aq) + e^- \longrightarrow \text{Co}^{2+}(aq)$	+1.82
$\text{H}_2\text{O}_2(aq) + 2\text{H}^+(aq) + 2e^- \longrightarrow 2\text{H}_2\text{O}$	+1.77
$\text{PbO}_2(s) + 4\text{H}^+(aq) + \text{SO}_4^{2-}(aq) + 2e^- \longrightarrow \text{PbSO}_4(s) + 2\text{H}_2\text{O}$	+1.70
$\text{Ce}^{4+}(aq) + e^- \longrightarrow \text{Ce}^{3+}(aq)$	+1.61
$\text{MnO}_4^-(aq) + 8\text{H}^+(aq) + 5e^- \longrightarrow \text{Mn}^{2+}(aq) + 4\text{H}_2\text{O}$	+1.51
$\text{Au}^{3+}(aq) + 3e^- \longrightarrow \text{Au}(s)$	+1.50
$\text{Cl}_2(g) + 2e^- \longrightarrow 2\text{Cl}^-(aq)$	+1.36
$\text{Cr}_2\text{O}_7^{2-}(aq) + 14\text{H}^+(aq) + 6e^- \longrightarrow 2\text{Cr}^{3+}(aq) + 7\text{H}_2\text{O}$	+1.33
$\text{MnO}_2(s) + 4\text{H}^+(aq) + 2e^- \longrightarrow \text{Mn}^{2+}(aq) + 2\text{H}_2\text{O}$	+1.23
$\text{O}_2(g) + 4\text{H}^+(aq) + 4e^- \longrightarrow 2\text{H}_2\text{O}$	+1.23
$\text{Br}_2(l) + 2e^- \longrightarrow 2\text{Br}^-(aq)$	+1.07
$\text{NO}_3^-(aq) + 4\text{H}^+(aq) + 3e^- \longrightarrow \text{NO}(g) + 2\text{H}_2\text{O}$	+0.96
$2\text{Hg}^{2+}(aq) + 2e^- \longrightarrow \text{Hg}_2^{2+}(aq)$	+0.92
$\text{Hg}_2^{2+}(aq) + 2e^- \longrightarrow 2\text{Hg}(l)$	+0.85
$\text{Ag}^+(aq) + e^- \longrightarrow \text{Ag}(s)$	+0.80
$\text{Fe}^{3+}(aq) + e^- \longrightarrow \text{Fe}^{2+}(aq)$	+0.77
$\text{O}_2(g) + 2\text{H}^+(aq) + 2e^- \longrightarrow \text{H}_2\text{O}_2(aq)$	+0.68
$\text{MnO}_4^-(aq) + 2\text{H}_2\text{O} + 3e^- \longrightarrow \text{MnO}_2(s) + 4\text{OH}^-(aq)$	+0.59
$\text{I}_2(s) + 2e^- \longrightarrow 2\text{I}^-(aq)$	+0.53
$\text{O}_2(g) + 2\text{H}_2\text{O} + 4e^- \longrightarrow 4\text{OH}^-(aq)$	+0.40
$\text{Cu}^{2+}(aq) + 2e^- \longrightarrow \text{Cu}(s)$	+0.34
$\text{AgCl}(s) + e^- \longrightarrow \text{Ag}(s) + \text{Cl}^-(aq)$	+0.22
$\text{SO}_4^{2-}(aq) + 4\text{H}^+(aq) + 2e^- \longrightarrow \text{SO}_2(g) + 2\text{H}_2\text{O}$	+0.20
$\text{Cu}^{2+}(aq) + e^- \longrightarrow \text{Cu}^+(aq)$	+0.15
$\text{Sn}^{4+}(aq) + 2e^- \longrightarrow \text{Sn}^{2+}(aq)$	+0.13
$2\text{H}^+(aq) + 2e^- \longrightarrow \text{H}_2(g)$	0.00
$\text{Pb}^{2+}(aq) + 2e^- \longrightarrow \text{Pb}(s)$	-0.13
$\text{Sn}^{2+}(aq) + 2e^- \longrightarrow \text{Sn}(s)$	-0.14
$\text{Ni}^{2+}(aq) + 2e^- \longrightarrow \text{Ni}(s)$	-0.25
$\text{Co}^{2+}(aq) + 2e^- \longrightarrow \text{Co}(s)$	-0.28
$\text{PbSO}_4(s) + 2e^- \longrightarrow \text{Pb}(s) + \text{SO}_4^{2-}(aq)$	-0.31
$\text{Cd}^{2+}(aq) + 2e^- \longrightarrow \text{Cd}(s)$	-0.40
$\text{Fe}^{2+}(aq) + 2e^- \longrightarrow \text{Fe}(s)$	-0.44
$\text{Cr}^{3+}(aq) + 3e^- \longrightarrow \text{Cr}(s)$	-0.74
$\text{Zn}^{2+}(aq) + 2e^- \longrightarrow \text{Zn}(s)$	-0.76
$2\text{H}_2\text{O} + 2e^- \longrightarrow \text{H}_2(g) + 2\text{OH}^-(aq)$	-0.83
$\text{Mn}^{2+}(aq) + 2e^- \longrightarrow \text{Mn}(s)$	-1.18
$\text{Al}^{3+}(aq) + 3e^- \longrightarrow \text{Al}(s)$	-1.66
$\text{Be}^{2+}(aq) + 2e^- \longrightarrow \text{Be}(s)$	-1.85
$\text{Mg}^{2+}(aq) + 2e^- \longrightarrow \text{Mg}(s)$	-2.37
$\text{Na}^+(aq) + e^- \longrightarrow \text{Na}(s)$	-2.71
$\text{Ca}^{2+}(aq) + 2e^- \longrightarrow \text{Ca}(s)$	-2.87
$\text{Sr}^{2+}(aq) + 2e^- \longrightarrow \text{Sr}(s)$	-2.89
$\text{Ba}^{2+}(aq) + 2e^- \longrightarrow \text{Ba}(s)$	-2.90
$\text{K}^+(aq) + e^- \longrightarrow \text{K}(s)$	-2.93
$\text{Li}^+(aq) + e^- \longrightarrow \text{Li}(s)$	-3.05

