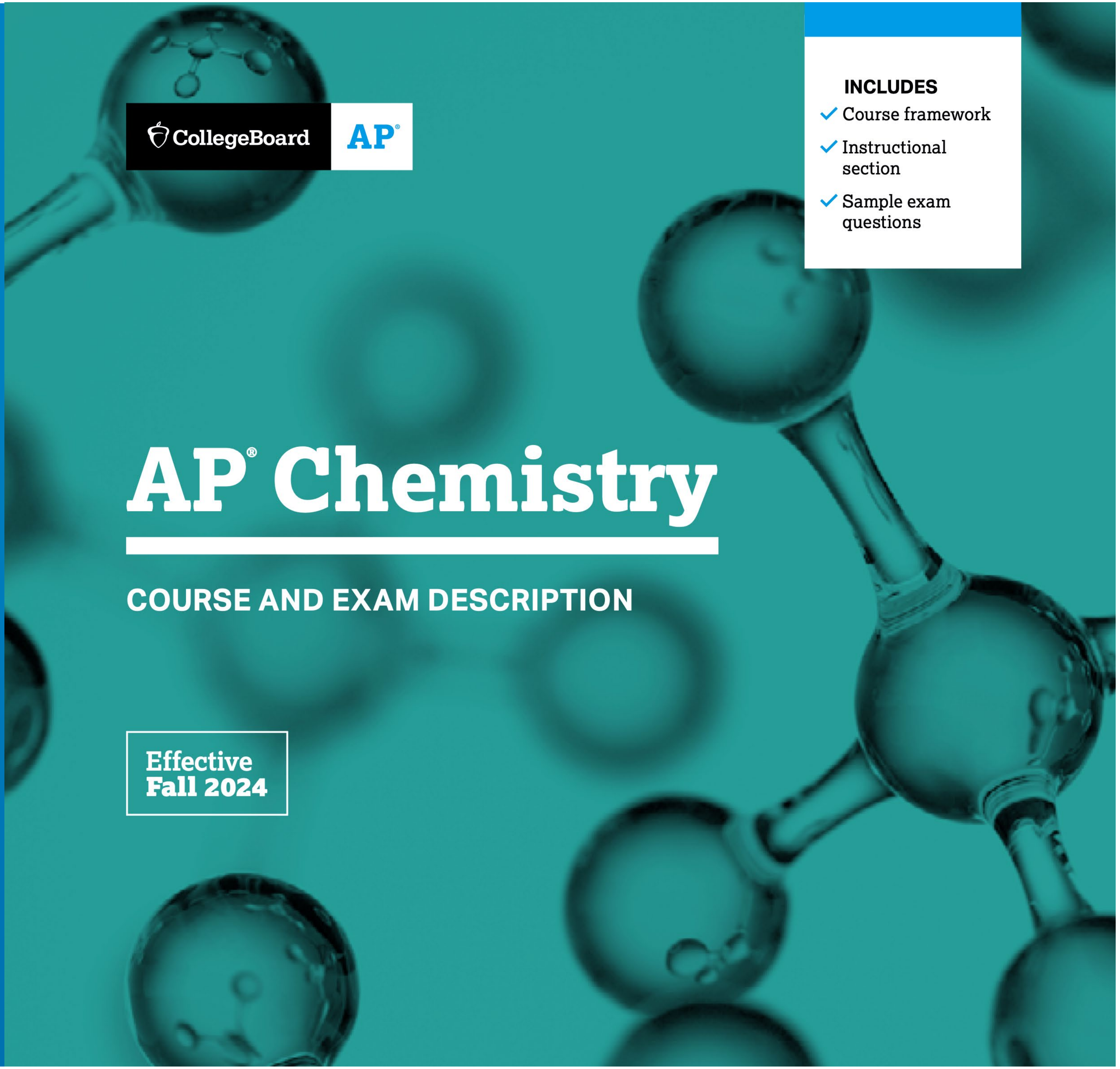
AP Chemistry CED Updates

Effective Fall 2024



CollegeBoard AP

INCLUDES
- ✓ Course framework
- ✓ Instructional section
- ✓ Sample exam questions

AP® Chemistry

COURSE AND EXAM DESCRIPTION

Effective
Fall 2024

Overview

1. Retitling Units and Topics
2. Resequencing Topics 7.13 and 7.14
3. Updating Equation Sheet
4. Changes to LOs, EKs, and Skills
5. AP Classroom Updates

1

Retitling Units and Topics

Unit and Topic Title Changes

UNIT 1
Atomic Structure and Properties

~9–10 Class Periods | 7–9% AP Exam Weighting

SPQ 5	1.1	Moles and Molar Mass
SPQ	1.2	Mass Spectroscopy of Elements
SPQ 2	1.3	Elemental Composition of Pure Substances
SPQ 5	1.4	Composition of Mixtures
SAP 1	1.5	Atomic Structure and Electron Configuration
SAP 4	1.6	Photoelectron Spectroscopy
SAP 4	1.7	Periodic Trends
SAP 4	1.8	Valence Electrons and Ionic Compounds

UNIT 2
Molecular and Ionic Compound Structure and Properties

~12–13 Class Periods | 7–9% AP Exam Weighting

SAP 6	2.1	Types of Chemical Bonds
SAP 3	2.2	Intramolecular Force and Potential Energy
SAP 4	2.3	Structure of Ionic Solids
SAP 4	2.4	Structure of Metals and Alloys
SAP 3	2.5	Lewis Diagrams
SAP 6	2.6	Resonance and Formal Charge
SAP 6	2.7	VSEPR and Bond Hybridization

Retitle:
“Mass Spectra of Elements”

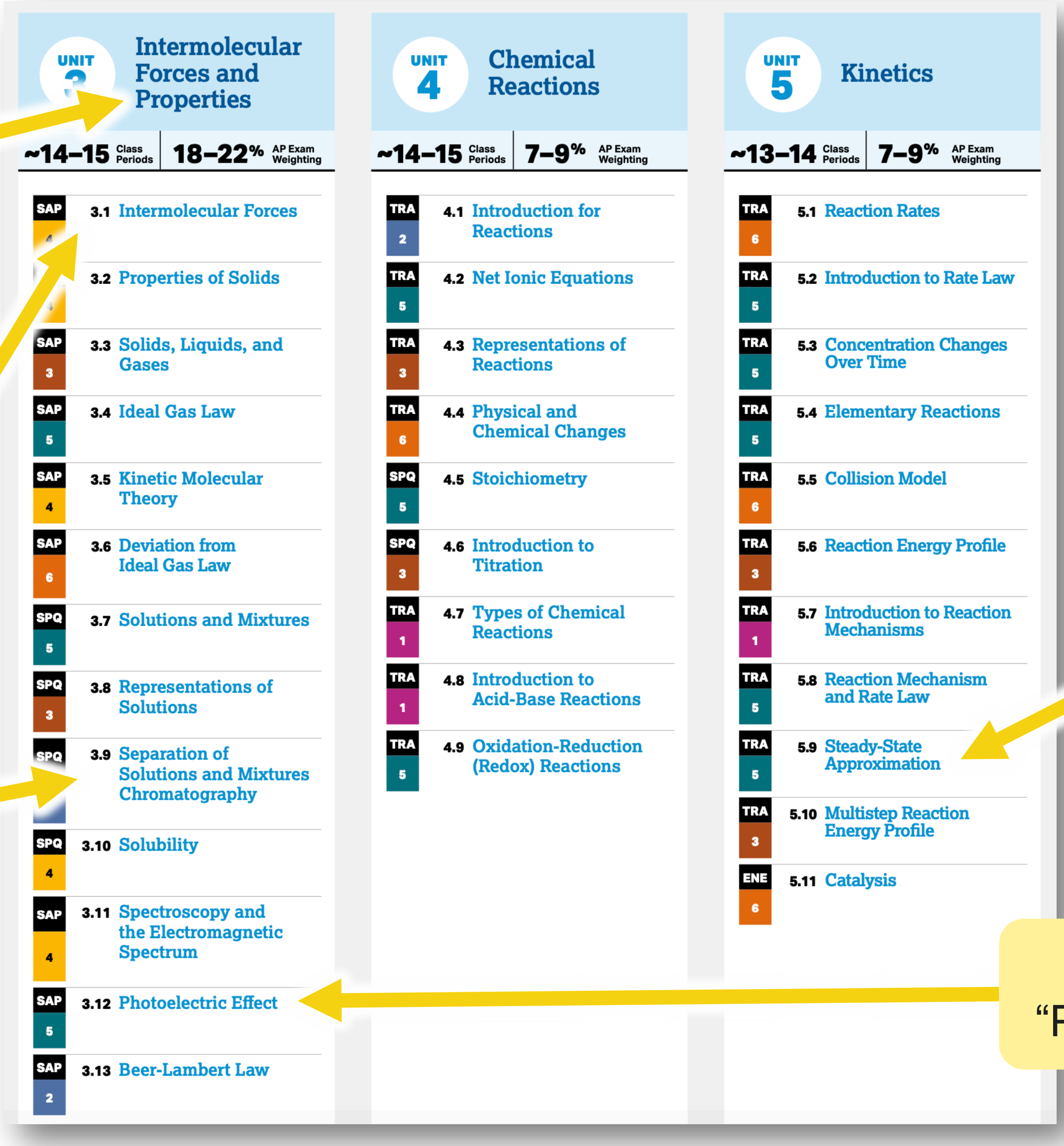
Retitle:
“Compound Structure and Properties”

Retitle:
“VSEPR and Hybridization”

Retitle:
"Properties of Substances and Mixtures"

Retitle:
"Intermolecular and Interparticle Forces"

Retitle:
"Separation of Solutions and Mixtures"



UNIT 3 Intermolecular Forces and Properties

~14–15 Class Periods | 18–22% AP Exam Weighting

SAP 4	3.1	Intermolecular Forces
4	3.2	Properties of Solids
SAP 3	3.3	Solids, Liquids, and Gases
SAP 5	3.4	Ideal Gas Law
SAP 4	3.5	Kinetic Molecular Theory
SAP 6	3.6	Deviation from Ideal Gas Law
SPQ 5	3.7	Solutions and Mixtures
SPQ 3	3.8	Representations of Solutions
SPQ	3.9	Separation of Solutions and Mixtures Chromatography
SPQ 4	3.10	Solubility
SAP 4	3.11	Spectroscopy and the Electromagnetic Spectrum
SAP 5	3.12	Photoelectric Effect
SAP 2	3.13	Beer-Lambert Law

UNIT 4 Chemical Reactions

~14–15 Class Periods | 7–9% AP Exam Weighting

TRA 2	4.1	Introduction for Reactions
TRA 5	4.2	Net Ionic Equations
TRA 3	4.3	Representations of Reactions
TRA 6	4.4	Physical and Chemical Changes
SPQ 5	4.5	Stoichiometry
SPQ 3	4.6	Introduction to Titration
TRA 1	4.7	Types of Chemical Reactions
TRA 1	4.8	Introduction to Acid-Base Reactions
TRA 5	4.9	Oxidation-Reduction (Redox) Reactions

UNIT 5 Kinetics

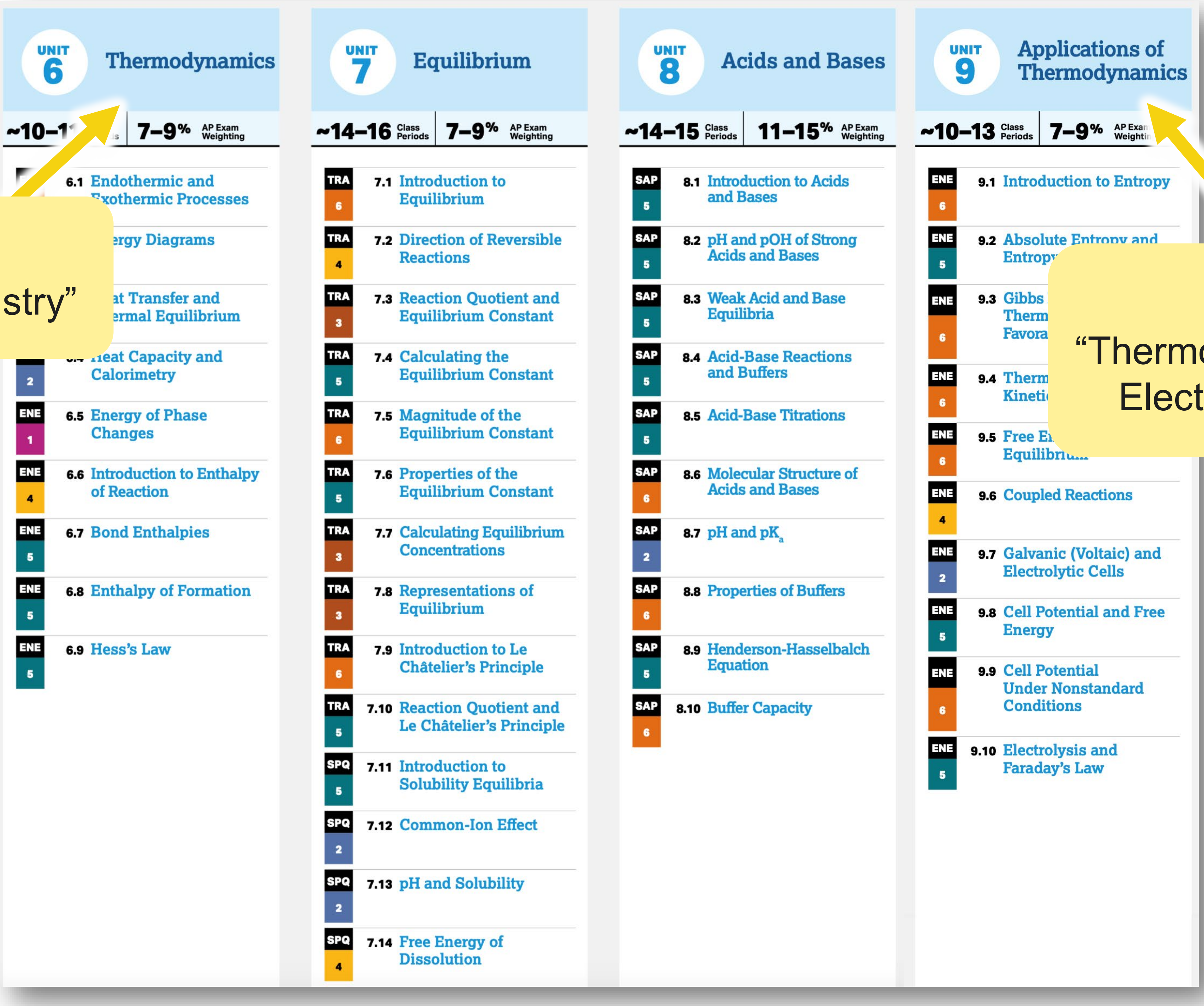
~13–14 Class Periods | 7–9% AP Exam Weighting

TRA 6	5.1	Reaction Rates
TRA 5	5.2	Introduction to Rate Law
TRA 5	5.3	Concentration Changes Over Time
TRA 5	5.4	Elementary Reactions
TRA 6	5.5	Collision Model
TRA 3	5.6	Reaction Energy Profile
TRA 1	5.7	Introduction to Reaction Mechanisms
TRA 5	5.8	Reaction Mechanism and Rate Law
TRA 5	5.9	Steady-State Approximation
TRA 3	5.10	Multistep Reaction Energy Profile
ENE 6	5.11	Catalysis

Retitle:
"Pre-Equilibrium Approximation"

Retitle:
"Properties of Photons"

Retitle: “Thermochemistry”



UNIT 6 Thermodynamics

~10–1 | 7–9% AP Exam Weighting

		6.1	Endothermic and Exothermic Processes
			ergy Diagrams
			at Transfer and ermal Equilibrium
	2		Heat Capacity and Calorimetry
ENE	1	6.5	Energy of Phase Changes
ENE	4	6.6	Introduction to Enthalpy of Reaction
ENE	5	6.7	Bond Enthalpies
ENE	5	6.8	Enthalpy of Formation
ENE	5	6.9	Hess’s Law

UNIT 7 Equilibrium

~14–16 Class Periods | 7–9% AP Exam Weighting

TRA	6	7.1	Introduction to Equilibrium
TRA	4	7.2	Direction of Reversible Reactions
TRA	3	7.3	Reaction Quotient and Equilibrium Constant
TRA	5	7.4	Calculating the Equilibrium Constant
TRA	6	7.5	Magnitude of the Equilibrium Constant
TRA	5	7.6	Properties of the Equilibrium Constant
TRA	3	7.7	Calculating Equilibrium Concentrations
TRA	3	7.8	Representations of Equilibrium
TRA	6	7.9	Introduction to Le Châtelier’s Principle
TRA	5	7.10	Reaction Quotient and Le Châtelier’s Principle
SPQ	5	7.11	Introduction to Solubility Equilibria
SPQ	2	7.12	Common-Ion Effect
SPQ	2	7.13	pH and Solubility
SPQ	4	7.14	Free Energy of Dissolution

UNIT 8 Acids and Bases

~14–15 Class Periods | 11–15% AP Exam Weighting

SAP	5	8.1	Introduction to Acids and Bases
SAP	5	8.2	pH and pOH of Strong Acids and Bases
SAP	5	8.3	Weak Acid and Base Equilibria
SAP	5	8.4	Acid-Base Reactions and Buffers
SAP	5	8.5	Acid-Base Titrations
SAP	6	8.6	Molecular Structure of Acids and Bases
SAP	2	8.7	pH and pK_a
SAP	6	8.8	Properties of Buffers
SAP	5	8.9	Henderson-Hasselbalch Equation
SAP	6	8.10	Buffer Capacity

UNIT 9 Applications of Thermodynamics

~10–13 Class Periods | 7–9% AP Exam Weightin

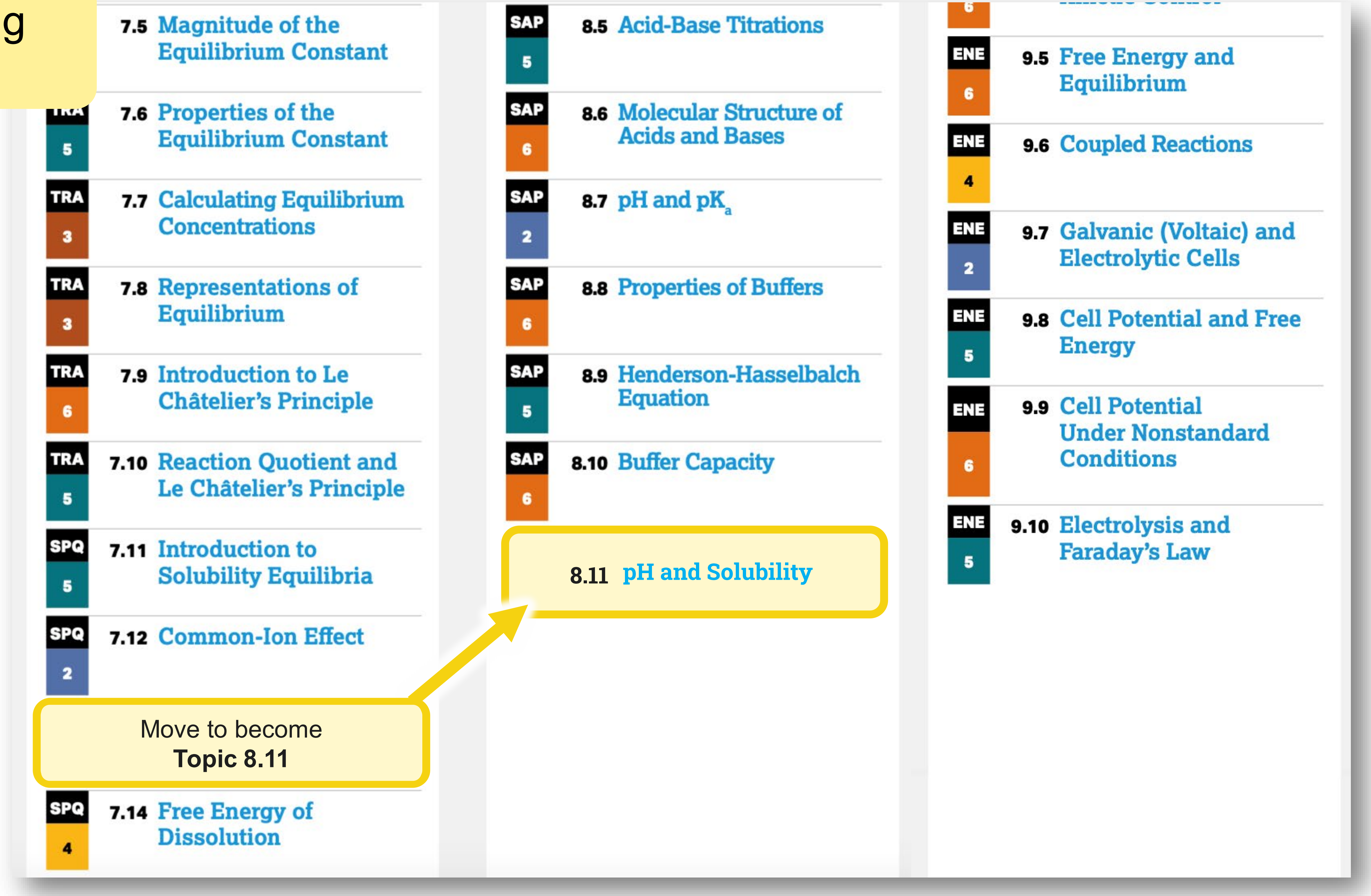
ENE	6	9.1	Introduction to Entropy
ENE	5	9.2	Absolute Entropy and Entropy
ENE	6	9.3	Gibbs Therm Favora
ENE	6	9.4	Therm Kineti
ENE	6	9.5	Free E Equilibrium
ENE	4	9.6	Coupled Reactions
ENE	2	9.7	Galvanic (Voltaic) and Electrolytic Cells
ENE	5	9.8	Cell Potential and Free Energy
ENE	6	9.9	Cell Potential Under Nonstandard Conditions
ENE	5	9.10	Electrolysis and Faraday’s Law

Retitle: “Thermodynamics and Electrochemistry”

2

Resequencing Topics 7.13 and 7.14

Resequencing **Topic** 7.13



- 7.5 Magnitude of the Equilibrium Constant
- 5 7.6 Properties of the Equilibrium Constant
- TRA 3 7.7 Calculating Equilibrium Concentrations
- TRA 3 7.8 Representations of Equilibrium
- TRA 6 7.9 Introduction to Le Châtelier's Principle
- TRA 5 7.10 Reaction Quotient and Le Châtelier's Principle
- SPQ 5 7.11 Introduction to Solubility Equilibria
- SPQ 2 7.12 Common-Ion Effect

Move to become
Topic 8.11

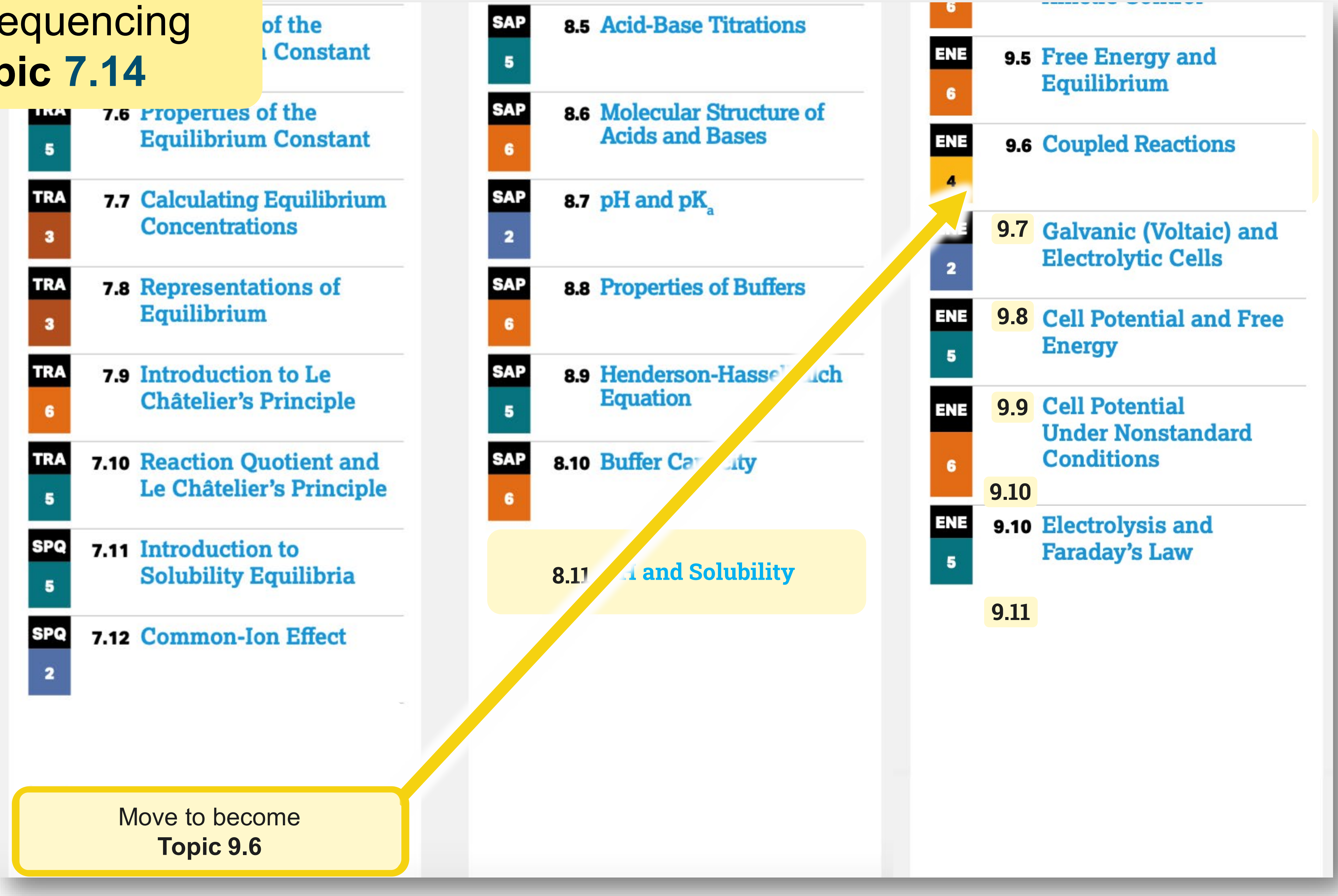
- SPQ 4 7.14 Free Energy of Dissolution

- SAP 5 8.5 Acid-Base Titrations
- SAP 6 8.6 Molecular Structure of Acids and Bases
- SAP 2 8.7 pH and pK_a
- SAP 6 8.8 Properties of Buffers
- SAP 5 8.9 Henderson-Hasselbalch Equation
- SAP 6 8.10 Buffer Capacity

8.11 pH and Solubility

- ENE 6 9.5 Free Energy and Equilibrium
- ENE 4 9.6 Coupled Reactions
- ENE 2 9.7 Galvanic (Voltaic) and Electrolytic Cells
- ENE 5 9.8 Cell Potential and Free Energy
- ENE 6 9.9 Cell Potential Under Nonstandard Conditions
- ENE 5 9.10 Electrolysis and Faraday's Law

Resequencing
Topic 7.14



of the
Constant

TRA 5 **7.6** Properties of the Equilibrium Constant

TRA 3 **7.7** Calculating Equilibrium Concentrations

TRA 3 **7.8** Representations of Equilibrium

TRA 6 **7.9** Introduction to Le Châtelier's Principle

TRA 5 **7.10** Reaction Quotient and Le Châtelier's Principle

SPQ 5 **7.11** Introduction to Solubility Equilibria

SPQ 2 **7.12** Common-Ion Effect

SAP 5 **8.5** Acid-Base Titrations

SAP 6 **8.6** Molecular Structure of Acids and Bases

SAP 2 **8.7** pH and pK_a

SAP 6 **8.8** Properties of Buffers

SAP 5 **8.9** Henderson-Hasse ich Equation

SAP 6 **8.10** Buffer Ca ity

8.11 and Solubility

ENE 6 **9.5** Free Energy and Equilibrium

ENE 4 **9.6** Coupled Reactions

ENE 2 **9.7** Galvanic (Voltaic) and Electrolytic Cells

ENE 5 **9.8** Cell Potential and Free Energy

ENE 6 **9.9** Cell Potential Under Nonstandard Conditions

9.10

ENE 5 **9.10** Electrolysis and Faraday's Law

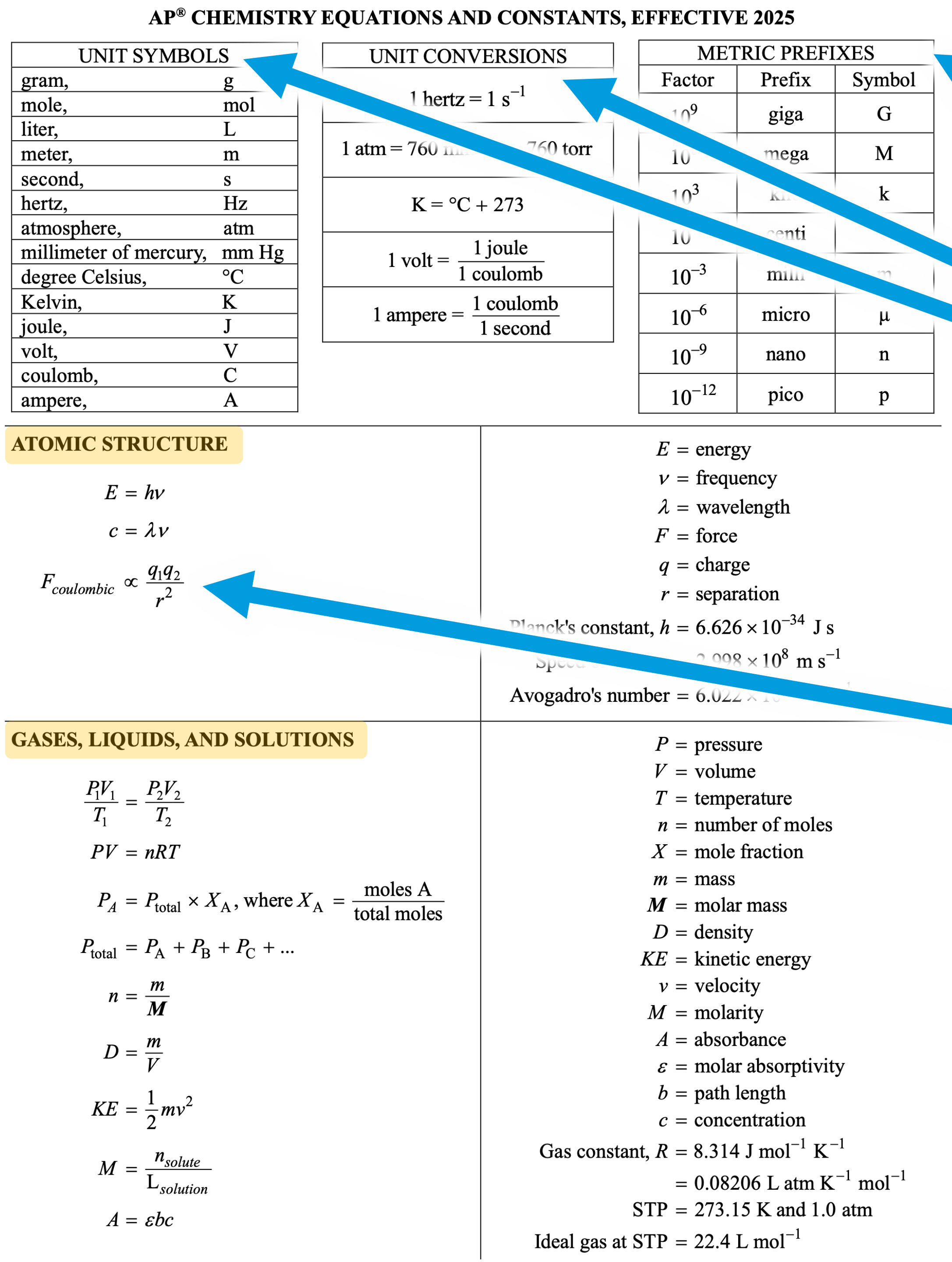
9.11

Move Topics **down one number**

Move to become **Topic 9.6**

3

Updating Equation Sheet



AP® CHEMISTRY EQUATIONS AND CONSTANTS, EFFECTIVE 2025

UNIT SYMBOLS	
gram,	g
mole,	mol
liter,	L
meter,	m
second,	s
hertz,	Hz
atmosphere,	atm
millimeter of mercury,	mm Hg
degree Celsius,	°C
Kelvin,	K
joule,	J
volt,	V
coulomb,	C
ampere,	A

UNIT CONVERSIONS
1 hertz = 1 s^{-1}
1 atm = 760 mm [illegible] 760 torr
K = °C + 273
1 volt = $\frac{\text{1 joule}}{\text{1 coulomb}}$
1 ampere = $\frac{\text{1 coulomb}}{\text{1 second}}$

METRIC PREFIXES		
Factor	Prefix	Symbol
10^9	giga	G
10	mega	M
10^3	kilo	k
10	centi	
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

ATOMIC STRUCTURE

$$E = h\nu$$

$$c = \lambda\nu$$

$$F_{coulombic} \propto \frac{q_1 q_2}{r^2}$$

E = energy
ν = frequency
λ = wavelength
F = force
q = charge
r = separation
Planck's constant, $h = 6.626 \times 10^{-34}$ J s
Speed [illegible] 2.998×10^8 m s^{-1}
Avogadro's number = 6.022 × 10 [illegible]

GASES, LIQUIDS, AND SOLUTIONS

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$PV = nRT$$

$$P_A = P_{total} \times X_A, \text{ where } X_A = \frac{\text{moles A}}{\text{total moles}}$$

$$P_{total} = P_A + P_B + P_C + \ldots$$

$$n = \frac{m}{\boldsymbol{M}}$$

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

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

$$M = \frac{n_{solute}}{L_{solution}}$$

$$A = \varepsilon bc$$

P = pressure
V = volume
T = temperature
n = number of moles
X = mole fraction
m = mass
$\boldsymbol{M}$ = molar mass
D = density
KE = kinetic energy
v = velocity
M = molarity
A = absorbance
ε = molar absorptivity
b = path length
c = concentration
Gas constant, $R = 8.314$ J mol^{-1} K^{-1}
= 0.08206 L atm K^{-1} mol^{-1}
STP = 273.15 K and 1.0 atm
Ideal gas at STP = 22.4 L mol^{-1}

Added metric prefixes table (consistent with other AP Sciences)

Consolidated list of unit symbols and conversions

Added EQN from Topic 1.5:

$$F_{coulombic} \propto \frac{q_1 q_2}{r^2}$$

Equation sections reordered to follow CED sequence

KINETICS

$$[A]_t - [A]_0 = -kt$$

$$\ln[A]_t - \ln[A]_0 = -kt$$

$$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$$

$$t_{1/2} = \frac{0.693}{k}$$

k = rate constant
t = time
$t_{1/2}$ = half-life

EQUILIBRIUM

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}, \text{ where } a\,A + b\,B \;\square\; c\,C + d\,D$$

$$K_p = \frac{(P_C)^c(P_D)^d}{(P_A)^a(P_B)^b}$$

$$K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14} \text{ at } 25°C$$

$$pK_w = 14 = pH + pOH \text{ at } 25°C$$

$$pH = -\log[H_3O^+], \qquad pOH = -\log[OH^-]$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}, \qquad K_b = \frac{[OH^-][HB^+]}{[B]}$$

$$pK_a = -\log K_a, \qquad pK_b = -\log K_b$$

$$K_w = K_a \times K_b, \qquad pK_w = pK_a + pK_b$$

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

Equilibrium Constants

K_c (molar concentrations)
K_p (gas pressures)
K_w (water)
K_a (acid)
K_b (base)

Reordered Equations to follow CED sequence

Added new EQNs from Topic 8.3:

$$K_w = K_a \times K_b$$

$$pK_w = pK_a + pK_b$$

THERMODYNAMICS/ELECTROCHEMISTRY

$$q = mc\Delta T$$

$$\Delta H^\circ_{reaction} = \sum \Delta H^\circ_{f\ products} - \sum \Delta H^\circ_{f\ reactants}$$

$$\Delta S^\circ_{reaction} = \sum S^\circ_{products} - \sum S^\circ_{reactants}$$

$$\Delta G^\circ_{reaction} = \sum \Delta G^\circ_{f\ products} - \sum \Delta G^\circ_{f\ reactants}$$

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

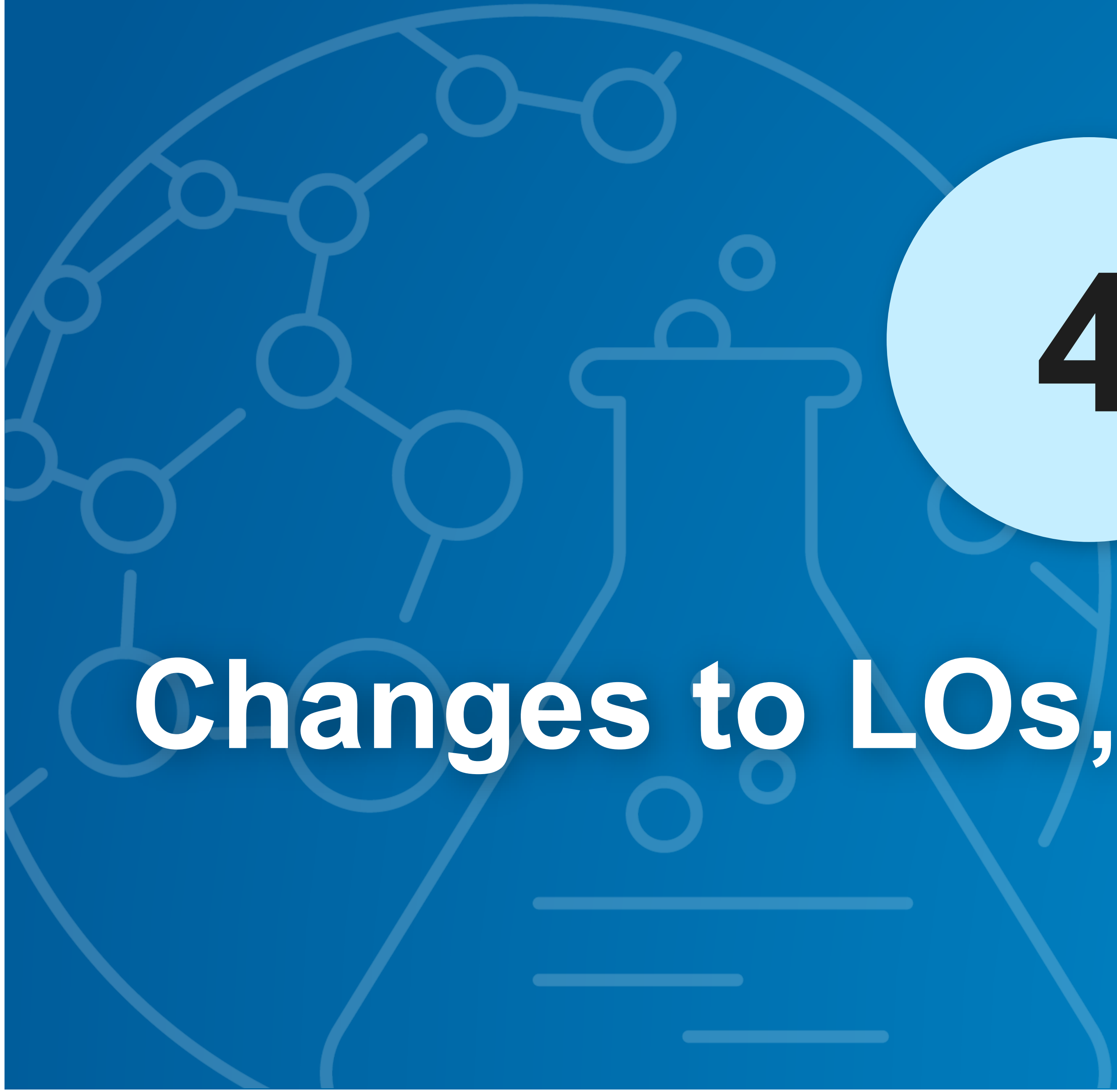
$$= -RT\ln K$$

$$= -nFE^\circ$$

$$I = \frac{q}{t}$$

$$E_{cell} = E^\circ_{cell} - \frac{RT}{nF}\ln Q$$

q = heat
m = mass
c = specific heat capacity
T = temperature
S° = standard entropy
H° = standard enthalpy
G° = standard Gibbs free energy
R = gas constant
K = equilibrium constant
n = number of moles of electrons
E° = standard potential
I = current (amperes)
q = charge (coulombs)
t = time (seconds)
Q = reaction quotient
Faraday's constant, F = 96,485 coulombs / 1 mol e^-



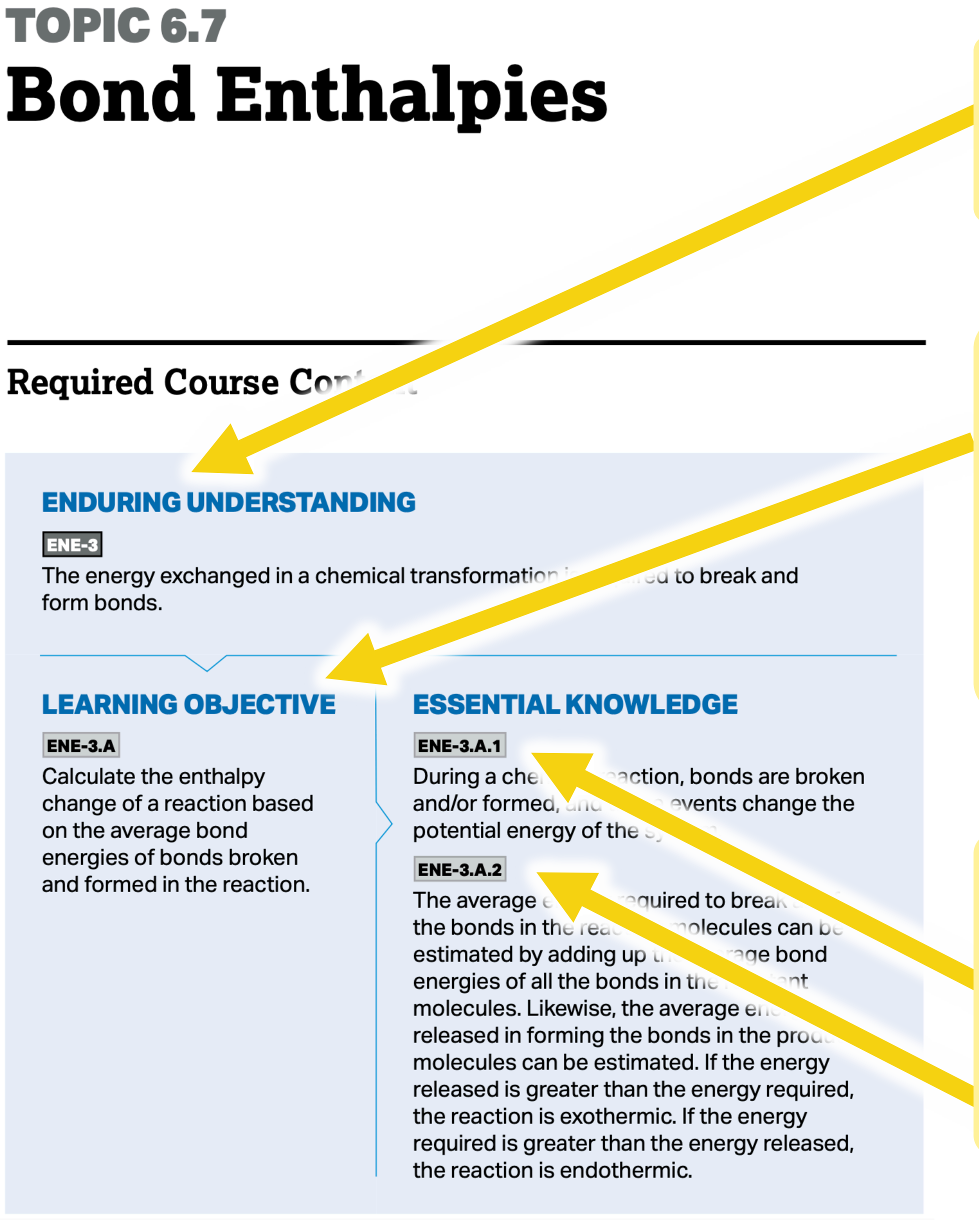
4

Changes to LOs, EKs, and Skills

Changes to LOs, EKs, and Skills

- **a** New LO and EK Coding
- **b** LO Addition to Unit 3, Topic 3.9
- **c** EK Additions to Units 6, 7, and 8
- **d** EK Migration (Topics 7.13, 7.14, 9.6 - 9.10)
- **e** Update to Skill 4.A

a New LO and EK Coding



TOPIC 6.7

Bond Enthalpies

Required Course Con[illegible]

ENDURING UNDERSTANDING

ENE-3

The energy exchanged in a chemical transformation [illegible] to break and form bonds.

LEARNING OBJECTIVE

ENE-3.A

Calculate the enthalpy change of a reaction based on the average bond energies of bonds broken and formed in the reaction.

ESSENTIAL KNOWLEDGE

ENE-3.A.1

During a che[illegible]action, bonds are broken and/or formed, [illegible] events change the potential energy of the [illegible]

ENE-3.A.2

The average [illegible]quired to break [illegible] the bonds in the rea[illegible]olecules can be estimated by adding up [illegible]age bond energies of all the bonds in the [illegible]nt molecules. Likewise, the average en[illegible] released in forming the bonds in the prod[illegible] molecules can be estimated. If the energy released is greater than the energy required, the reaction is exothermic. If the energy required is greater than the energy released, the reaction is endothermic.

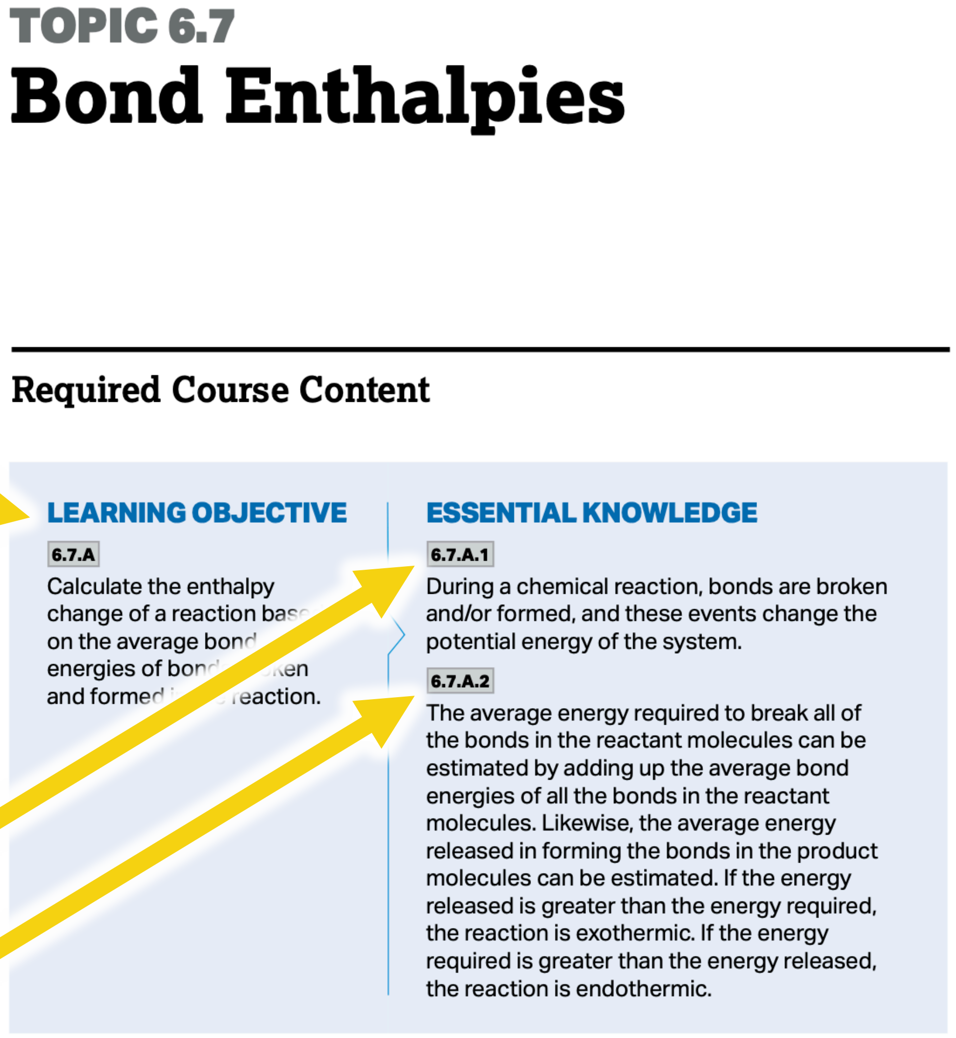
Remove all Big Ideas and Enduring Understanding Statements (EUs)

All Learning Objectives are **coded to the Topic** instead of Big Idea and EU.

For example, ENE-3.A becomes 6.7.A because it is the first LO in Topic 6.7

Essential Knowledge statements are **coded to Topic** instead of Big Idea/EU:

ENE-3.A.1 becomes 6.7.A.1
ENE-3.A.2 becomes 6.7.A.2



TOPIC 6.7

Bond Enthalpies

Required Course Content

LEARNING OBJECTIVE

6.7.A

Calculate the enthalpy change of a reaction bas[illegible] on the average bond[illegible] energies of bon[illegible]ken and formed i[illegible] reaction.

ESSENTIAL KNOWLEDGE

6.7.A.1

During a chemical reaction, bonds are broken and/or formed, and these events change the potential energy of the system.