*For all half-reactions the concentration is 1 M for dissolved species and the pressure is 1 atm for gases. These are the standard-state values.

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)

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

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)

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

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)

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

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)

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

Henderson-Hasselbalch Equation (16.2)

$$\text{pH} = \text{p}K_a + \log \frac{[\text{base}]}{[\text{acid}]}$$

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)

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

 ΔG° and E_{cell}° (18.5)

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

 E_{cell}° 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)

$$E = mc^2$$

PERIODIC TABLE OF THE ELEMENTS

PERIODIC TABLE OF THE ELEMENTS																	18 VIIIa	
																		18 Ne Helium 4.0028
1 IA	H Hydrogen 1.0079	2 IIA	14 Group IUPAC IVA Group CAS Selected Oxidation States						13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 Ne Helium 4.0028				
1 Li Lithium 6.941 2-1	2 Be Beryllium 9.0122 2-2	3 Na Sodium 22.990 2-8-1	4 Mg Magnesium 24.305 2-8-2	5 Al Aluminum 26.982 2-8-3	6 Si Silicon 28.085 2-8-4	7 N Nitrogen 14.007 2-5	8 O Oxygen 15.999 2-6	9 F Fluorine 18.998 2-7	10 Ne Neon 20.179 2-8									
11 Na Sodium 22.990 2-8-1	12 Mg Magnesium 24.305 2-8-2	13 Al Aluminum 26.982 2-8-3	14 Si Silicon 30.974 2-8-5	15 P Phosphorus 31.974 2-8-6	16 S Sulphur 32.085 2-8-7	17 Cl Chlorine 35.453 2-8-8	18 Ar Argon 39.948 2-8-9											
19 K Potassium 39.998 2-8-8-1	20 Ca Calcium 40.078 2-8-8-2	21 Sc Scandium 44.956 2-8-9-2	22 Ti Titanium 47.867 2-8-10-2	23 V Vanadium 50.942 2-8-11-2	24 Cr Chromium 51.996 2-8-13-1	25 Mn Manganese 54.938 2-8-13-2	26 Fe Iron 55.845 2-8-14-2	27 Co Cobalt 58.933 2-8-15-2	28 Ni Nickel 58.693 2-8-16-2	29 Cu Copper 63.546 2-8-17-1	30 Zn Zinc 65.39 2-8-18-2	31 Ga Gallium 69.723 2-8-18-3	32 Ge Germanium 72.64 2-8-18-4	33 As Arsenic 74.922 2-8-18-5	34 Se Selenium 78.96 2-8-18-6	35 Br Bromine 79.904 2-8-18-7	36 Kr Krypton 83.80 2-8-18-8	
37 Rb Rubidium 85.468 2-8-18-9-1	38 Sr Strontium 87.62 2-8-18-9-2	39 Y Yttrium 88.906 2-8-18-9-2	40 Zr Zirconium 91.224 2-8-18-10-2	41 Nb Niobium 92.906 2-8-18-12-1	42 Mo Molybdenum 95.94 2-8-18-12-1	43 Tc Technetium (98) 2-8-18-14-1	44 Ru Ruthenium 101.07 2-8-18-15-1	45 Rh Rhodium 102.91 2-8-18-15-1	46 Pd Palladium 106.42 2-8-18-16-1	47 Ag Silver 107.87 2-8-18-16-1	48 Cd Cadmium 112.41 2-8-18-16-2	49 In Indium 114.82 2-8-18-16-3	50 Sn Tin 118.71 2-8-18-16-4	51 Sb Antimony 121.76 2-8-18-16-5	52 Te Tellurium 127.60 2-8-18-16-6	53 I Iodine 126.90 2-8-18-16-7	54 Xe Xenon 131.29 2-8-18-16-8	