6.7.A.2

The average energy required to break all of the bonds in the reactant molecules can be estimated by adding up the average bond energies of all the bonds in the reactant molecules. Likewise, the average energy released in forming the bonds in the product molecules can be estimated. If the energy released is greater than the energy required, the reaction is exothermic. If the energy required is greater than the energy released, the reaction is endothermic.

b LO Addition to Unit 3, Topic 3.9

Topic	Current LO	Current LO Text	New LO	New LO Text
3.9	SPQ-3.C	Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles.	3.9.A	**Explain the results of a separation experiment based on intermolecular interactions.**
3.10	SPQ-3.C	Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles.	3.10.A	**unchanged**

c EK Additions to Unit 6

Topic	EK	Text
6.4	**Add** EK 6.4.A.7	In calorimetry experiments involving dissolution, temperature changes of the mixture within the calorimeter can be used to determine the direction of energy flow. If the temperature of the mixture increases, thermal energy is released by the dissolution process (exothermic). If the temperature of the mixture decreases, thermal energy is absorbed by the dissolution process (endothermic).
6.6	**Move** EK ENE-3.D.1 from Topic 6.9 to become 6.6.A.2	When the products of a reaction are at a different temperature than their surroundings, they exchange energy with the surroundings to reach thermal equilibrium. Thermal energy is transferred to the surroundings as the reactants convert to products in an exothermic reaction. Thermal energy is transferred from the surroundings as the reactants convert to products in an endothermic reaction.
6.6	**Add** EK 6.6.A.3	The chemical potential energy of the products of a reaction is different from that of the reactants because of the breaking and forming of bonds. The energy difference results in a change in the kinetic energy of the particles, which manifests as a temperature change.

c EK Additions to Unit 6 (continued)

Topic	EK	Text
6.9	**Add** EK 6.9.A.1	Many processes can be broken down into a series of steps. Each step in the series has its own energy change.
6.9	**Add** EK 6.9.B.1	Because total energy is conserved (first law of thermodynamics), and each individual reaction in a sequence transfers thermal energy to or from the surroundings, the net thermal energy transferred in the sequence will be equal to the sum of the thermal energy transfers in each of the steps. These thermal energy transfers are the result of potential energy changes among the species in the reaction sequence; thus, at constant pressure, the enthalpy change of the overall process is equal to the sum of the enthalpy changes of the individual steps.
6.9	**Add** EK 6.9.B.2	The following are essential principles of Hess's law: i. When a reaction is reversed, the enthalpy change stays constant in magnitude but becomes reversed in mathematical sign. ii. When a reaction is multiplied by a factor *c*, the enthalpy change is multiplied by the same factor *c*. iii. When two (or more) reactions are added to obtain an overall reaction, the individual enthalpy changes of each reaction are added to obtain the net enthalpy of the overall reaction.

c

EK Additions to Unit 7

Topic	EK	Text
7.7	**Add** EK 7.7.A.2	When $Q < K$, the reaction will proceed with a net consumption of reactants and generation of products. When $Q > K$, the reaction will proceed with a net consumption of products and generation of reactants. When $Q = K$, the system is at dynamic equilibrium; both forward and reverse reactions proceed at the same rate, and the proportion of reactants and products remains constant.
7.11	**Add** EK 7.11.A.4	The molar solubility of one or more species in a saturated solution can be used to calculate the K_{sp} of a substance.

c EK Additions to Unit 8

Topic	EK	Text
8.3	**Add** EK 8.3.A.6	For any conjugate acid-base pair, the acid ionization constant and base ionization constant are related by K_w: EQN: $K_w = K_a \times K_b$ EQN: $pK_w = pK_a + pK_b$
8.5	**Add** EK 8.5.A.4	At the equivalence point, pH is determined by the major species in solution. Strong acid and strong base titrations result in neutral pH at the equivalence point. However, in titrations of weak acids (weak bases), the conjugate base of the weak acid (conjugate acid of the weak base) is present at the equivalence point and can undergo proton-transfer reactions with the surrounding water, producing basic (acidic) solutions.
8.7	**Add** EK 8.7.A.3	8.7.A.3 To ensure accurate results in a titration experiment, acid-base indicators should be selected that have a pK_a close to the pH at the equivalence point.

d

EK Migration: Topics 7.13 and 7.14

Old Topic	Old EK Code	New Topic	New EK Code	EK Text
7.13	SPQ-5.C.1	**8.11**	8.11.A.1	unchanged
7.14	SPQ-5.D.1	**9.6**	9.6.A.1	unchanged

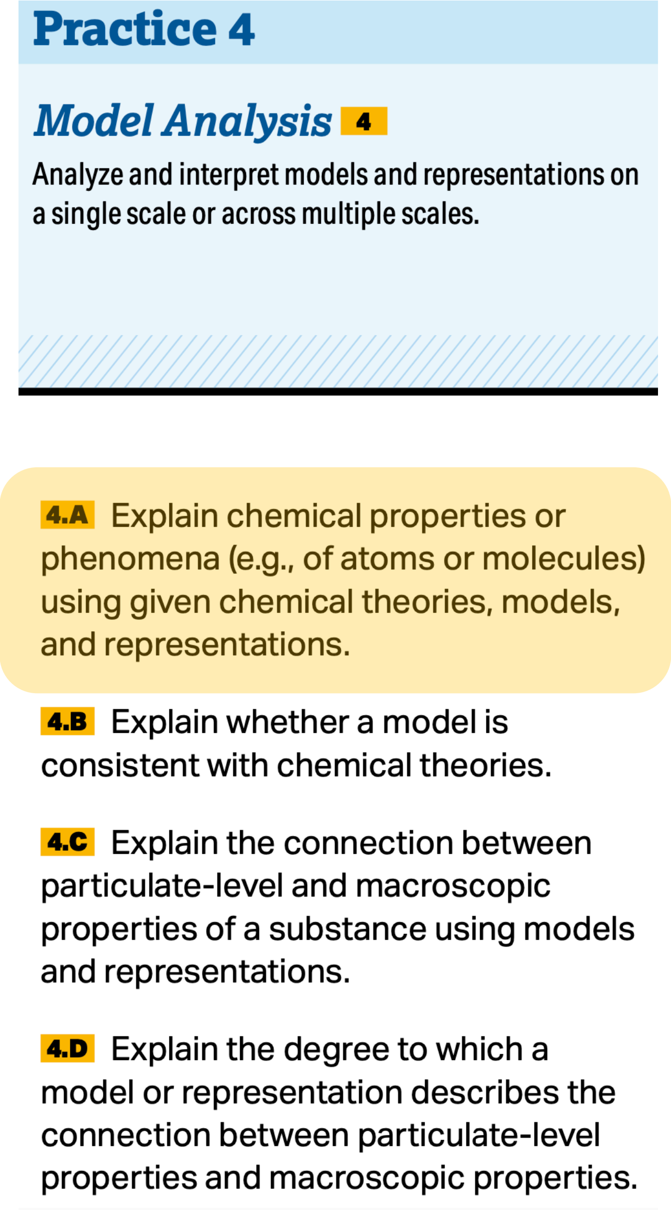
d EK Migration: Topics 9.6 and 9.10

EK Migration for **Topics 9.6 - 9.10** to become **9.7 - 9.11**

Old Topic	Old EK Code	New Topic	New EK Code	EK Text
9.6	ENE-5.B.1 ENE-5.B.2	**9.7**	9.7.A.1 9.7.A.2	unchanged
9.7	ENE-6.A.1 ENE-6.A.2 ENE-6.A.3	**9.8**	9.8.A.1 9.8.A.2 9.8.A.3	unchanged
9.8	ENE-6.B.1 ENE-6.B.2 ENE-6.B.3	**9.9**	9.9.A.1 9.9.A.2 9.9.A.3	unchanged
9.9	ENE-6.C.1 ENE-6.C.2 ENE-6.C.3 ENE-6.C.4	**9.10**	9.10.A.1 9.10.A.2 9.10.A.3 9.10.A.4	unchanged
9.10	ENE-6.D.1	**9.11**	9.11.D.1	unchanged

e

Update to Skill 4.A



Practice 4

Model Analysis 4

Analyze and interpret models and representations on a single scale or across multiple scales.

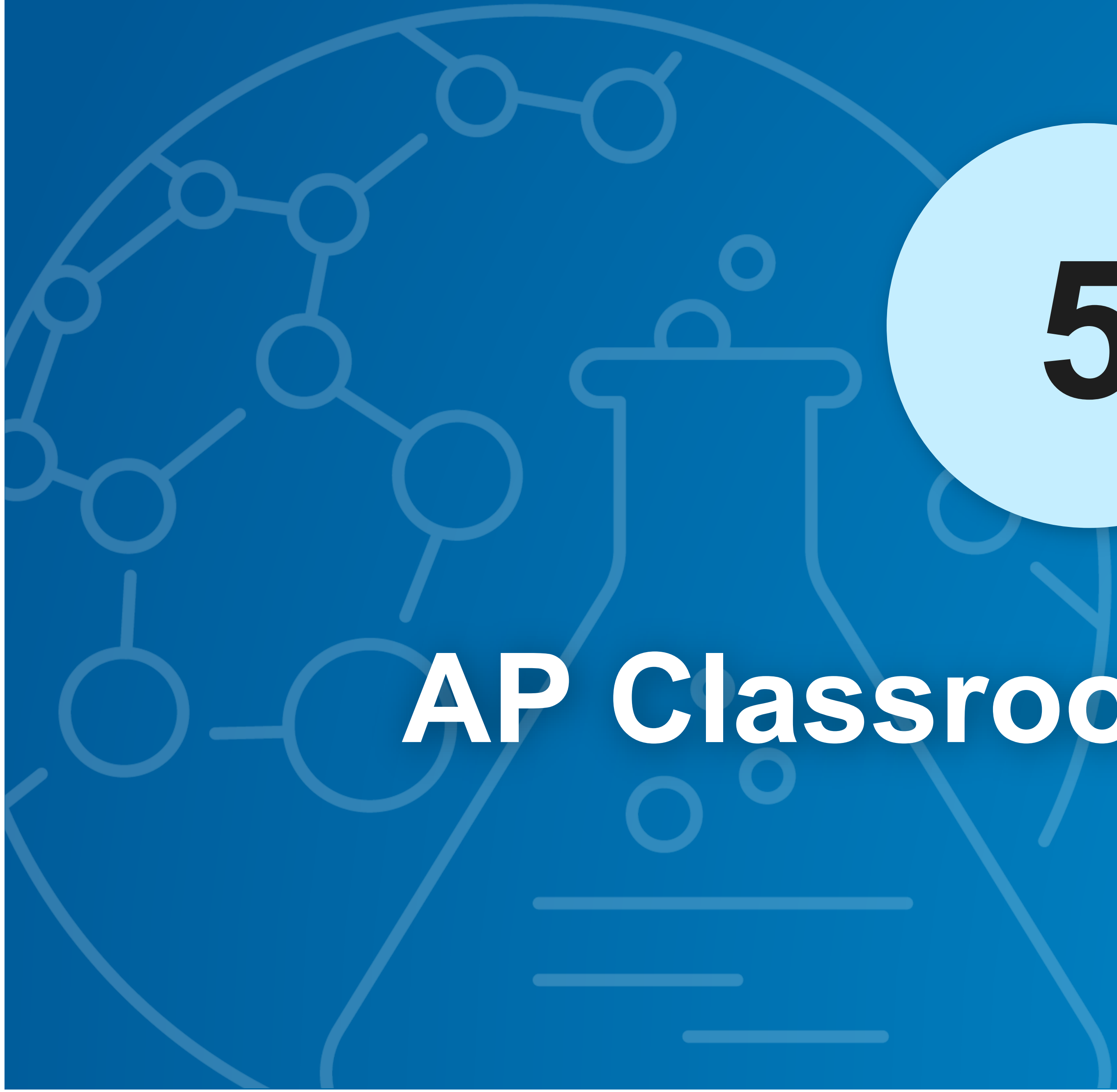
4.A Explain chemical properties or phenomena (e.g., of atoms or molecules) using given chemical theories, models, and representations.

4.B Explain whether a model is consistent with chemical theories.

4.C Explain the connection between particulate-level and macroscopic properties of a substance using models and representations.

4.D Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.

4.A Explain **and/or predict** chemical properties or phenomena (e.g., of atoms or molecules) using given chemical theories, models, and representations.



5

AP Classroom Updates

AP Classroom Updates

a Updated Topic Videos

b Question Bank Updates

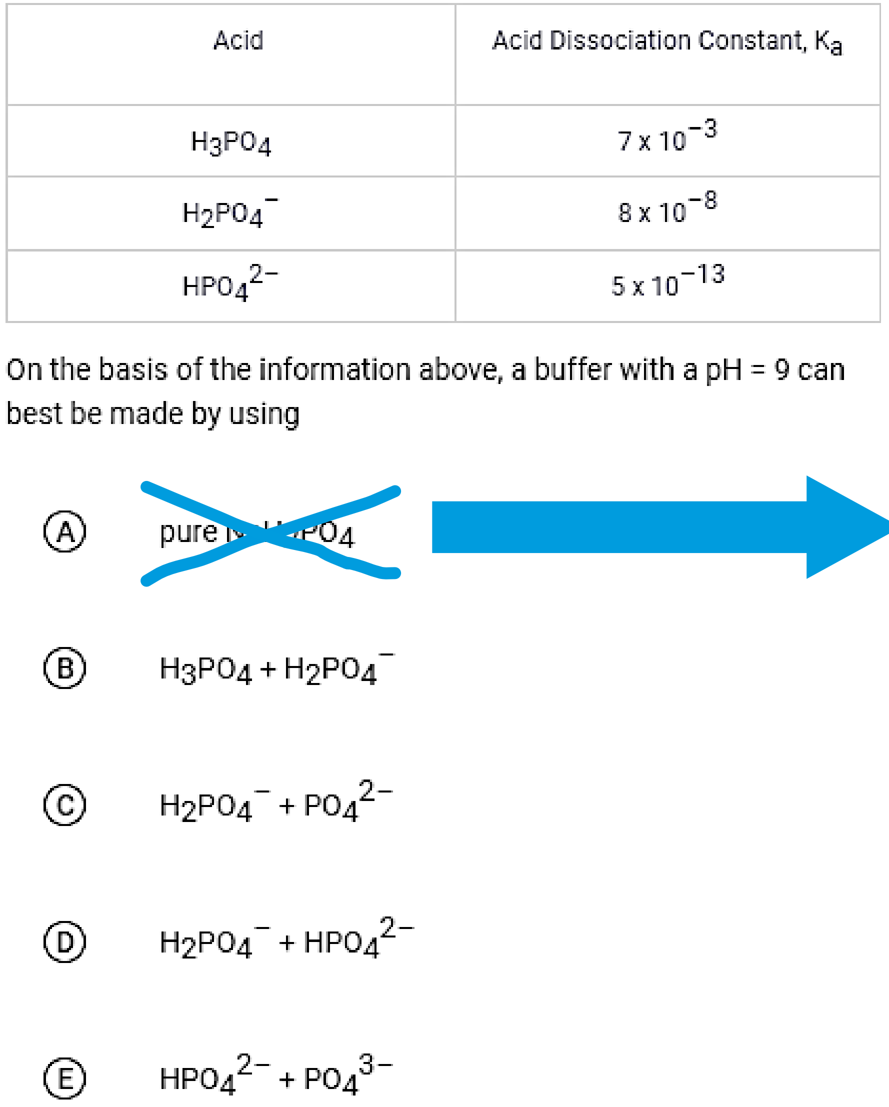
c Practice Exam Updates

a Updated Topic Videos

- All **titles and text updated** to match new CED
- **New Topic Video** for **Topic 9.6** (Free Energy of Dissolution)

b Question Bank Updates

- All **questions recoded** to new CED
- Progress Checks **updated** (Units 7-9)
- “**Option Type**” on MCQs
  - Diagram
  - Chemical Reaction Equation
  - Numerical/Mathematical Expression
  - Text
- All MCQs are now **4 options**
  - pre-2014 items
  - Source: “Summative Practice”
- Retired 25 **duplicate MCQs**



Acid	Acid Dissociation Constant, K_a
H_3PO_4	7×10^{-3}
$H_2PO_4^-$	8×10^{-8}
HPO_4^{2-}	5×10^{-13}

On the basis of the information above, a buffer with a pH = 9 can best be made by using

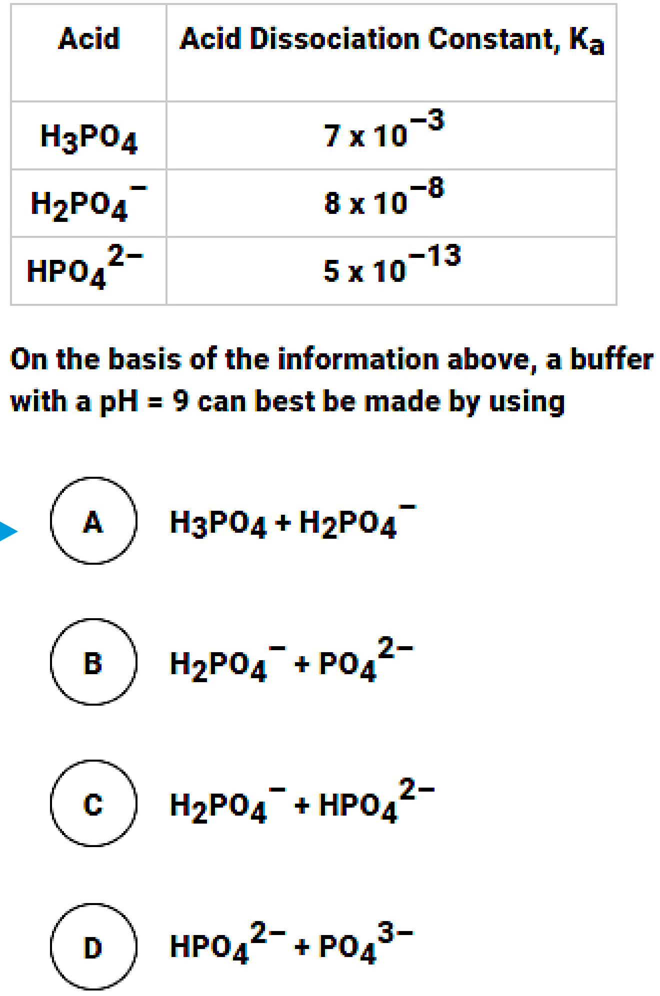
Ⓐ ~~pure NaH_2PO_4~~

Ⓑ $H_3PO_4 + H_2PO_4^-$

Ⓒ $H_2PO_4^- + PO_4^{2-}$

Ⓓ $H_2PO_4^- + HPO_4^{2-}$

Ⓔ $HPO_4^{2-} + PO_4^{3-}$



Acid	**Acid Dissociation Constant, K_a**
H_3PO_4	7×10^{-3}
$H_2PO_4^-$	8×10^{-8}
HPO_4^{2-}	5×10^{-13}

On the basis of the information above, a buffer with a pH = 9 can best be made by using

A $H_3PO_4 + H_2PO_4^-$

B $H_2PO_4^- + PO_4^{2-}$

C $H_2PO_4^- + HPO_4^{2-}$

D $HPO_4^{2-} + PO_4^{3-}$

c

Practice Exam Updates

- **2017 and 2018 International Practice Exams** become Source: “AP Exam” items
- **2019 International Practice Exam** becomes Practice Exam #1
- **New Practice Exam #2** will be added in Fall 2024
- **2024 International Exam** becomes Practice Exam #3 (released Spring 2025)

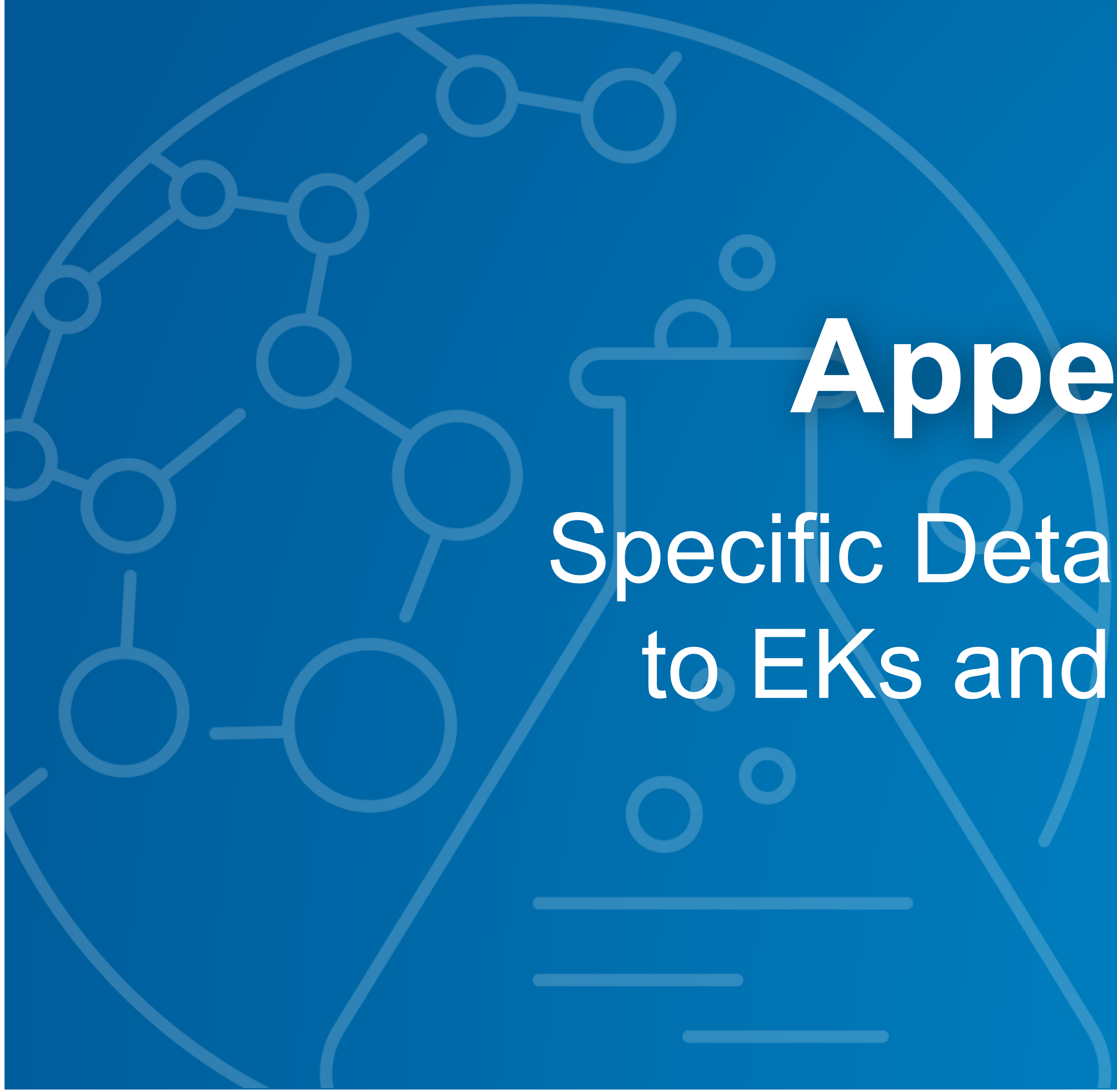
What is NOT Changing

1. **Exam Structure**
    - Number of questions
    - Timing
    - Percentage of Units and Skills assessed
2. **Scope of the Course**

Thank You!

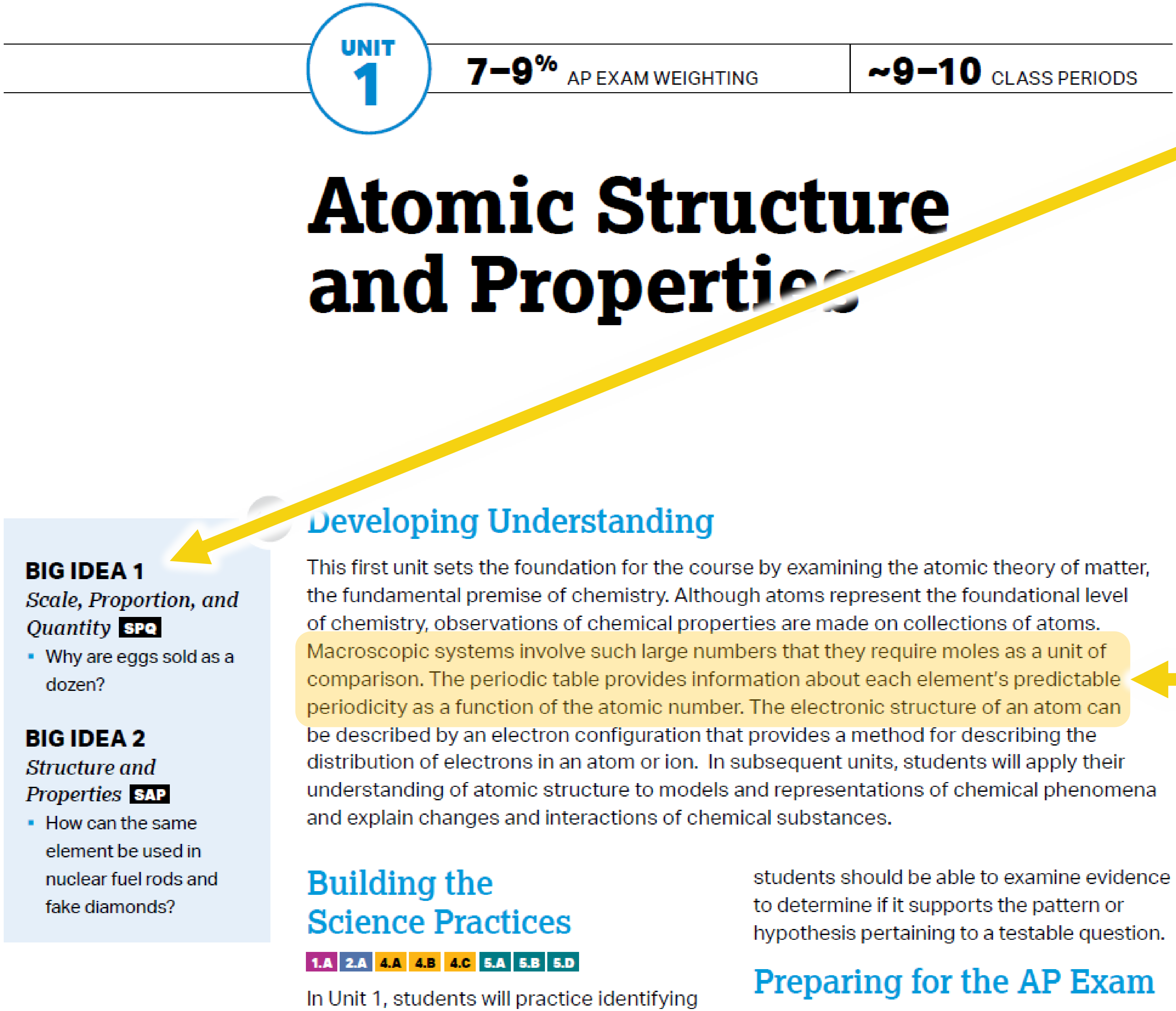
Jamie Benigna

jbenigna@collegeboard.org



Appendix:

Specific Detail of Changes to EKs and Other Text



UNIT 1 7–9% AP EXAM WEIGHTING ~9–10 CLASS PERIODS

Atomic Structure and Properties

BIG IDEA 1
Scale, Proportion, and Quantity **SPQ**

- Why are eggs sold as a dozen?

BIG IDEA 2
Structure and Properties **SAP**

- How can the same element be used in nuclear fuel rods and fake diamonds?

Developing Understanding

This first unit sets the foundation for the course by examining the atomic theory of matter, the fundamental premise of chemistry. Although atoms represent the foundational level of chemistry, observations of chemical properties are made on collections of atoms. Macroscopic systems involve such large numbers that they require moles as a unit of comparison. The periodic table provides information about each element's predictable periodicity as a function of the atomic number. The electronic structure of an atom can be described by an electron configuration that provides a method for describing the distribution of electrons in an atom or ion. In subsequent units, students will apply their understanding of atomic structure to models and representations of chemical phenomena and explain changes and interactions of chemical substances.

Building the Science Practices

1.A 2.A 4.A 4.B 4.C 5.A 5.B 5.D

In Unit 1, students will practice identifying

students should be able to examine evidence to determine if it supports the pattern or hypothesis pertaining to a testable question.

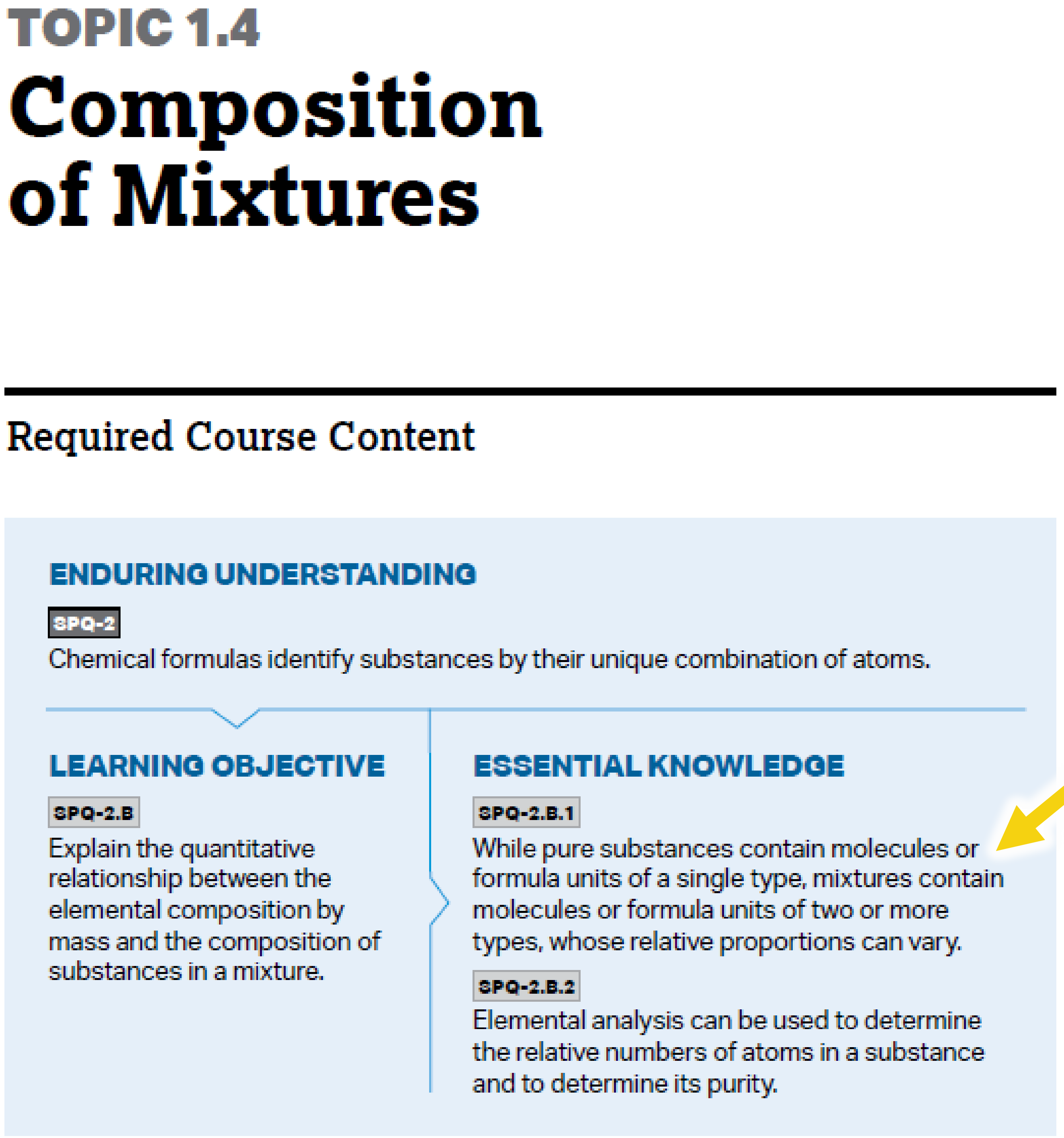
Preparing for the AP Exam

Remove references to Big Ideas.

Updated Essential Questions:

- How can the same element be used in nuclear fuel rods and fake diamonds?
- How can large quantities of objects be counted by weighing?
- If atoms are too small to be observed directly, how do we know how they're structured?
- Why does the periodic table have the shape that it does?

Reword: "Macroscopic systems involve such large numbers of particles that they require the units of moles to translate between this and the particulate scale. The organization of the periodic table reflects the periodicity of element properties as a function of atomic number."



TOPIC 1.4

Composition of Mixtures

Required Course Content

ENDURING UNDERSTANDING

SPQ-2

Chemical formulas identify substances by their unique combination of atoms.

LEARNING OBJECTIVE

SPQ-2.B

Explain the quantitative relationship between the elemental composition by mass and the composition of substances in a mixture.

ESSENTIAL KNOWLEDGE

SPQ-2.B.1

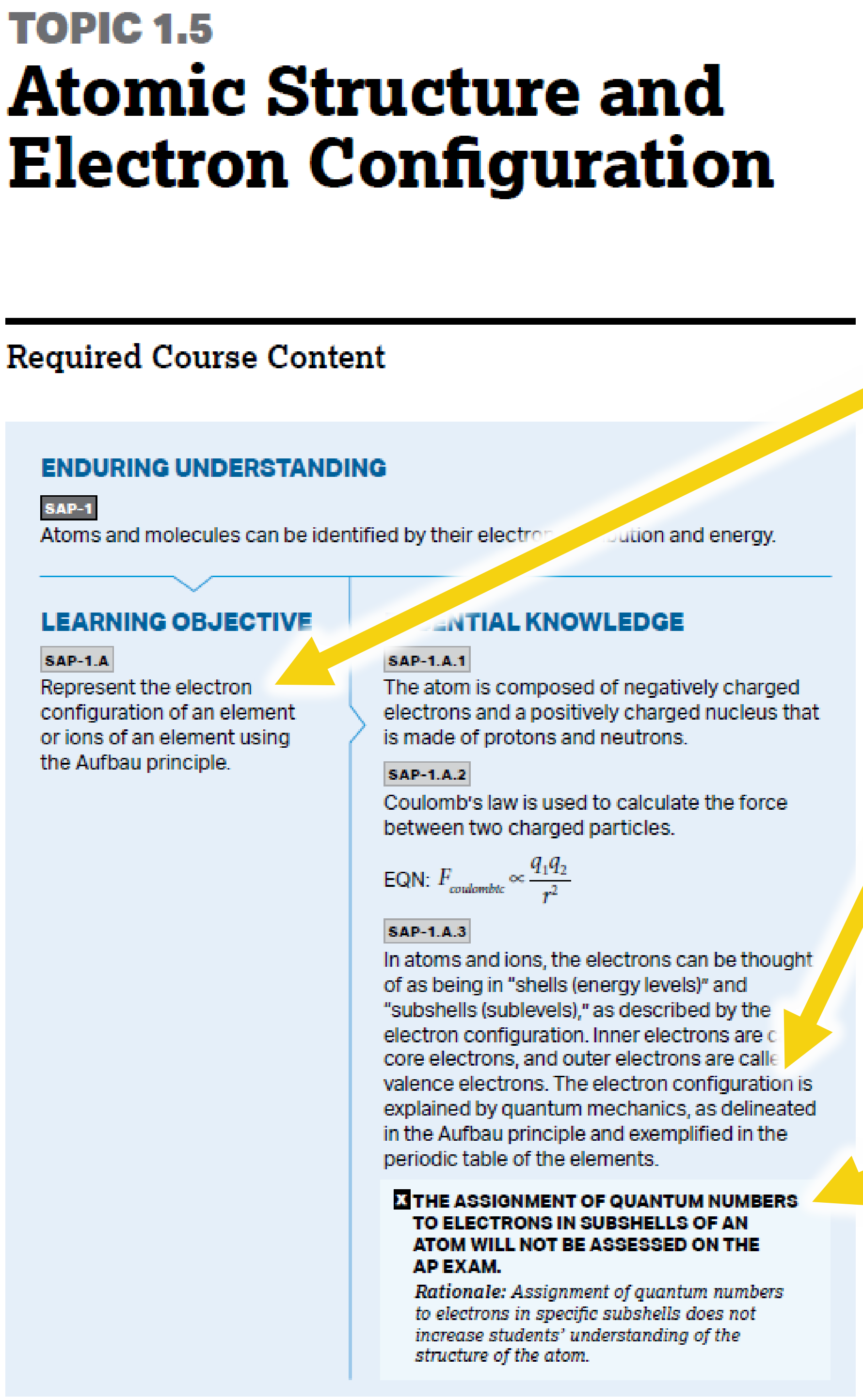
While pure substances contain molecules or formula units of a single type, mixtures contain molecules or formula units of two or more types, whose relative proportions can vary.

SPQ-2.B.2

Elemental analysis can be used to determine the relative numbers of atoms in a substance and to determine its purity.

Rephrase:

Pure substances contain **atoms,** molecules, or formula units of a single type. Mixtures contain **atoms,** molecules, or formula units of two or more types, whose relative proportions can vary.



TOPIC 1.5

Atomic Structure and Electron Configuration

Required Course Content

ENDURING UNDERSTANDING

SAP-1

Atoms and molecules can be identified by their electr ution and energy.

LEARNING OBJECTIVE

SAP-1.A

Represent the electron configuration of an element or ions of an element using the Aufbau principle.

ENTIAL KNOWLEDGE

SAP-1.A.1

The atom is composed of negatively charged electrons and a positively charged nucleus that is made of protons and neutrons.

SAP-1.A.2

Coulomb's law is used to calculate the force between two charged particles.

EQN: $F_{coulombic} \propto \frac{q_1 q_2}{r^2}$

SAP-1.A.3

In atoms and ions, the electrons can be thought of as being in "shells (energy levels)" and "subshells (sublevels)," as described by the electron configuration. Inner electrons are c core electrons, and outer electrons are calle valence electrons. The electron configuration is explained by quantum mechanics, as delineated in the Aufbau principle and exemplified in the periodic table of the elements.

☒ **THE ASSIGNMENT OF QUANTUM NUMBERS TO ELECTRONS IN SUBSHELLS OF AN ATOM WILL NOT BE ASSESSED ON THE AP EXAM.**

Rationale: *Assignment of quantum numbers to electrons in specific subshells does not increase students' understanding of the structure of the atom.*

Add “ground-state” before electron configuration

1.5.A

Represent the **ground-state** electron configuration of an element or ions of an element using the Aufbau principle.

1.5.A.3

In atoms and ions, the electrons can be thought of as being in “shells (energy levels)” and “subshells (sublevels,” as described by the **ground-state** electron configuration…

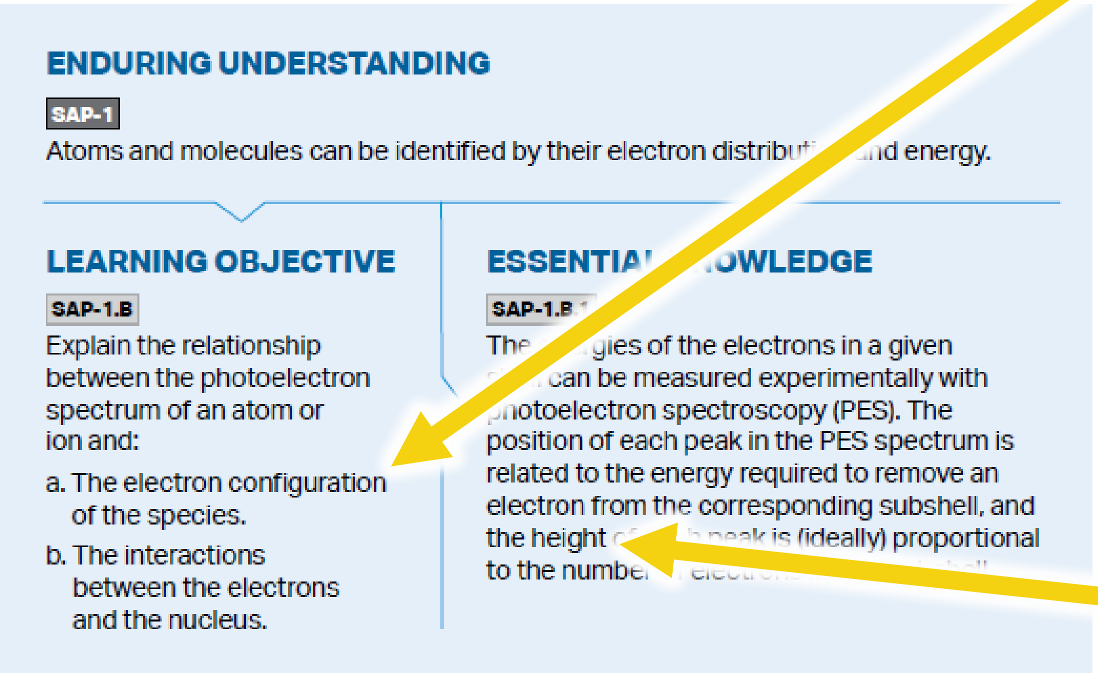
Remove Rationale from Exclusion Statement, and label as “Exclusion Statement:”

Exclusion Statement: The assignment of quantum numbers to electrons in subshells of an atom will not be assess on the AP Exam.

TOPIC 1.6

Photoelectron Spectroscopy

Required Course Content



ENDURING UNDERSTANDING

SAP-1

Atoms and molecules can be identified by their electron distribut nd energy.

LEARNING OBJECTIVE

SAP-1.B

Explain the relationship between the photoelectron spectrum of an atom or ion and:

a. The electron configuration of the species.

b. The interactions between the electrons and the nucleus.

ESSENTIA OWLEDGE

SAP-1.B.1

The gies of the electrons in a given can be measured experimentally with photoelectron spectroscopy (PES). The position of each peak in the PES spectrum is related to the energy required to remove an electron from the corresponding subshell, and the height peak is (ideally) proportional to the numbe electron

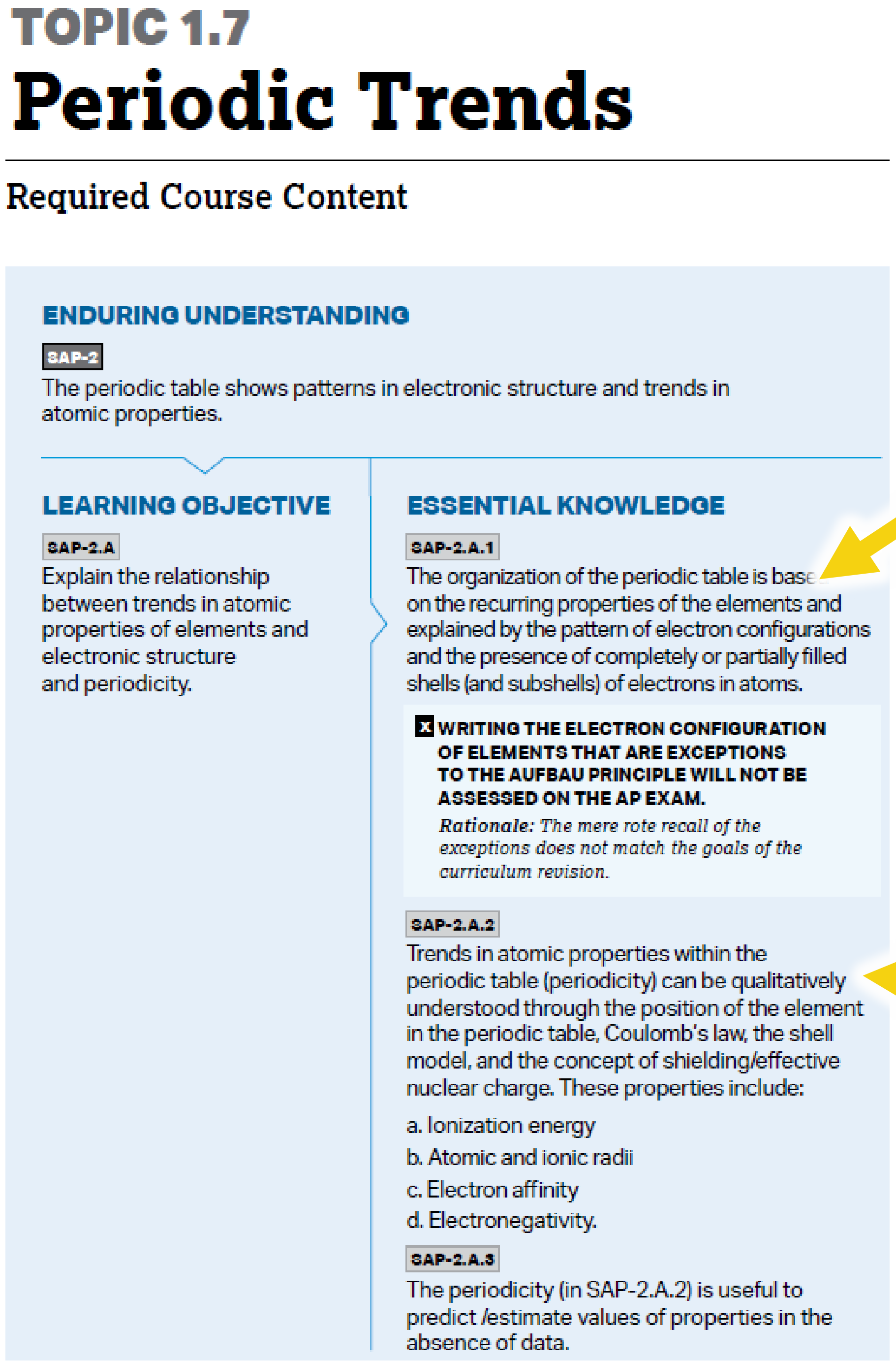
Add “ground-state”

SAP-1.B

Explain the relationship between the photoelectron spectrum of an atom or ion and:

1. The **ground-state** electron configuration of the species.
2. The interactions between the electrons and the nucleus

Add "relative” before “height”



TOPIC 1.7

Periodic Trends

Required Course Content

ENDURING UNDERSTANDING

SAP-2

The periodic table shows patterns in electronic structure and trends in atomic properties.

LEARNING OBJECTIVE

SAP-2.A

Explain the relationship between trends in atomic properties of elements and electronic structure and periodicity.

ESSENTIAL KNOWLEDGE

SAP-2.A.1

The organization of the periodic table is base on the recurring properties of the elements and explained by the pattern of electron configurations and the presence of completely or partially filled shells (and subshells) of electrons in atoms.

☒ **WRITING THE ELECTRON CONFIGURATION OF ELEMENTS THAT ARE EXCEPTIONS TO THE AUFBAU PRINCIPLE WILL NOT BE ASSESSED ON THE AP EXAM.**

Rationale: *The mere rote recall of the exceptions does not match the goals of the curriculum revision.*

SAP-2.A.2

Trends in atomic properties within the periodic table (periodicity) can be qualitatively understood through the position of the element in the periodic table, Coulomb's law, the shell model, and the concept of shielding/effective nuclear charge. These properties include:

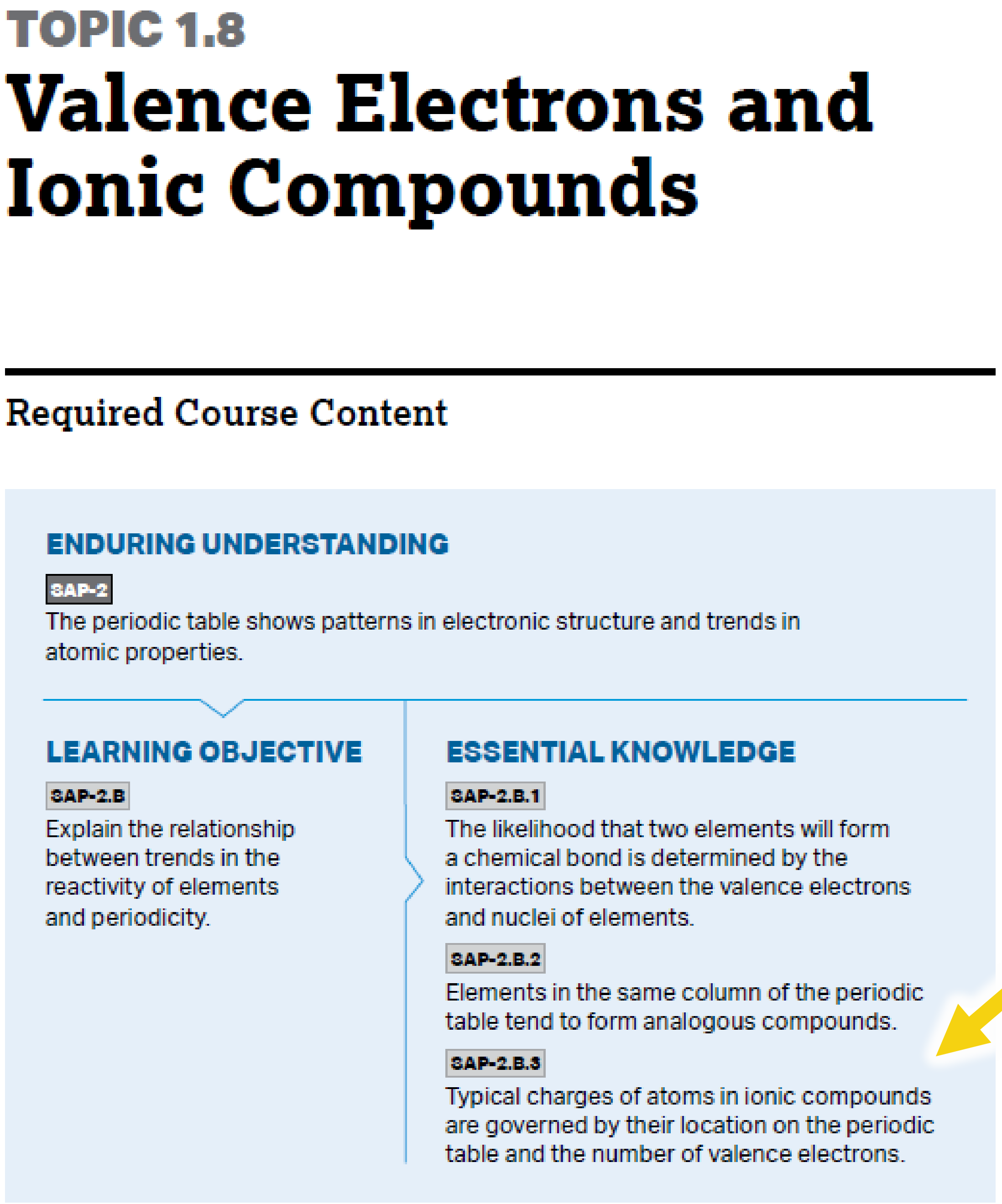
a. Ionization energy
b. Atomic and ionic radii
c. Electron affinity
d. Electronegativity.

SAP-2.A.3

The periodicity (in SAP-2.A.2) is useful to predict /estimate values of properties in the absence of data.

Rephrase:
"The organization of the periodic table is based on patterns of recurring properties of the elements, which is explained by patterns of ground-state electron configurations and the presences of completely or partially filled shells (and subshells) of electrons in atoms."

Rephrase:
"Trends in atomic properties within the periodic table (periodicity) can be predicted by the position of the element in the periodic table, and qualitatively understood using Coulomb's law, the shell model, and the concepts of shielding and effective nuclear charge. These properties include:"



TOPIC 1.8

Valence Electrons and Ionic Compounds

Required Course Content

ENDURING UNDERSTANDING

SAP-2

The periodic table shows patterns in electronic structure and trends in atomic properties.

LEARNING OBJECTIVE

SAP-2.B

Explain the relationship between trends in the reactivity of elements and periodicity.

ESSENTIAL KNOWLEDGE

SAP-2.B.1

The likelihood that two elements will form a chemical bond is determined by the interactions between the valence electrons and nuclei of elements.