55 Cs Cesium 132.91 2-8-18-18-1	56 Ba Barium 137.33 2-8-18-18-2	57-71 La Lanthanide 178.49 2-8-18-32-10-2	72 Hf Hafnium 178.49 2-8-18-32-11-2	73 Ta Tantalum 180.95 2-8-18-32-11-2	74 W Tungsten 183.84 2-8-18-32-12-2	75 Re Rhenium 186.21 2-8-18-32-12-2	76 Os Osmium 190.23 2-8-18-32-12-2	77 Ir Iridium 192.22 2-8-18-32-12-2	78 Pt Platinum 195.08 2-8-18-32-12-2	79 Au Gold 196.97 2-8-18-32-12-2	80 Hg Mercury 200.59 2-8-18-32-12-2	81 Tl Thallium 204.38 2-8-18-32-12-2	82 Pb Lead 207.2 2-8-18-32-12-2	83 Bi Bismuth 208.98 2-8-18-32-12-2	84 Po Polonium (209) 2-8-18-32-12-2	85 At Astatine (210) 2-8-18-32-12-2	86 Rn Radon (222) 2-8-18-32-12-2	
87 Fr Francium (223) 18-32-18-9-1	88 Ra Radium (226) 18-32-18-9-2	89-103 Ac Actinide (261) 18-32-32-10-2	104 Rf Rutherfordium (261) 18-32-32-11-2	105 Db Dubnium (262) 18-32-32-12-2	106 Sg Seaborgium (266) 18-32-32-12-2	107 Bh Bohrium (264) 18-32-32-12-2	108 Hs Hassium (271) 18-32-32-12-2	109 Mt Meitnerium (277) 18-32-32-12-2	110 Uun Ununnilium (281) 18-32-32-12-2	111 Uuu Ununtrium (285) 18-32-32-12-2	112 Uub Ununbium (281) 18-32-32-12-2	113 Uut Ununtrium (284) 18-32-32-12-2	114 Uuo Ununoctium (289) 18-32-32-12-2	115 Uuh Ununpentium (288) 18-32-32-12-2	116 Uus Ununhexium (291) 18-32-32-12-2	117 Uuo Ununseptium (294) 18-32-32-12-2	118 Uua Ununoctium (294) 18-32-32-12-2	

Electron Shells

1	K	2	s2	p	d	f
2	L	8	2	6		
3	M	18	2	6	10	
4	N	32	2	6	10	14
5	O	32	2	6	10	14
6	P	18	2	6	10	
7	Q	8	2	6		
8	R	2	2			

Lanthanide

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Lanthanum 138.91 2-8-18-18-9-2	Cerium 140.12 2-8-18-20-8-2	Praseodymium 140.91 2-8-18-21-8-2	Neodymium 144.24 2-8-18-22-8-2	Promethium (145) 2-8-18-23-8-2	Samarium 150.36 2-8-18-24-8-2	Europium 151.96 2-8-18-25-8-2	Gadolinium 157.25 2-8-18-25-9-2	Terbium 158.93 2-8-18-27-8-2	Dysprosium 162.50 2-8-18-28-8-2	Holmium 164.93 2-8-18-29-8-2	Erbium 167.26 2-8-18-30-8-2	Thulium 169.93 2-8-18-31-8-2	Ytterbium 173.04 2-8-19-32-8-2	Lutetium 174.97 2-8-18-32-9-2
Actinide														
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
Actinium (227) 1-8-32-18-8-2	Thorium 232.04 1-8-32-18-10-2	Proactinium 231.04 1-8-32-20-9-2	Uranium 238.03 1-8-32-21-9-2	Neptunium (237) 1-8-32-23-8-2	Plutonium (244) 1-8-32-24-8-2	Americium (243) 1-8-32-25-8-2	Curium (247) 1-8-32-25-9-2	Berkelium (247) 1-8-32-27-8-2	Californium (251) 1-8-32-28-8-2	Einsteinium (252) 1-8-32-29-8-2	Fermium (258) 1-8-32-30-8-2	Mendelevium (265) 1-8-32-31-8-2	Nobelium (262) 1-8-32-37-8-2	Lawrencium (263) 1-8-32-37-9-2