SAP-2.B.2

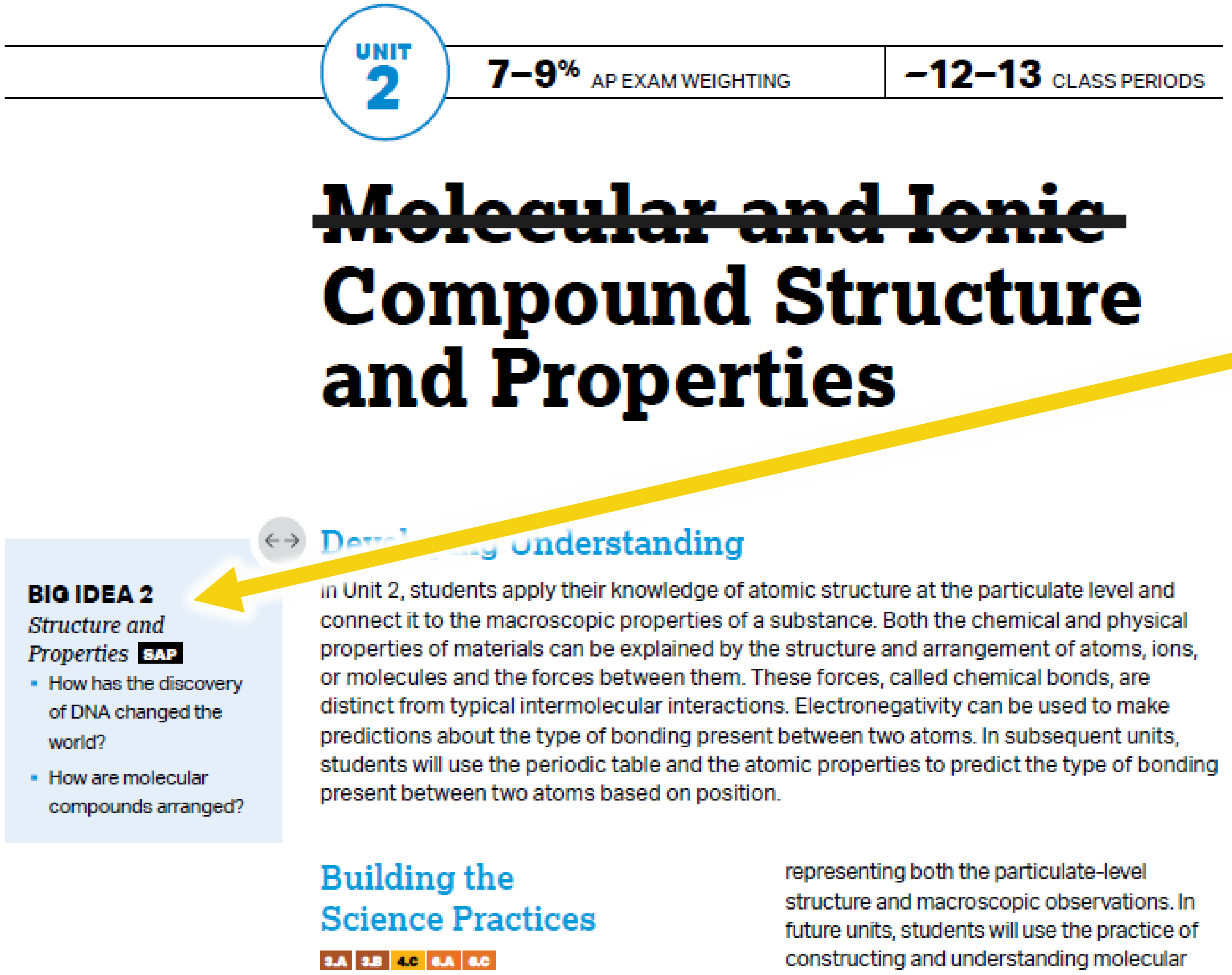
Elements in the same column of the periodic table tend to form analogous compounds.

SAP-2.B.3

Typical charges of atoms in ionic compounds are governed by their location on the periodic table and the number of valence electrons.

Rephrase:

"Typical charges of atoms in ionic compounds are governed by the number of valence electrons and predicted by their location on the periodic table."



UNIT 2

7–9% AP EXAM WEIGHTING

~12–13 CLASS PERIODS

~~Molecular and Ionic~~ Compound Structure and Properties

BIG IDEA 2
Structure and Properties SAP

- How has the discovery of DNA changed the world?
- How are molecular compounds arranged?

Developing Understanding

In Unit 2, students apply their knowledge of atomic structure at the particulate level and connect it to the macroscopic properties of a substance. Both the chemical and physical properties of materials can be explained by the structure and arrangement of atoms, ions, or molecules and the forces between them. These forces, called chemical bonds, are distinct from typical intermolecular interactions. Electronegativity can be used to make predictions about the type of bonding present between two atoms. In subsequent units, students will use the periodic table and the atomic properties to predict the type of bonding present between two atoms based on position.

Building the Science Practices

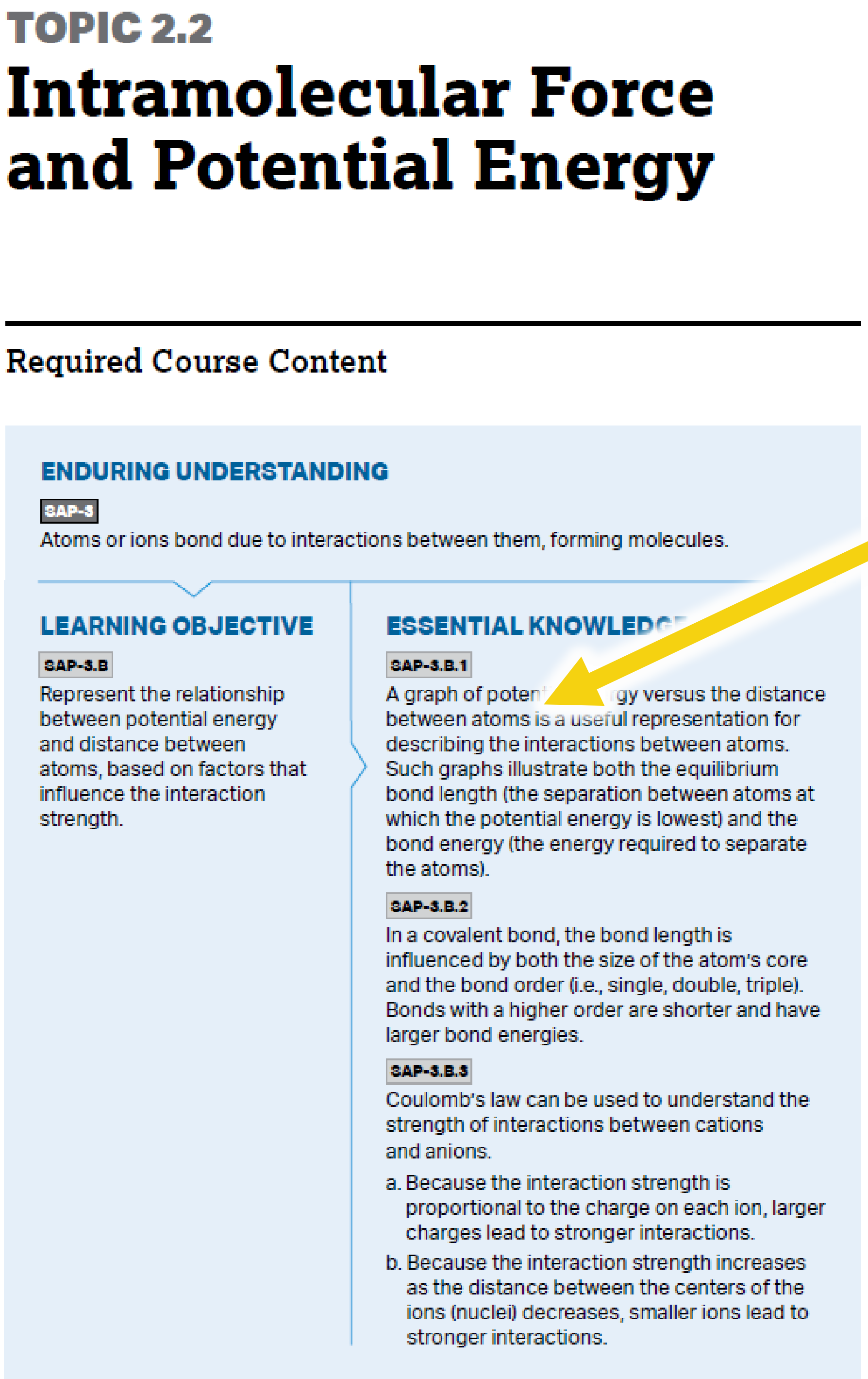
3.A 3.B 4.C 6.A 6.C

representing both the particulate-level structure and macroscopic observations. In future units, students will use the practice of constructing and understanding molecular

Remove references to Big Ideas.

Updated Essential Questions:

- How are molecular compounds arranged?
- Why are some bonds easier to break than others?
- In what ways does a diagram drawn on paper accurately reflect the structure of a molecule? In what ways does it not accurately reflect the structure?



TOPIC 2.2

Intramolecular Force and Potential Energy

Required Course Content

ENDURING UNDERSTANDING

SAP-3

Atoms or ions bond due to interactions between them, forming molecules.

LEARNING OBJECTIVE

SAP-3.B

Represent the relationship between potential energy and distance between atoms, based on factors that influence the interaction strength.

ESSENTIAL KNOWLEDG

SAP-3.B.1

A graph of poten gy versus the distance between atoms is a useful representation for describing the interactions between atoms. Such graphs illustrate both the equilibrium bond length (the separation between atoms at which the potential energy is lowest) and the bond energy (the energy required to separate the atoms).

SAP-3.B.2

In a covalent bond, the bond length is influenced by both the size of the atom's core and the bond order (i.e., single, double, triple). Bonds with a higher order are shorter and have larger bond energies.

SAP-3.B.3

Coulomb's law can be used to understand the strength of interactions between cations and anions.

a. Because the interaction strength is proportional to the charge on each ion, larger charges lead to stronger interactions.

b. Because the interaction strength increases as the distance between the centers of the ions (nuclei) decreases, smaller ions lead to stronger interactions.

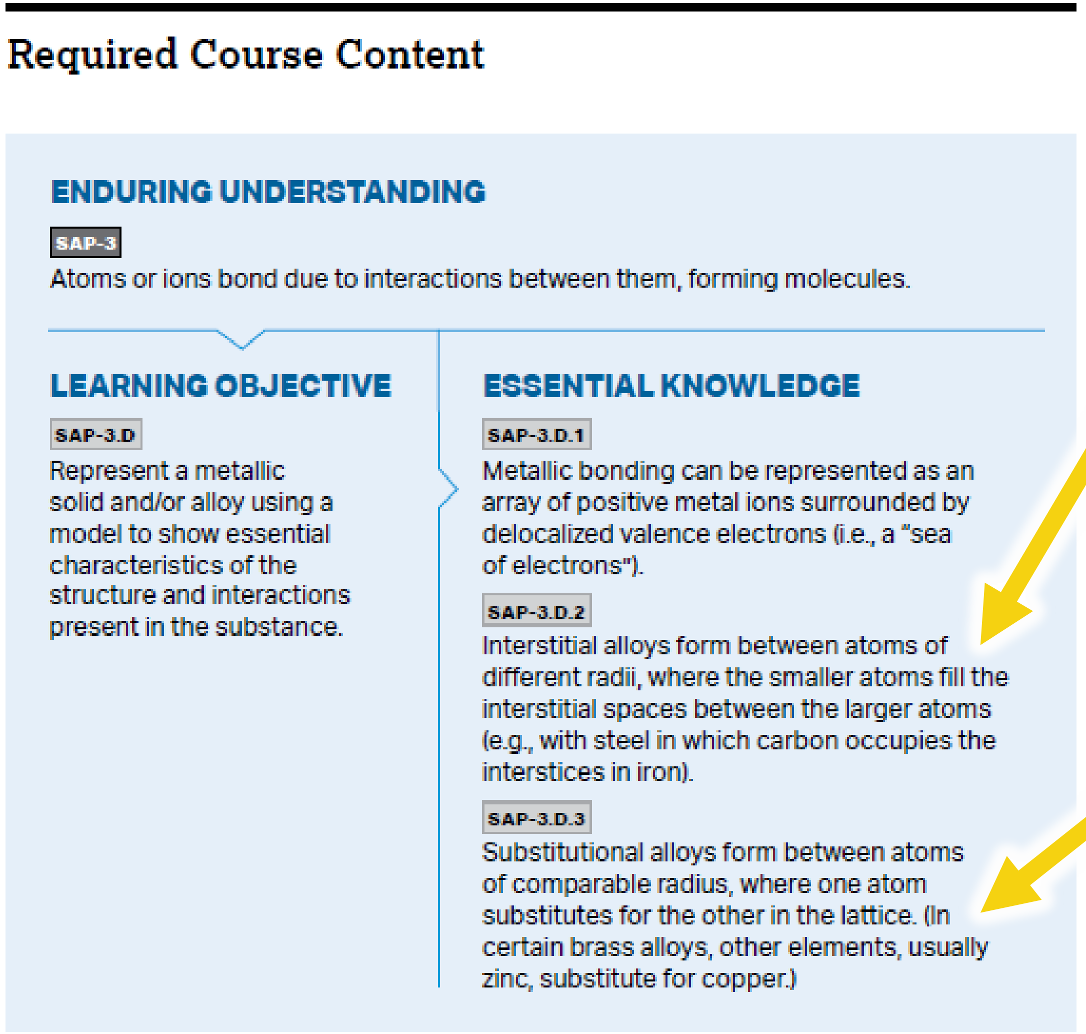
Add “internuclear distance”,

SAP-3.B.1

A graph of potential energy versus the distance between atoms **(internuclear distance)** is a useful representation…

TOPIC 2.4

Structure of Metals and Alloys



Required Course Content

ENDURING UNDERSTANDING

SAP-3

Atoms or ions bond due to interactions between them, forming molecules.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
SAP-3.D Represent a metallic solid and/or alloy using a model to show essential characteristics of the structure and interactions present in the substance.	**SAP-3.D.1** Metallic bonding can be represented as an array of positive metal ions surrounded by delocalized valence electrons (i.e., a "sea of electrons"). **SAP-3.D.2** Interstitial alloys form between atoms of different radii, where the smaller atoms fill the interstitial spaces between the larger atoms (e.g., with steel in which carbon occupies the interstices in iron). **SAP-3.D.3** Substitutional alloys form between atoms of comparable radius, where one atom substitutes for the other in the lattice. (In certain brass alloys, other elements, usually zinc, substitute for copper.)

Add “significantly”

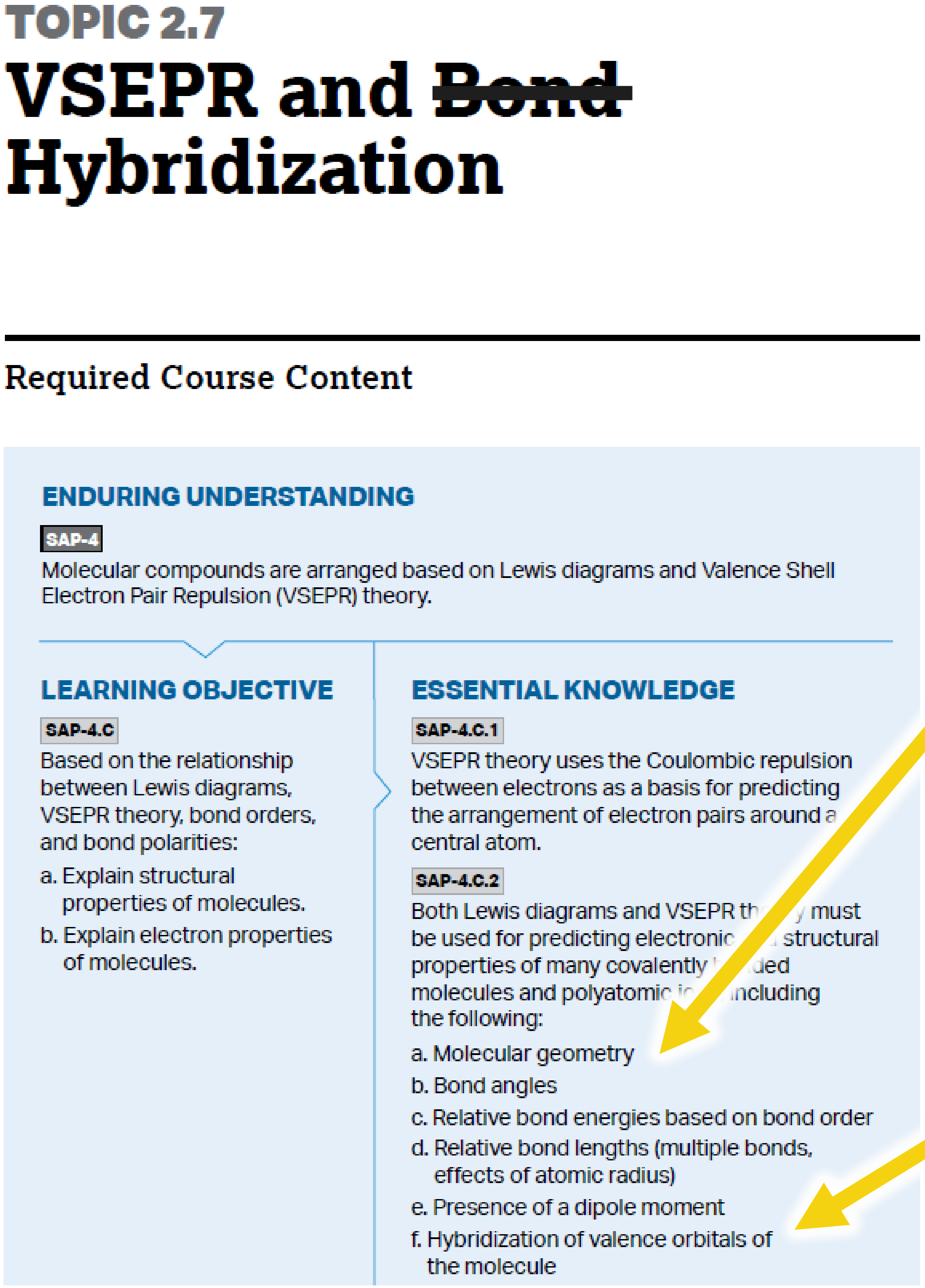
2.4.A.2

Interstitial alloys form between atoms of **significantly** different radii…

Add “(e.g., ”

2.4.A.2

Substitutional alloys form between atoms of comparable radius, where one atom substitutes for the other in the lattice. (**e.g.,** in certain brass alloys, other elements, usually zinc, substitute for copper.)



TOPIC 2.7

VSEPR and ~~Bond~~ Hybridization

Required Course Content

ENDURING UNDERSTANDING

SAP-4

Molecular compounds are arranged based on Lewis diagrams and Valence Shell Electron Pair Repulsion (VSEPR) theory.

LEARNING OBJECTIVE

SAP-4.C

Based on the relationship between Lewis diagrams, VSEPR theory, bond orders, and bond polarities:

a. Explain structural properties of molecules.

b. Explain electron properties of molecules.

ESSENTIAL KNOWLEDGE

SAP-4.C.1

VSEPR theory uses the Coulombic repulsion between electrons as a basis for predicting the arrangement of electron pairs around a central atom.

SAP-4.C.2

Both Lewis diagrams and VSEPR theory must be used for predicting electronic and structural properties of many covalently bonded molecules and polyatomic ions, including the following:

a. Molecular geometry

b. Bond angles

c. Relative bond energies based on bond order

d. Relative bond lengths (multiple bonds, effects of atomic radius)

e. Presence of a dipole moment

f. Hybridization of valence orbitals of the molecule

Add types:

i. Molecular geometry (**linear, trigonal planar, tetrahedral, trigonal pyramidal, bent, trigonal bipyramidal, seesaw, T-shaped, octahedral, square pyramidal, square planar)**

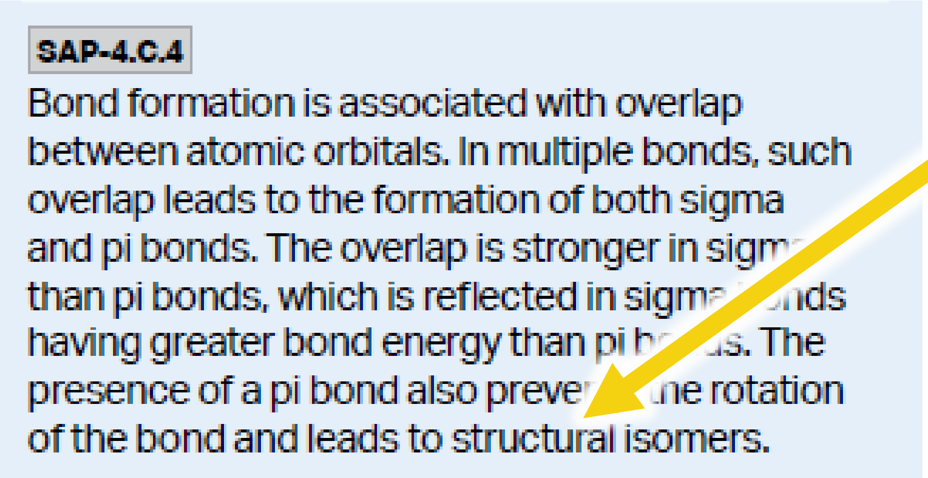
Rephrase:

vi. Hybridization of valence orbitals **for atoms within a molecule.**

TOPIC 2.7

VSEPR and ~~Bond~~ Hybridization

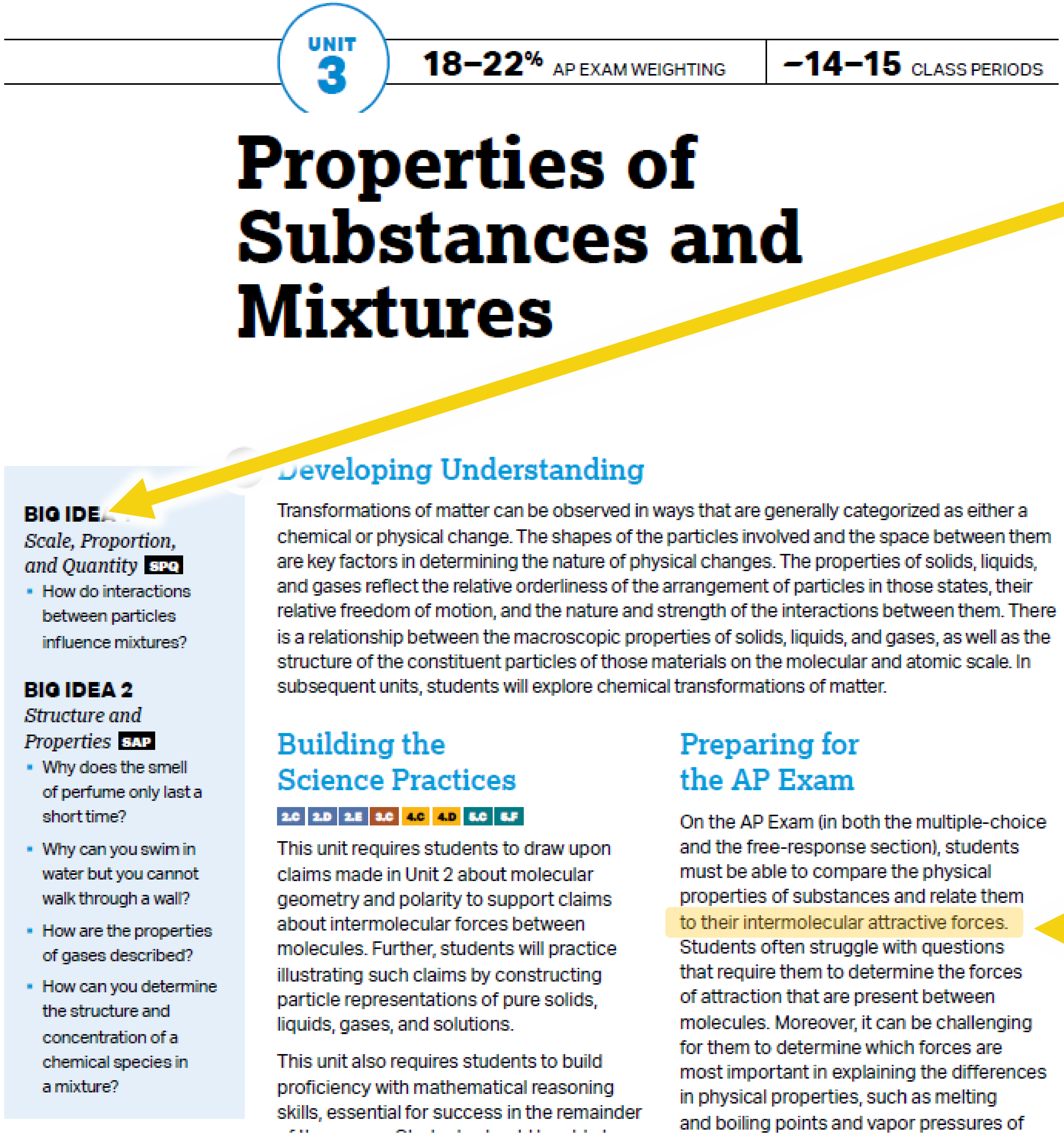
Required Course Content



SAP-4.C.4

Bond formation is associated with overlap between atomic orbitals. In multiple bonds, such overlap leads to the formation of both sigma and pi bonds. The overlap is stronger in sigma than pi bonds, which is reflected in sigma bonds having greater bond energy than pi bonds. The presence of a pi bond also prevents the rotation of the bond and leads to structural isomers.

Replace “structural” with “geometric”



UNIT 3

18–22% AP EXAM WEIGHTING

~14–15 CLASS PERIODS

Properties of Substances and Mixtures

BIG IDEA 1
Scale, Proportion, and Quantity SPQ
- How do interactions between particles influence mixtures?

BIG IDEA 2
Structure and Properties SAP
- Why does the smell of perfume only last a short time?
- Why can you swim in water but you cannot walk through a wall?
- How are the properties of gases described?
- How can you determine the structure and concentration of a chemical species in a mixture?

Developing Understanding

Transformations of matter can be observed in ways that are generally categorized as either a chemical or physical change. The shapes of the particles involved and the space between them are key factors in determining the nature of physical changes. The properties of solids, liquids, and gases reflect the relative orderliness of the arrangement of particles in those states, their relative freedom of motion, and the nature and strength of the interactions between them. There is a relationship between the macroscopic properties of solids, liquids, and gases, as well as the structure of the constituent particles of those materials on the molecular and atomic scale. In subsequent units, students will explore chemical transformations of matter.

Building the Science Practices

2.C 2.D 2.E 3.C 4.C 4.D 5.C 5.F

This unit requires students to draw upon claims made in Unit 2 about molecular geometry and polarity to support claims about intermolecular forces between molecules. Further, students will practice illustrating such claims by constructing particle representations of pure solids, liquids, gases, and solutions.

This unit also requires students to build proficiency with mathematical reasoning skills, essential for success in the remainder

Preparing for the AP Exam

On the AP Exam (in both the multiple-choice and the free-response section), students must be able to compare the physical properties of substances and relate them to their intermolecular attractive forces. Students often struggle with questions that require them to determine the forces of attraction that are present between molecules. Moreover, it can be challenging for them to determine which forces are most important in explaining the differences in physical properties, such as melting and boiling points and vapor pressures of

Remove references to Big Ideas.

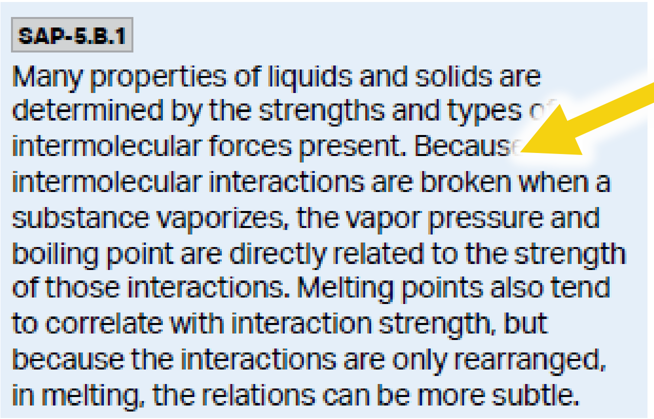
Updated Essential Questions:
- How do interactions between particles influence the properties of pure substances and mixtures?
- Why does the smell of perfume only last for a short time?
- Why can you swim in water, but you can't walk through a wall?
- How does the spacing and motion of particles relate to a substance's state of matter and the properties of gases?
- How can you determine the structure and concentration of a chemical species in a mixture?

Rephrase:
"…to the attractive forces between particles."

TOPIC 3.2

Properties of Solids

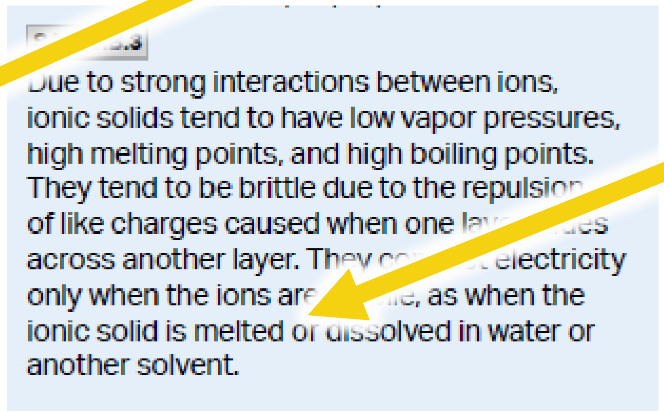
Required Course Content



SAP-5.B.1

Many properties of liquids and solids are determined by the strengths and types of intermolecular forces present. Because intermolecular interactions are broken when a substance vaporizes, the vapor pressure and boiling point are directly related to the strength of those interactions. Melting points also tend to correlate with interaction strength, but because the interactions are only rearranged, in melting, the relations can be more subtle.

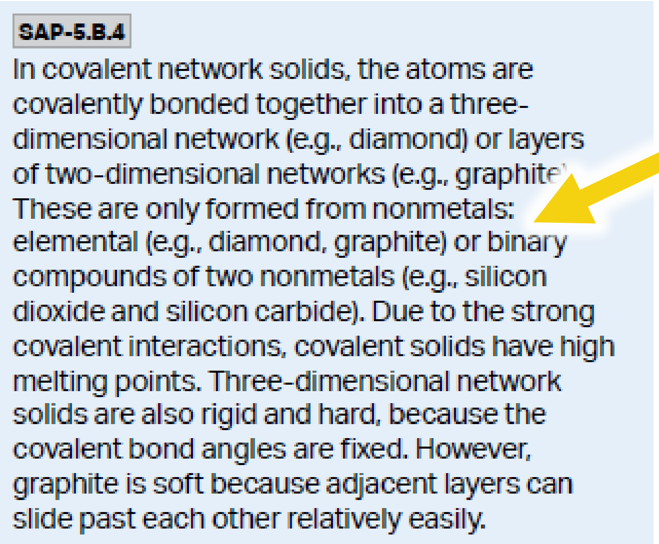
Replace “broken” with “**overcome completely**”



SAP-5.B.3

Due to strong interactions between ions, ionic solids tend to have low vapor pressures, high melting points, and high boiling points. They tend to be brittle due to the repulsion of like charges caused when one layer slides across another layer. They conduct electricity only when the ions are mobile, as when the ionic solid is melted or dissolved in water or another solvent.

Add “(i.e., in a molten state)”



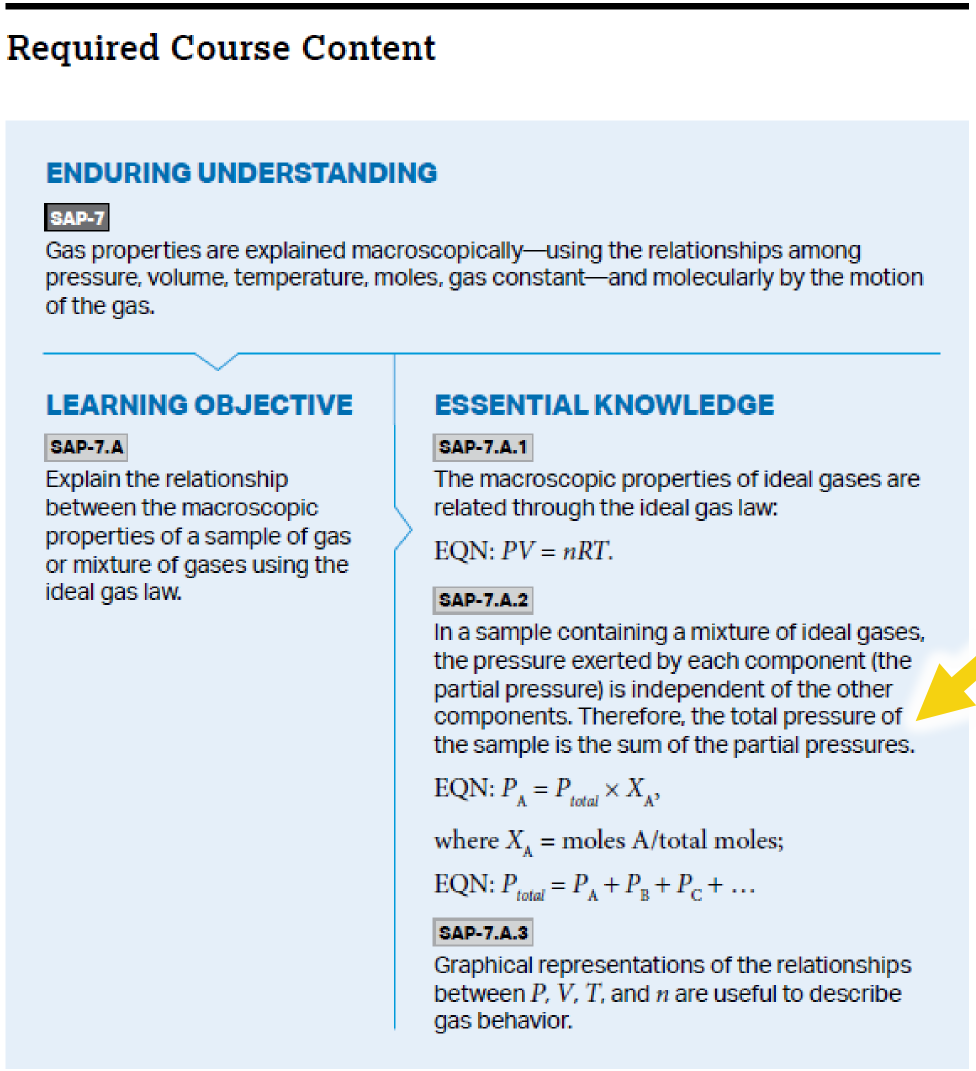
SAP-5.B.4

In covalent network solids, the atoms are covalently bonded together into a three-dimensional network (e.g., diamond) or layers of two-dimensional networks (e.g., graphite). These are only formed from nonmetals: elemental (e.g., diamond, graphite) or binary compounds of two nonmetals (e.g., silicon dioxide and silicon carbide). Due to the strong covalent interactions, covalent solids have high melting points. Three-dimensional network solids are also rigid and hard, because the covalent bond angles are fixed. However, graphite is soft because adjacent layers can slide past each other relatively easily.

Rephrase:
“These are only formed from nonmetals **and metalloids**: elemental (e.g., diamond, graphite) or binary compounds (e.g., silicon dioxide and silicon carbide).”

TOPIC 3.4

Ideal Gas Law



Required Course Content

ENDURING UNDERSTANDING

SAP-7

Gas properties are explained macroscopically—using the relationships among pressure, volume, temperature, moles, gas constant—and molecularly by the motion of the gas.

LEARNING OBJECTIVE

SAP-7.A

Explain the relationship between the macroscopic properties of a sample of gas or mixture of gases using the ideal gas law.

ESSENTIAL KNOWLEDGE

SAP-7.A.1

The macroscopic properties of ideal gases are related through the ideal gas law:

EQN: $PV = nRT$.

SAP-7.A.2

In a sample containing a mixture of ideal gases, the pressure exerted by each component (the partial pressure) is independent of the other components. Therefore, the total pressure of the sample is the sum of the partial pressures.

EQN: $P_A = P_{total} \times X_A$,

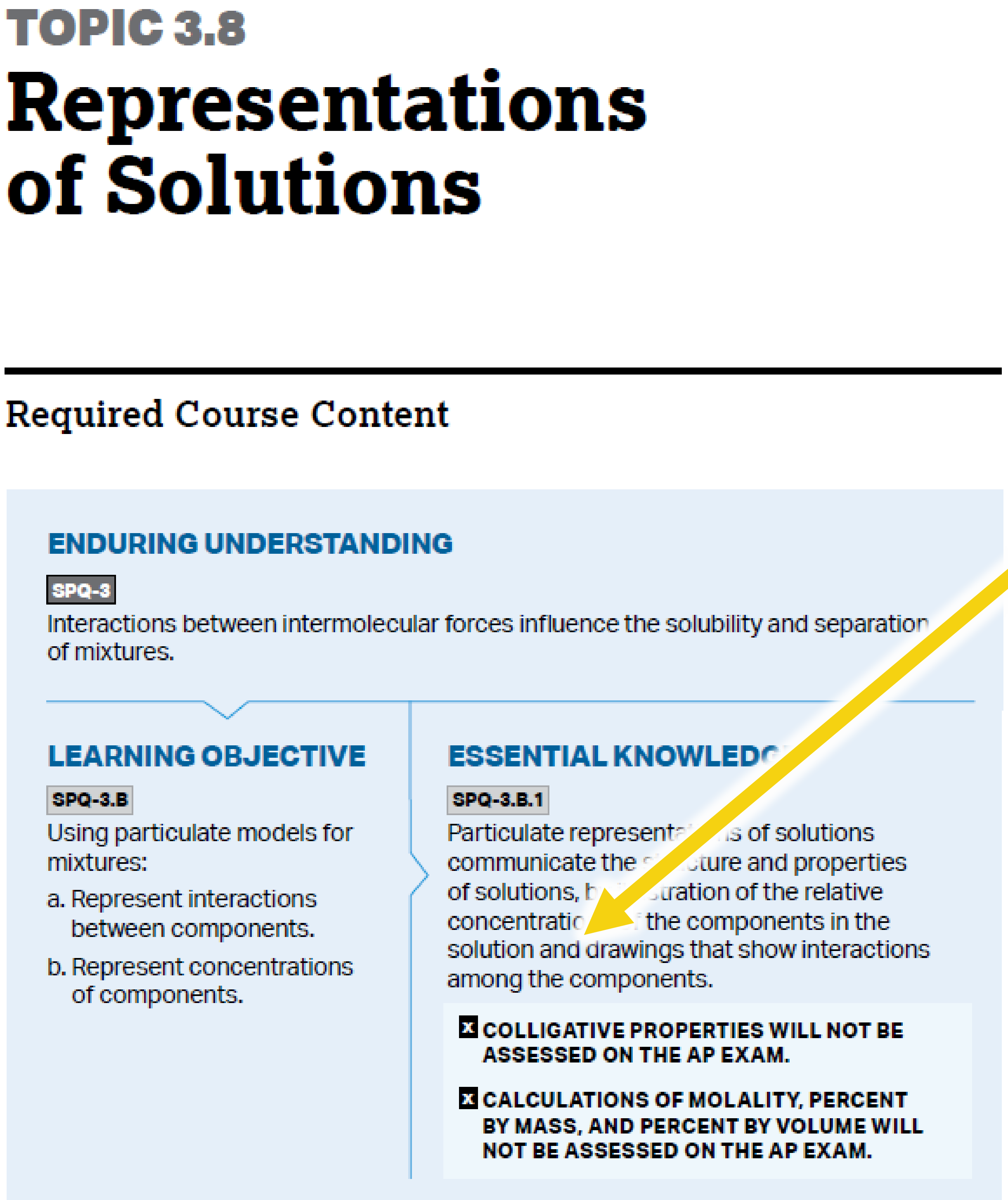
where X_A = moles A/total moles;

EQN: $P_{total} = P_A + P_B + P_C + \ldots$

SAP-7.A.3

Graphical representations of the relationships between P, V, T, and n are useful to describe gas behavior.

Rephrase:
"Therefore, **the partial pressure of a gas within the mixture is proportional to its mole fraction, (X), and** the total pressure of the sample is the sum of the partial pressures."



TOPIC 3.8

Representations of Solutions

Required Course Content

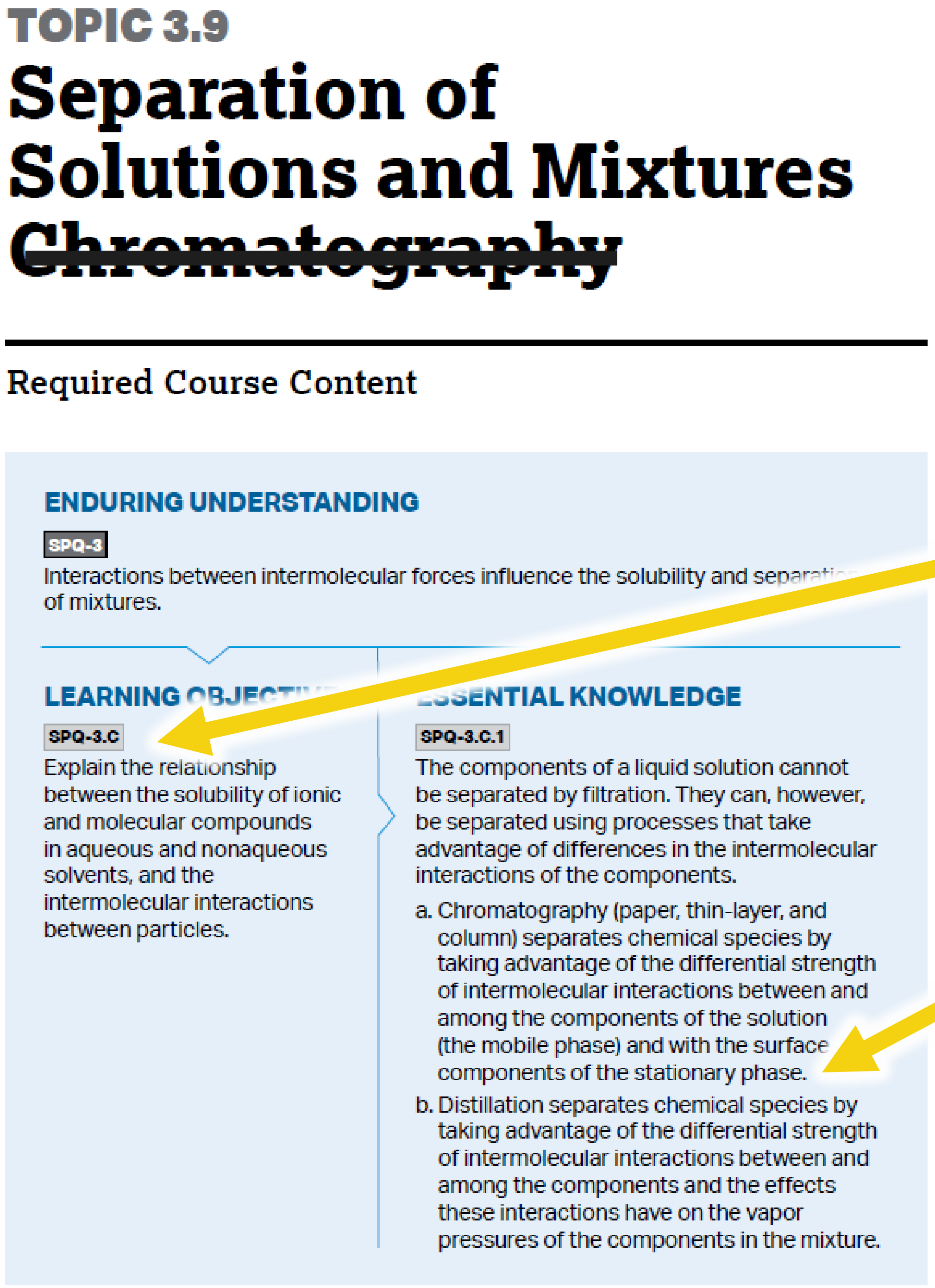
ENDURING UNDERSTANDING

SPQ-3

Interactions between intermolecular forces influence the solubility and separation of mixtures.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
SPQ-3.B Using particulate models for mixtures: a. Represent interactions between components. b. Represent concentrations of components.	**SPQ-3.B.1** Particulate representations of solutions communicate the structure and properties of solutions, by illustration of the relative concentrations of the components in the solution and drawings that show interactions among the components. ☒ **COLLIGATIVE PROPERTIES WILL NOT BE ASSESSED ON THE AP EXAM.** ☒ **CALCULATIONS OF MOLALITY, PERCENT BY MASS, AND PERCENT BY VOLUME WILL NOT BE ASSESSED ON THE AP EXAM.**

Replace “and” with “**and/or**”



TOPIC 3.9

Separation of Solutions and Mixtures ~~Chromatography~~

Required Course Content

ENDURING UNDERSTANDING

SPQ-3

Interactions between intermolecular forces influence the solubility and separati of mixtures.

LEARNING OBJECTIVE

SPQ-3.C

Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles.

ESSENTIAL KNOWLEDGE

SPQ-3.C.1

The components of a liquid solution cannot be separated by filtration. They can, however, be separated using processes that take advantage of differences in the intermolecular interactions of the components.

a. Chromatography (paper, thin-layer, and column) separates chemical species by taking advantage of the differential strength of intermolecular interactions between and among the components of the solution (the mobile phase) and with the surface components of the stationary phase.

b. Distillation separates chemical species by taking advantage of the differential strength of intermolecular interactions between and among the components and the effects these interactions have on the vapor pressures of the components in the mixture.

New LO:

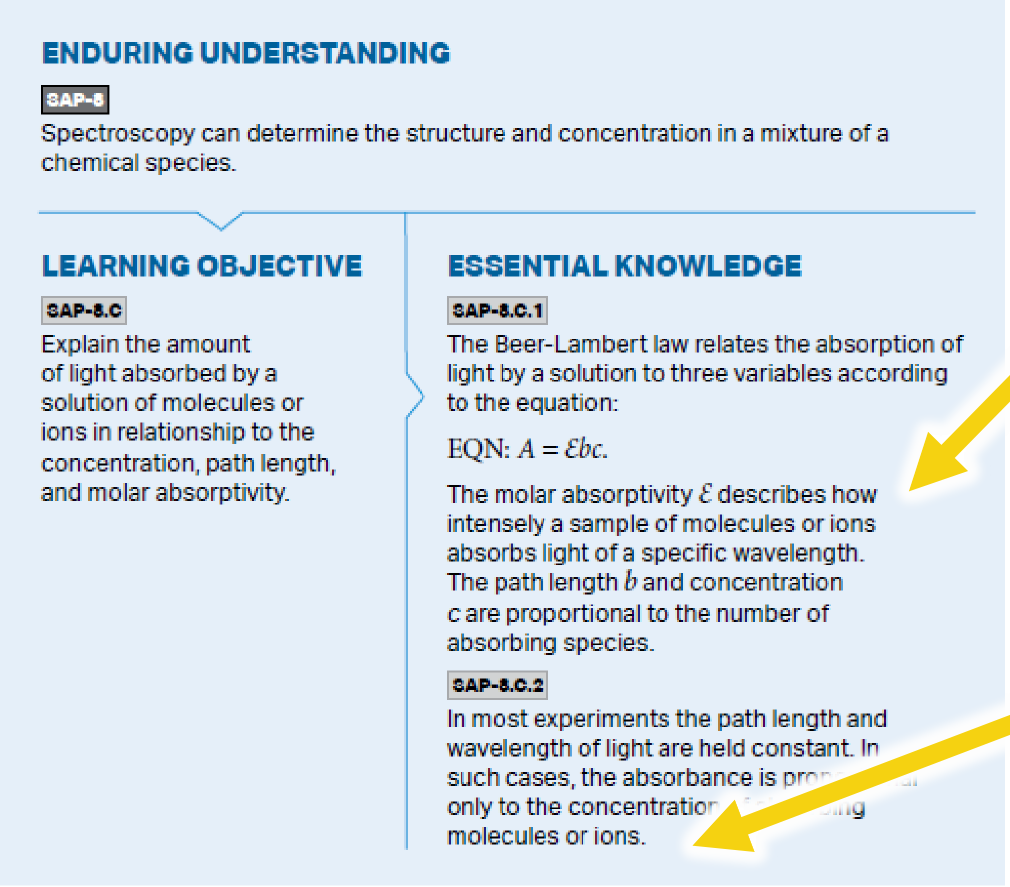
3.9.A
Explain the results of a separation experiment based on intermolecular interactions.

Add “The resulting chromatogram can be used to infer the relative polarities of components in a mixture.”

TOPIC 3.13

Beer-Lambert Law

Required Course Content



ENDURING UNDERSTANDING

SAP-8

Spectroscopy can determine the structure and concentration in a mixture of a chemical species.

LEARNING OBJECTIVE

SAP-8.C

Explain the amount of light absorbed by a solution of molecules or ions in relationship to the concentration, path length, and molar absorptivity.

ESSENTIAL KNOWLEDGE

SAP-8.C.1

The Beer-Lambert law relates the absorption of light by a solution to three variables according to the equation:

EQN: $A = \mathcal{E}bc$.

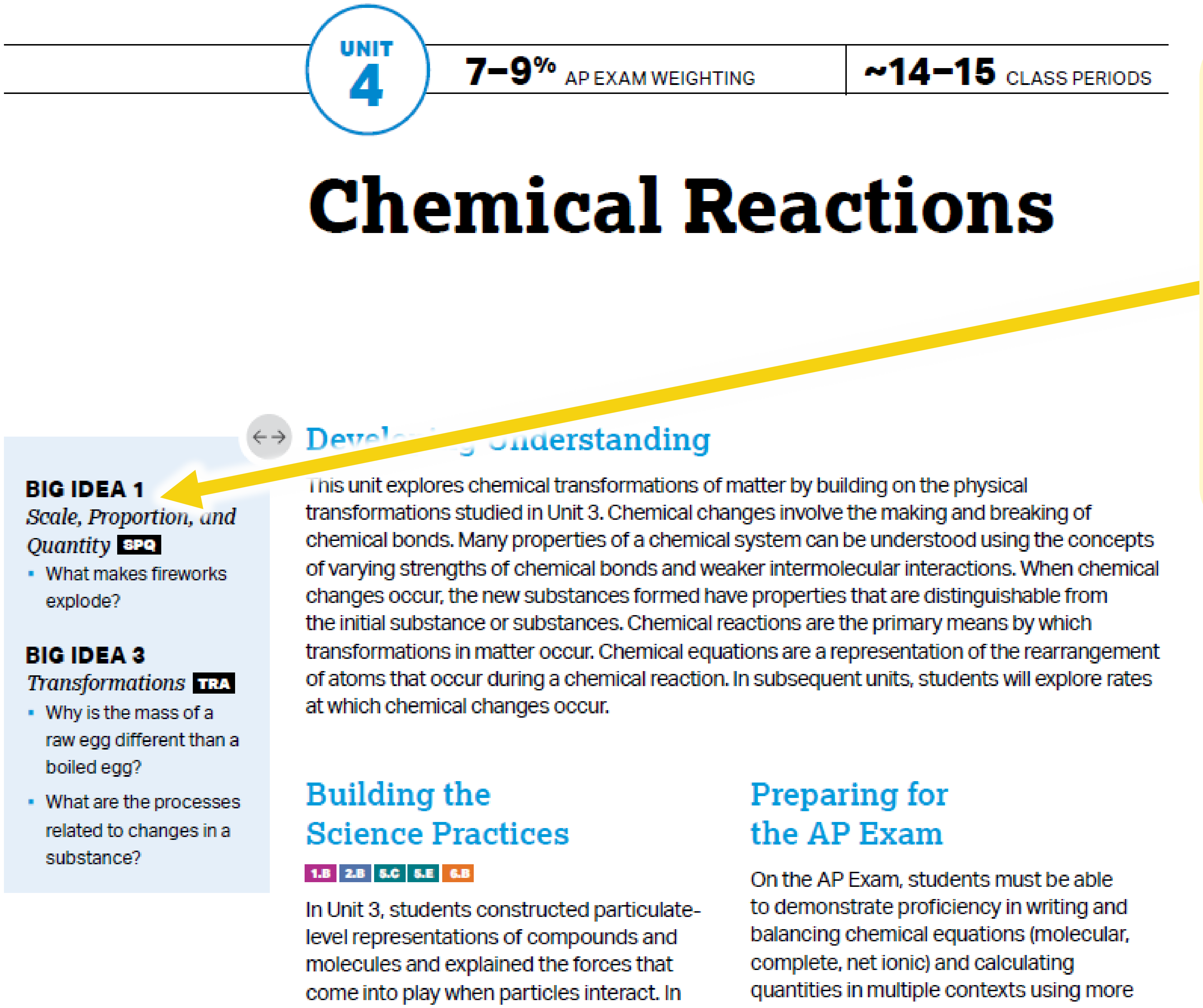
The molar absorptivity $\mathcal{E}$ describes how intensely a sample of molecules or ions absorbs light of a specific wavelength. The path length b and concentration c are proportional to the number of absorbing species.

SAP-8.C.2

In most experiments the path length and wavelength of light are held constant. In such cases, the absorbance is proportional only to the concentration of absorbing molecules or ions.

Rephrase:
"The molar absorptivity, ε, reflects how strongly a **chemical species** absorbs light at a specific wavelength. The path length, *b*, and concentration, *c*, are proportional to the number of **light-absorbing particles in the light path**."

Add "To ensure the maximum sensitivity of measurement, the spectrophotometer is typically set to the wavelength of maximum absorbance (optimum wavelength) for the species being analyzed."



UNIT 4

7–9% AP EXAM WEIGHTING

~14–15 CLASS PERIODS

Chemical Reactions

BIG IDEA 1
Scale, Proportion, and Quantity **SPQ**
- What makes fireworks explode?

BIG IDEA 3
Transformations **TRA**
- Why is the mass of a raw egg different than a boiled egg?
- What are the processes related to changes in a substance?

Developing Understanding

This unit explores chemical transformations of matter by building on the physical transformations studied in Unit 3. Chemical changes involve the making and breaking of chemical bonds. Many properties of a chemical system can be understood using the concepts of varying strengths of chemical bonds and weaker intermolecular interactions. When chemical changes occur, the new substances formed have properties that are distinguishable from the initial substance or substances. Chemical reactions are the primary means by which transformations in matter occur. Chemical equations are a representation of the rearrangement of atoms that occur during a chemical reaction. In subsequent units, students will explore rates at which chemical changes occur.

Building the Science Practices

1.B 2.B 5.C 5.E 6.B

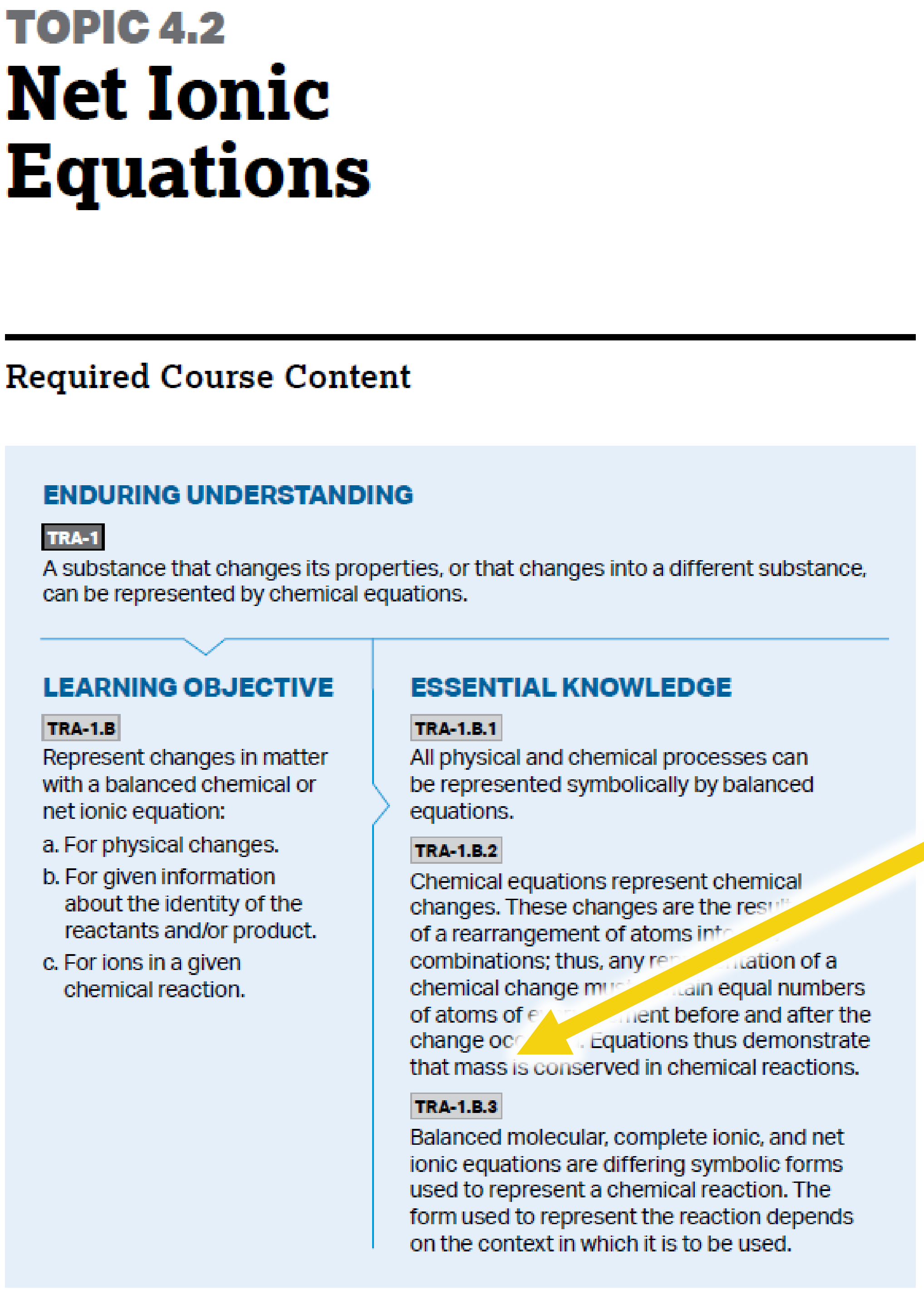
In Unit 3, students constructed particulate-level representations of compounds and molecules and explained the forces that come into play when particles interact. In

Preparing for the AP Exam

On the AP Exam, students must be able to demonstrate proficiency in writing and balancing chemical equations (molecular, complete, net ionic) and calculating quantities in multiple contexts using more

Remove references to Big Ideas.

Updated Essential Questions:
- What makes fireworks explode?
- In what ways can a chemical change be described and documented?
- How can you predict that a chemical reaction will generate enough product?



TOPIC 4.2

Net Ionic Equations

Required Course Content

ENDURING UNDERSTANDING

TRA-1

A substance that changes its properties, or that changes into a different substance, can be represented by chemical equations.

LEARNING OBJECTIVE

TRA-1.B

Represent changes in matter with a balanced chemical or net ionic equation:

a. For physical changes.

b. For given information about the identity of the reactants and/or product.

c. For ions in a given chemical reaction.

ESSENTIAL KNOWLEDGE

TRA-1.B.1

All physical and chemical processes can be represented symbolically by balanced equations.

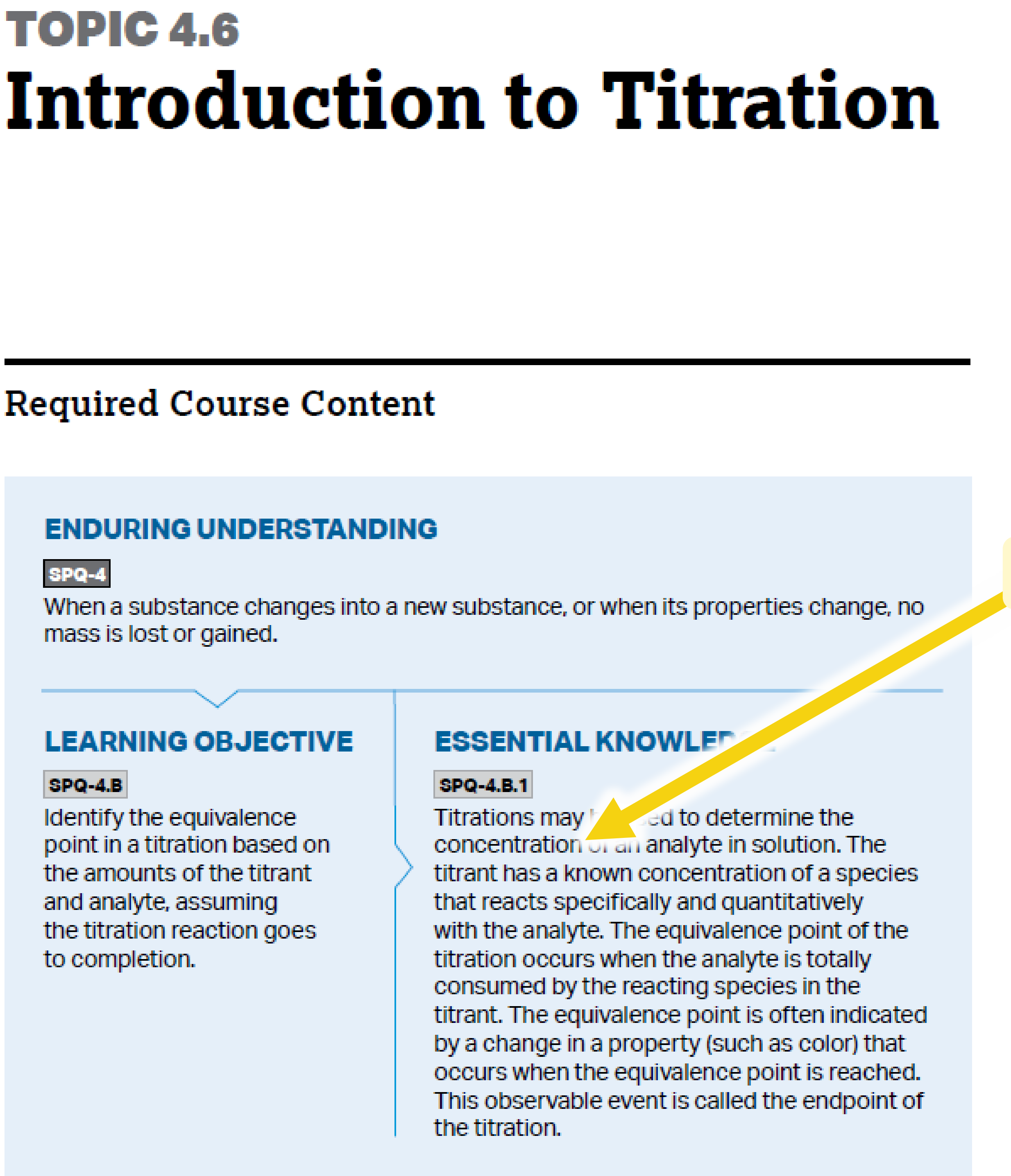
TRA-1.B.2

Chemical equations represent chemical changes. These changes are the res[illegible] of a rearrangement of atoms int[illegible] combinations; thus, any re[illegible]ation of a chemical change mu[illegible]ain equal numbers of atoms of e[illegible]ent before and after the change oc[illegible]. Equations thus demonstrate that mass is conserved in chemical reactions.

TRA-1.B.3

Balanced molecular, complete ionic, and net ionic equations are differing symbolic forms used to represent a chemical reaction. The form used to represent the reaction depends on the context in which it is used.

Add "…and charge are conserved…"



TOPIC 4.6

Introduction to Titration

Required Course Content

ENDURING UNDERSTANDING

SPQ-4

When a substance changes into a new substance, or when its properties change, no mass is lost or gained.

LEARNING OBJECTIVE

SPQ-4.B

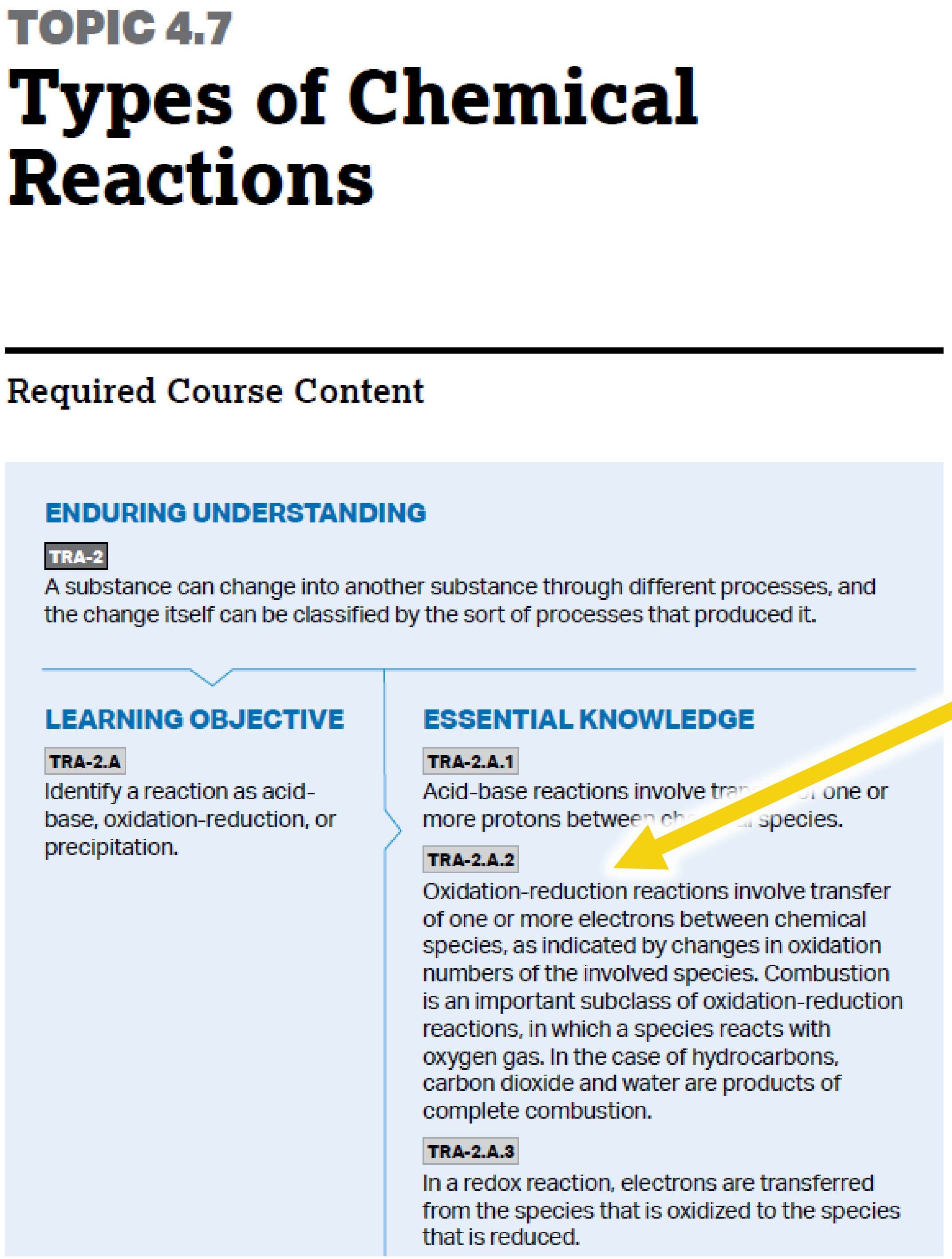
Identify the equivalence point in a titration based on the amounts of the titrant and analyte, assuming the titration reaction goes to completion.

ESSENTIAL KNOWLEDGE

SPQ-4.B.1

Titrations may be used to determine the concentration of an analyte in solution. The titrant has a known concentration of a species that reacts specifically and quantitatively with the analyte. The equivalence point of the titration occurs when the analyte is totally consumed by the reacting species in the titrant. The equivalence point is often indicated by a change in a property (such as color) that occurs when the equivalence point is reached. This observable event is called the endpoint of the titration.

Replace “concentration” with “**amount**”



TOPIC 4.7

Types of Chemical Reactions

Required Course Content

ENDURING UNDERSTANDING

TRA-2

A substance can change into another substance through different processes, and the change itself can be classified by the sort of processes that produced it.

LEARNING OBJECTIVE

TRA-2.A

Identify a reaction as acid-base, oxidation-reduction, or precipitation.

ESSENTIAL KNOWLEDGE

TRA-2.A.1

Acid-base reactions involve transfer of one or more protons between chemical species.

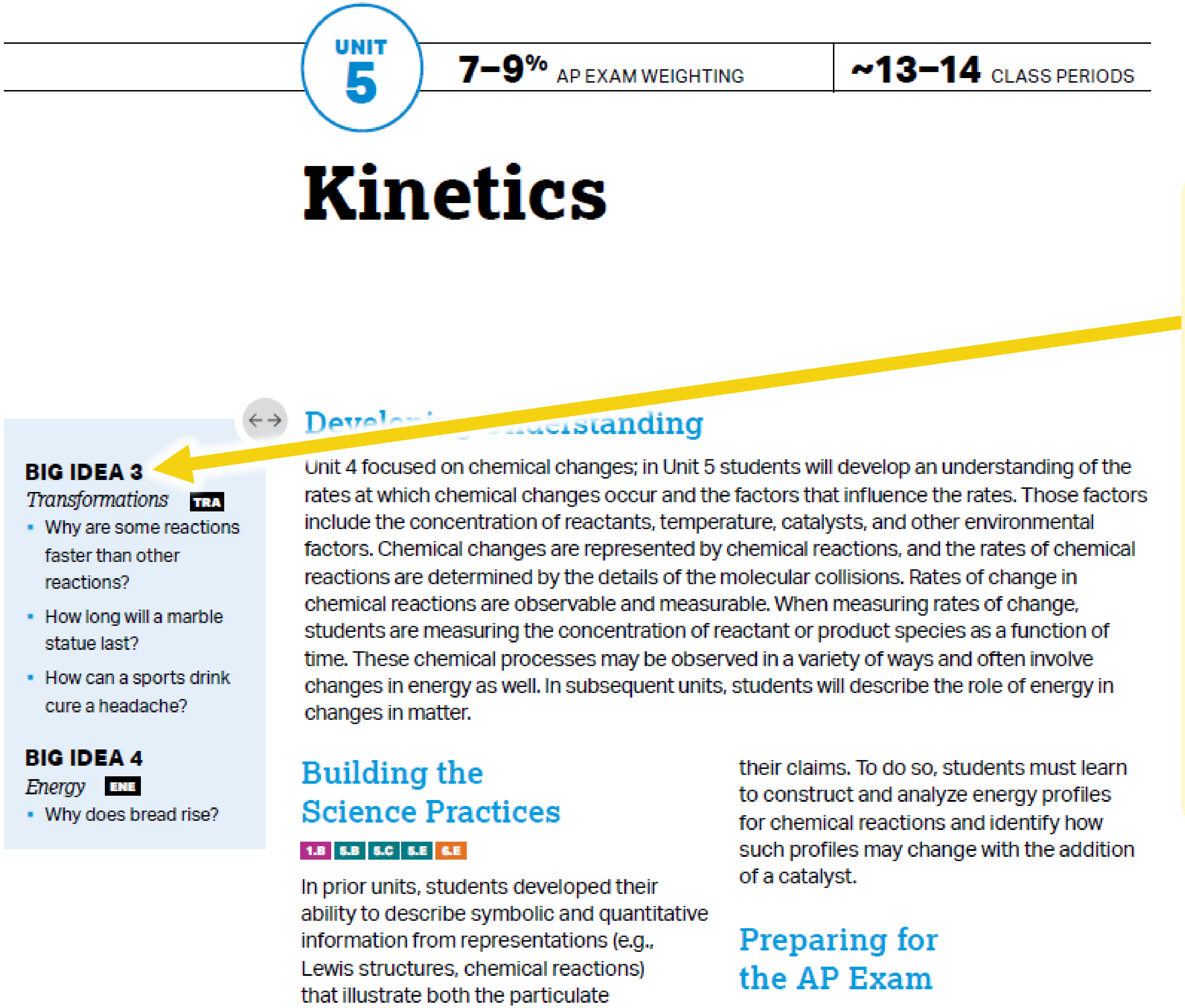
TRA-2.A.2

Oxidation-reduction reactions involve transfer of one or more electrons between chemical species, as indicated by changes in oxidation numbers of the involved species. Combustion is an important subclass of oxidation-reduction reactions, in which a species reacts with oxygen gas. In the case of hydrocarbons, carbon dioxide and water are products of complete combustion.

TRA-2.A.3

In a redox reaction, electrons are transferred from the species that is oxidized to the species that is reduced.

Add “**(redox)**”



UNIT 5

7–9% AP EXAM WEIGHTING

~13–14 CLASS PERIODS

Kinetics

BIG IDEA 3

Transformations **TRA**

- Why are some reactions faster than other reactions?
- How long will a marble statue last?
- How can a sports drink cure a headache?

BIG IDEA 4

Energy **ENE**

- Why does bread rise?

Developing Understanding

Unit 4 focused on chemical changes; in Unit 5 students will develop an understanding of the rates at which chemical changes occur and the factors that influence the rates. Those factors include the concentration of reactants, temperature, catalysts, and other environmental factors. Chemical changes are represented by chemical reactions, and the rates of chemical reactions are determined by the details of the molecular collisions. Rates of change in chemical reactions are observable and measurable. When measuring rates of change, students are measuring the concentration of reactant or product species as a function of time. These chemical processes may be observed in a variety of ways and often involve changes in energy as well. In subsequent units, students will describe the role of energy in changes in matter.

Building the Science Practices

1.B 5.B 5.C 5.E 6.E

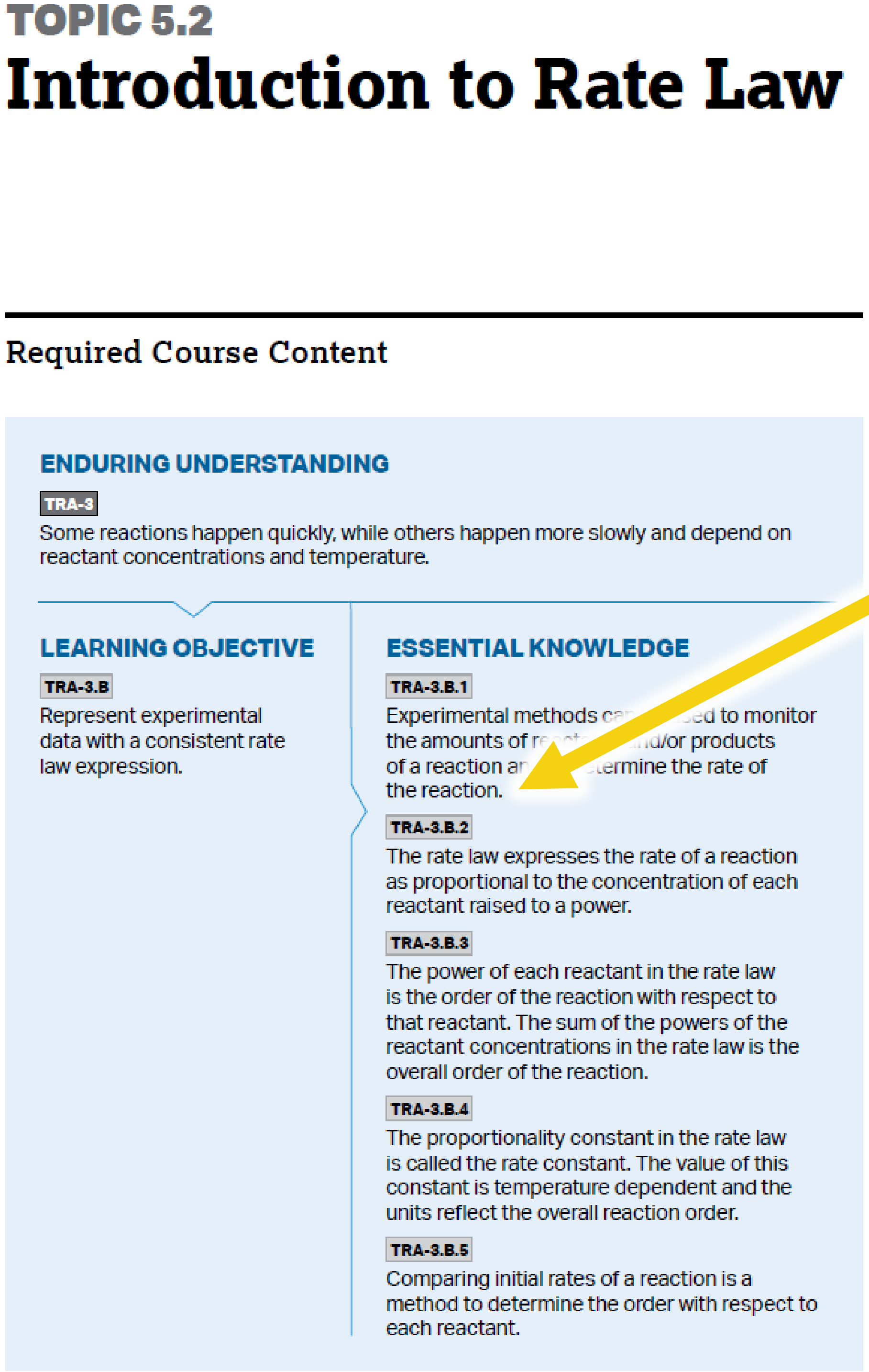
In prior units, students developed their ability to describe symbolic and quantitative information from representations (e.g., Lewis structures, chemical reactions) that illustrate both the particulate their claims. To do so, students must learn to construct and analyze energy profiles for chemical reactions and identify how such profiles may change with the addition of a catalyst.

Preparing for the AP Exam

Remove references to Big Ideas.

Updated Essential Questions:

- Why are some reactions faster than other reactions?
- Why are some medications taken every 8 hours and others once a day?
- Why is food stored in a refrigerator, but bread dough is kept in a warm place to rise?
- How can the speed of a reaction be controlled by understanding the collisions that occur on the particle level?



TOPIC 5.2

Introduction to Rate Law

Required Course Content

ENDURING UNDERSTANDING

TRA-3

Some reactions happen quickly, while others happen more slowly and depend on reactant concentrations and temperature.

LEARNING OBJECTIVE

TRA-3.B

Represent experimental data with a consistent rate law expression.

ESSENTIAL KNOWLEDGE

TRA-3.B.1

Experimental methods can [illegible] used to monitor the amounts of reactants and/or products of a reaction and determine the rate of the reaction.

TRA-3.B.2

The rate law expresses the rate of a reaction as proportional to the concentration of each reactant raised to a power.

TRA-3.B.3

The power of each reactant in the rate law is the order of the reaction with respect to that reactant. The sum of the powers of the reactant concentrations in the rate law is the overall order of the reaction.

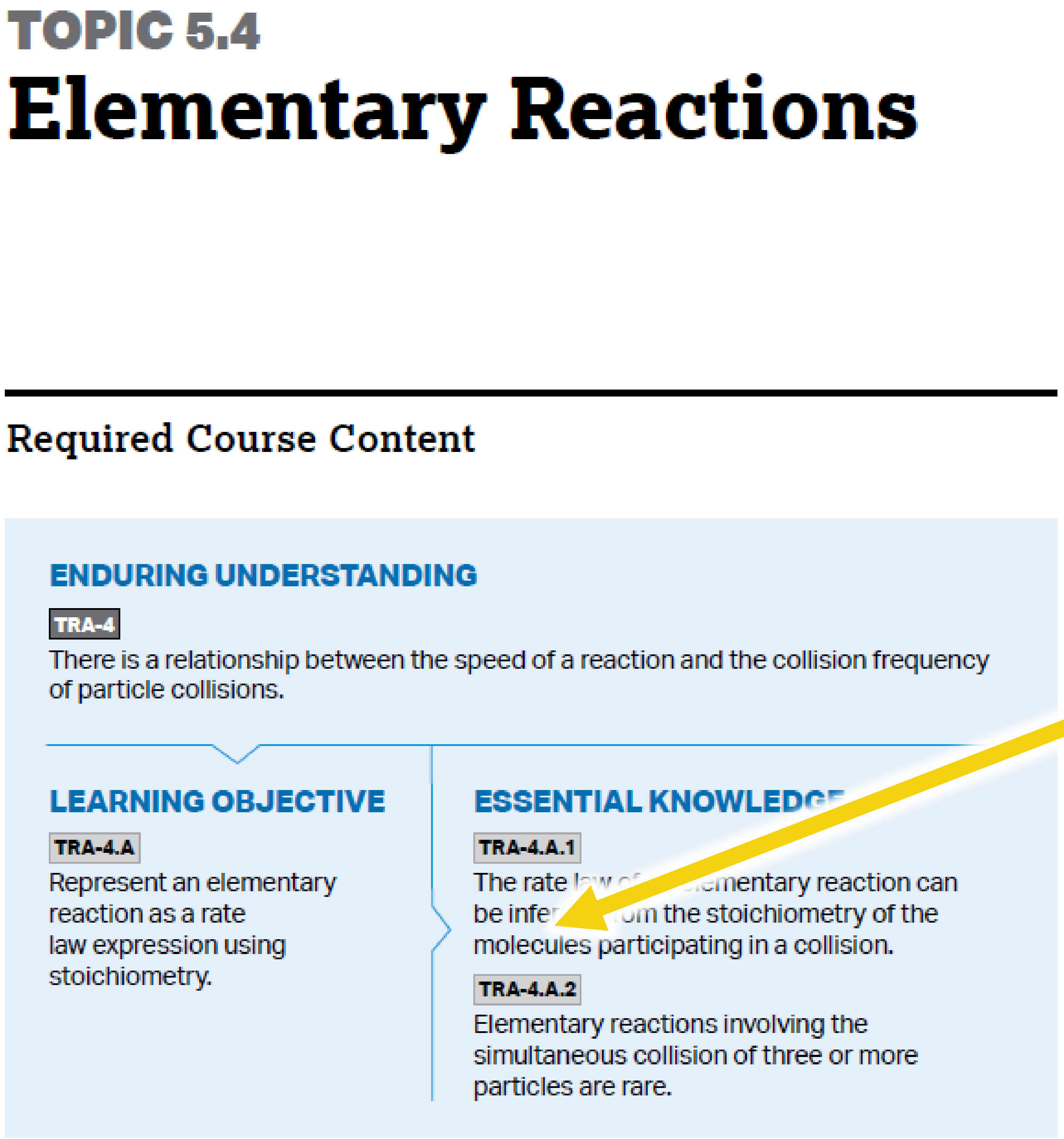
TRA-3.B.4

The proportionality constant in the rate law is called the rate constant. The value of this constant is temperature dependent and the units reflect the overall reaction order.

TRA-3.B.5

Comparing initial rates of a reaction is a method to determine the order with respect to each reactant.

Add “**over time.**”



TOPIC 5.4

Elementary Reactions

Required Course Content

ENDURING UNDERSTANDING

TRA-4

There is a relationship between the speed of a reaction and the collision frequency of particle collisions.

LEARNING OBJECTIVE

TRA-4.A

Represent an elementary reaction as a rate law expression using stoichiometry.

ESSENTIAL KNOWLEDGE

TRA-4.A.1

The rate law of an elementary reaction can be inferred from the stoichiometry of the molecules participating in a collision.

TRA-4.A.2

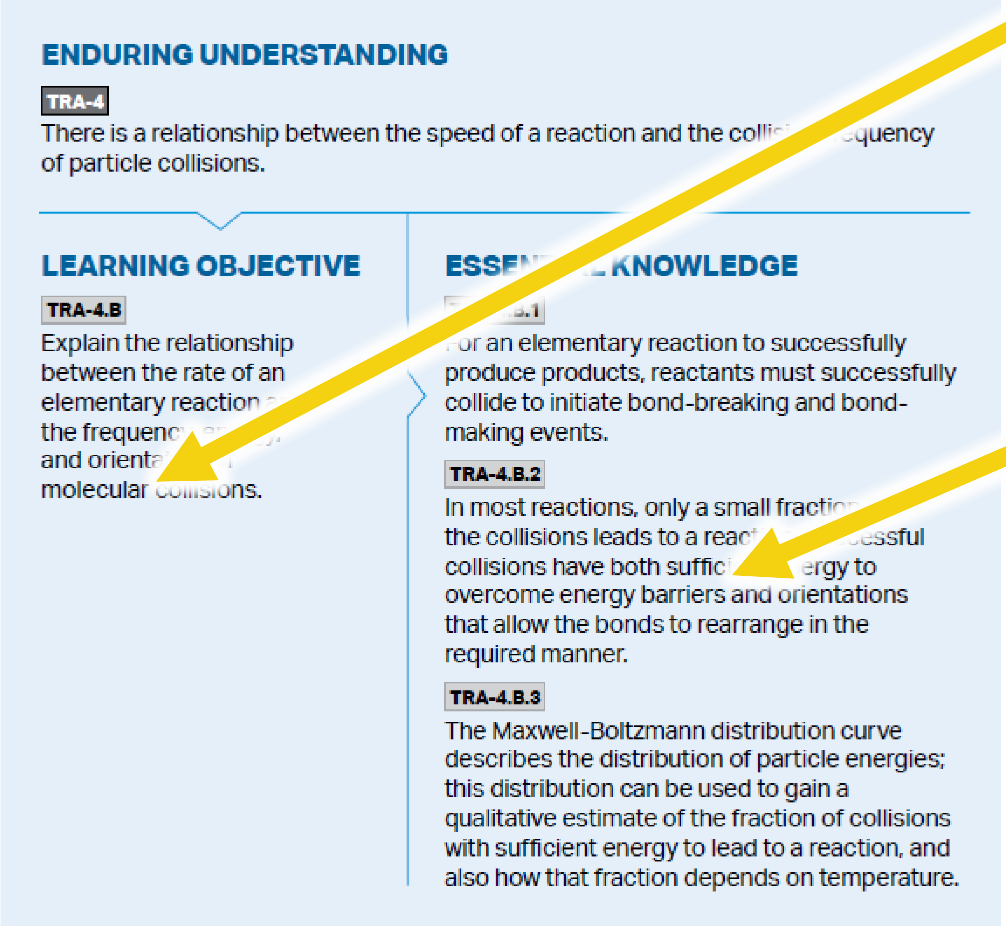
Elementary reactions involving the simultaneous collision of three or more particles are rare.

Replace “molecules” with “**particles**”

TOPIC 5.5

Collision Model

Required Course Content



ENDURING UNDERSTANDING

TRA-4

There is a relationship between the speed of a reaction and the collision frequency of particle collisions.

LEARNING OBJECTIVE

TRA-4.B

Explain the relationship between the rate of an elementary reaction and the frequency, energy, and orientation of molecular collisions.

ESSENTIAL KNOWLEDGE

TRA-4.B.1

For an elementary reaction to successfully produce products, reactants must successfully collide to initiate bond-breaking and bond-making events.

TRA-4.B.2

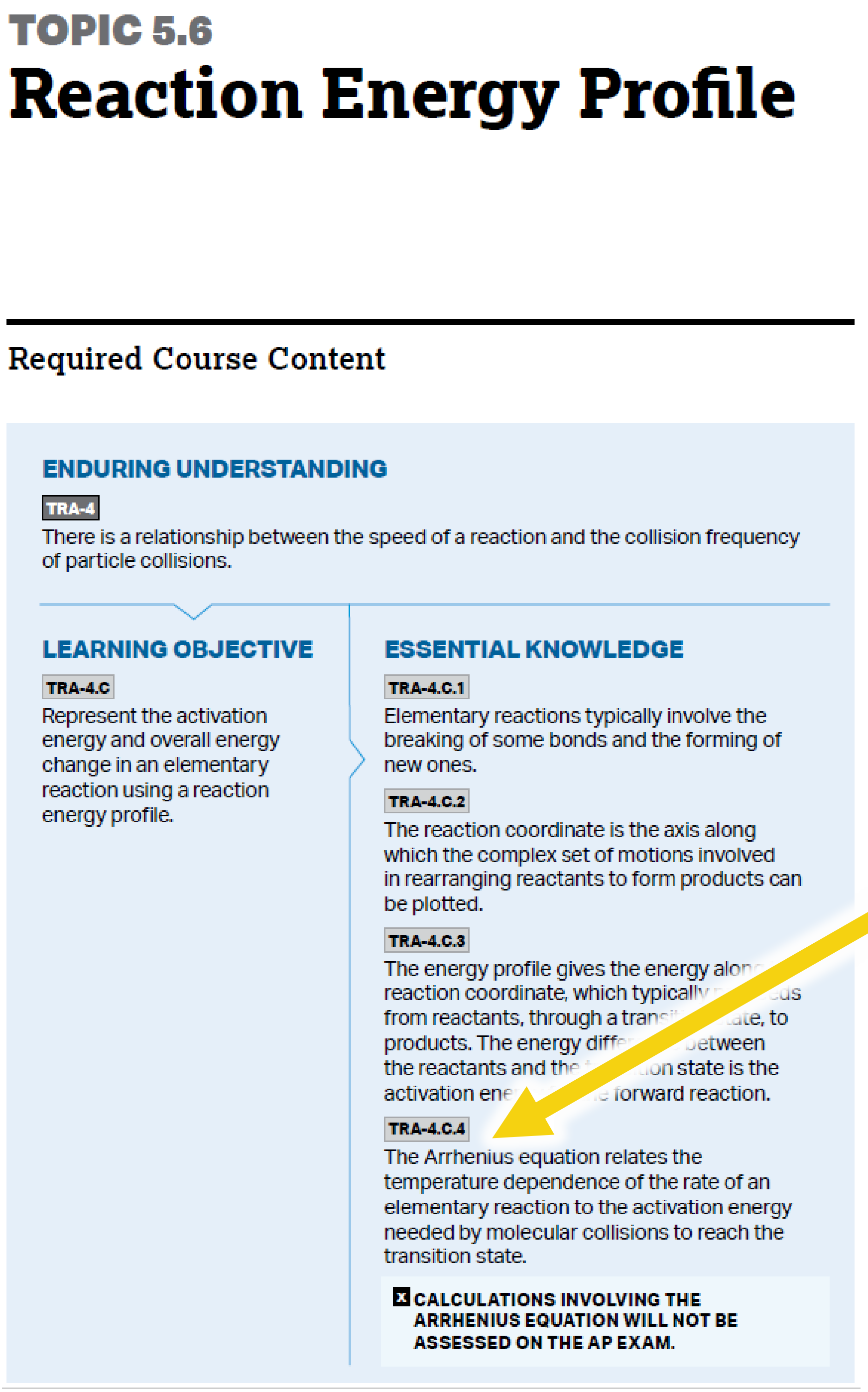
In most reactions, only a small fraction of the collisions leads to a reaction. Successful collisions have both sufficient energy to overcome energy barriers and orientations that allow the bonds to rearrange in the required manner.

TRA-4.B.3

The Maxwell-Boltzmann distribution curve describes the distribution of particle energies; this distribution can be used to gain a qualitative estimate of the fraction of collisions with sufficient energy to lead to a reaction, and also how that fraction depends on temperature.

Replace “molecular” with “**particle**”

Replace “energy barriers” with “**the activation energy requirements**”



TOPIC 5.6

Reaction Energy Profile

Required Course Content

ENDURING UNDERSTANDING

TRA-4

There is a relationship between the speed of a reaction and the collision frequency of particle collisions.

LEARNING OBJECTIVE

TRA-4.C

Represent the activation energy and overall energy change in an elementary reaction using a reaction energy profile.

ESSENTIAL KNOWLEDGE

TRA-4.C.1

Elementary reactions typically involve the breaking of some bonds and the forming of new ones.

TRA-4.C.2

The reaction coordinate is the axis along which the complex set of motions involved in rearranging reactants to form products can be plotted.

TRA-4.C.3

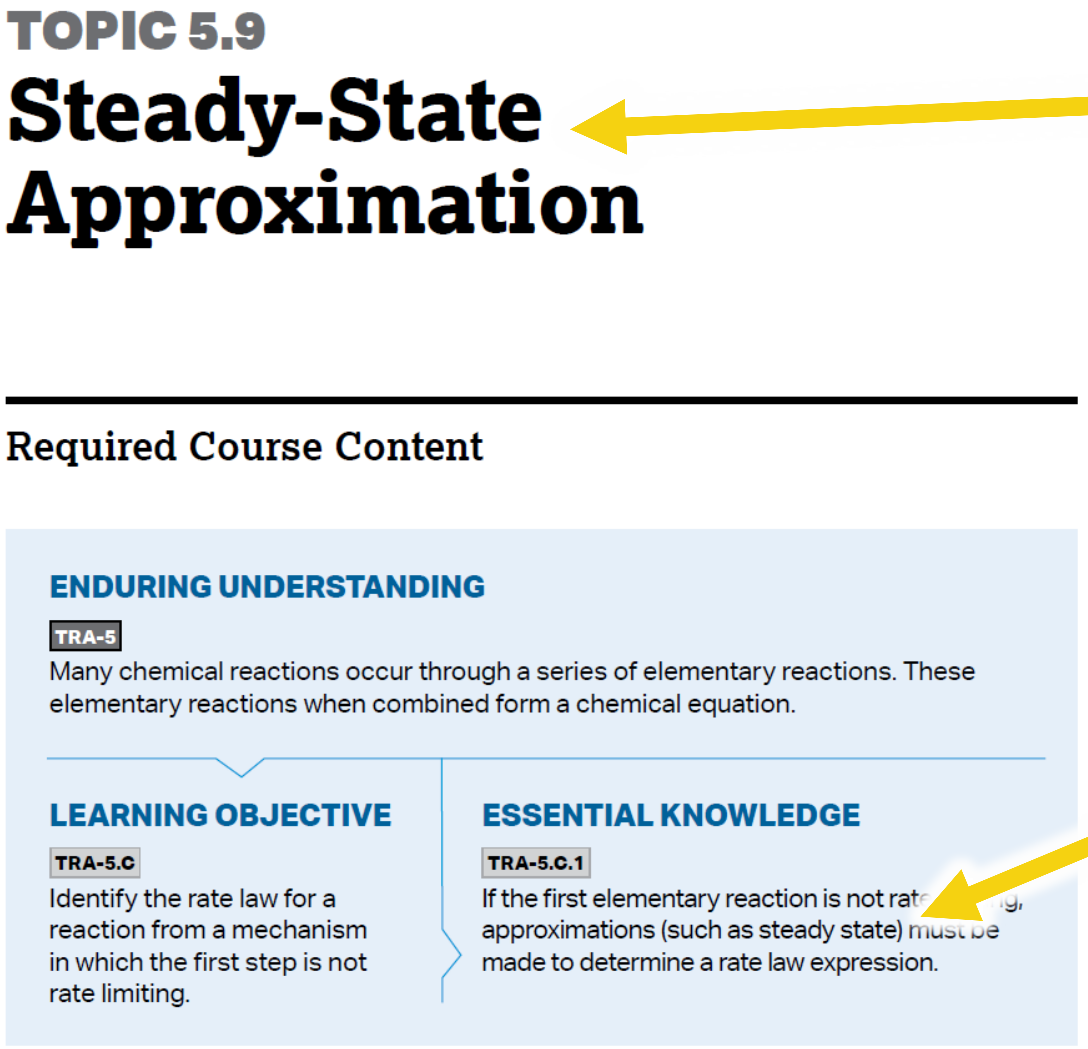
The energy profile gives the energy along the reaction coordinate, which typically proceeds from reactants, through a transition state, to products. The energy difference between the reactants and the transition state is the activation energy [illegible] the forward reaction.

TRA-4.C.4

The Arrhenius equation relates the temperature dependence of the rate of an elementary reaction to the activation energy needed by molecular collisions to reach the transition state.

☒ **CALCULATIONS INVOLVING THE ARRHENIUS EQUATION WILL NOT BE ASSESSED ON THE AP EXAM.**

Add "**The rate of an elementary reaction is temperature dependent because the proportion of particle collisions that are energetic enough to reach the transition state varies with temperature**. The Arrhenius equation…"



TOPIC 5.9

Steady-State Approximation

Required Course Content

ENDURING UNDERSTANDING

TRA-5

Many chemical reactions occur through a series of elementary reactions. These elementary reactions when combined form a chemical equation.

LEARNING OBJECTIVE

TRA-5.C

Identify the rate law for a reaction from a mechanism in which the first step is not rate limiting.

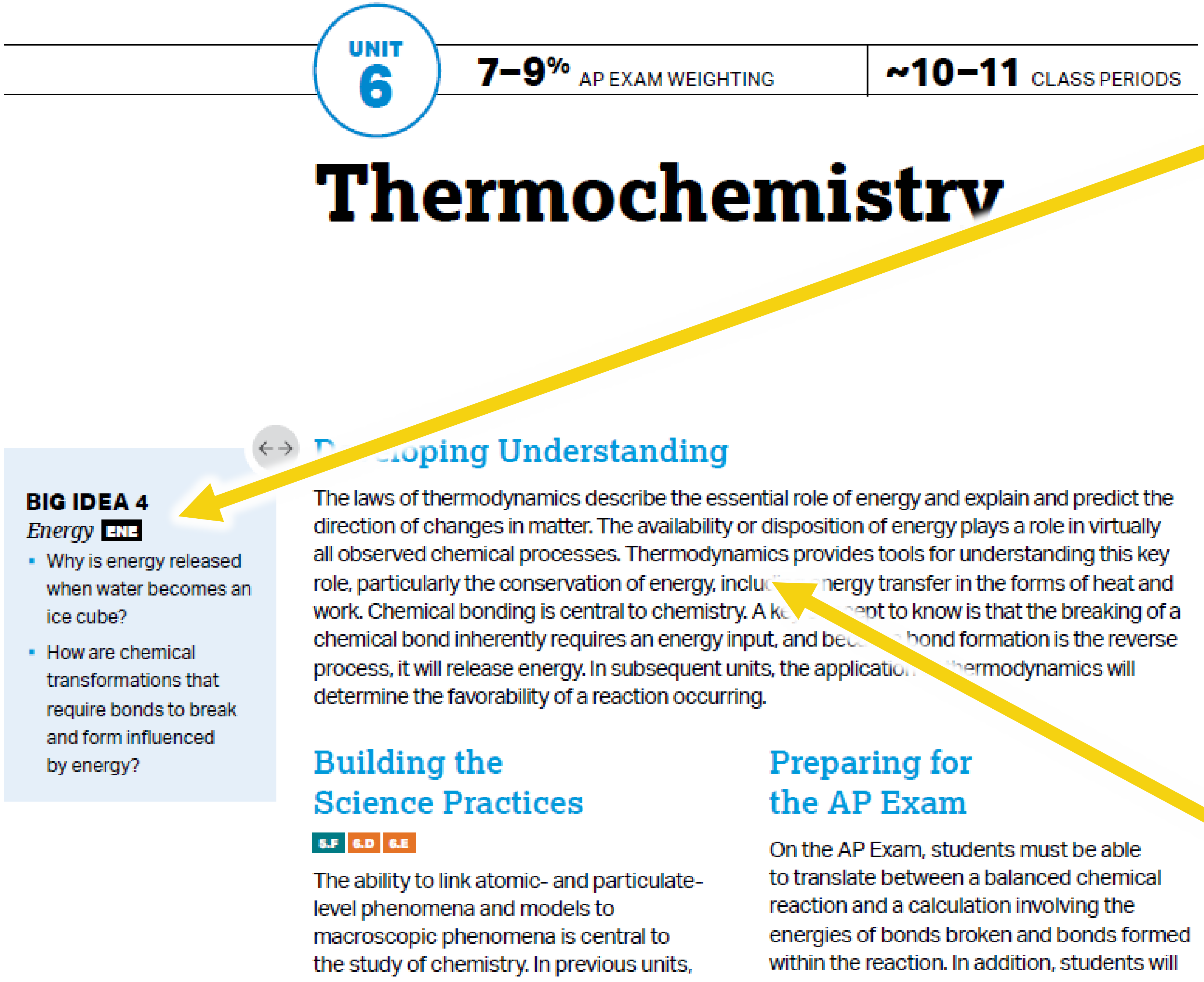
ESSENTIAL KNOWLEDGE

TRA-5.C.1

If the first elementary reaction is not rate limiting, approximations (such as steady state) must be made to determine a rate law expression.

Retitle: “Pre-Equilibrium Approximation”

Rephrase for consistency:
“…**(such as pre-equilibrium)**…”



UNIT 6

7–9% AP EXAM WEIGHTING

~10–11 CLASS PERIODS

Thermochemistry

BIG IDEA 4

Energy ENE

- Why is energy released when water becomes an ice cube?
- How are chemical transformations that require bonds to break and form influenced by energy?

Developing Understanding

The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter. The availability or disposition of energy plays a role in virtually all observed chemical processes. Thermodynamics provides tools for understanding this key role, particularly the conservation of energy, including energy transfer in the forms of heat and work. Chemical bonding is central to chemistry. A key concept to know is that the breaking of a chemical bond inherently requires an energy input, and because bond formation is the reverse process, it will release energy. In subsequent units, the application of thermodynamics will determine the favorability of a reaction occurring.

Building the Science Practices

5.F 6.D 6.E

The ability to link atomic- and particulate-level phenomena and models to macroscopic phenomena is central to the study of chemistry. In previous units,

Preparing for the AP Exam

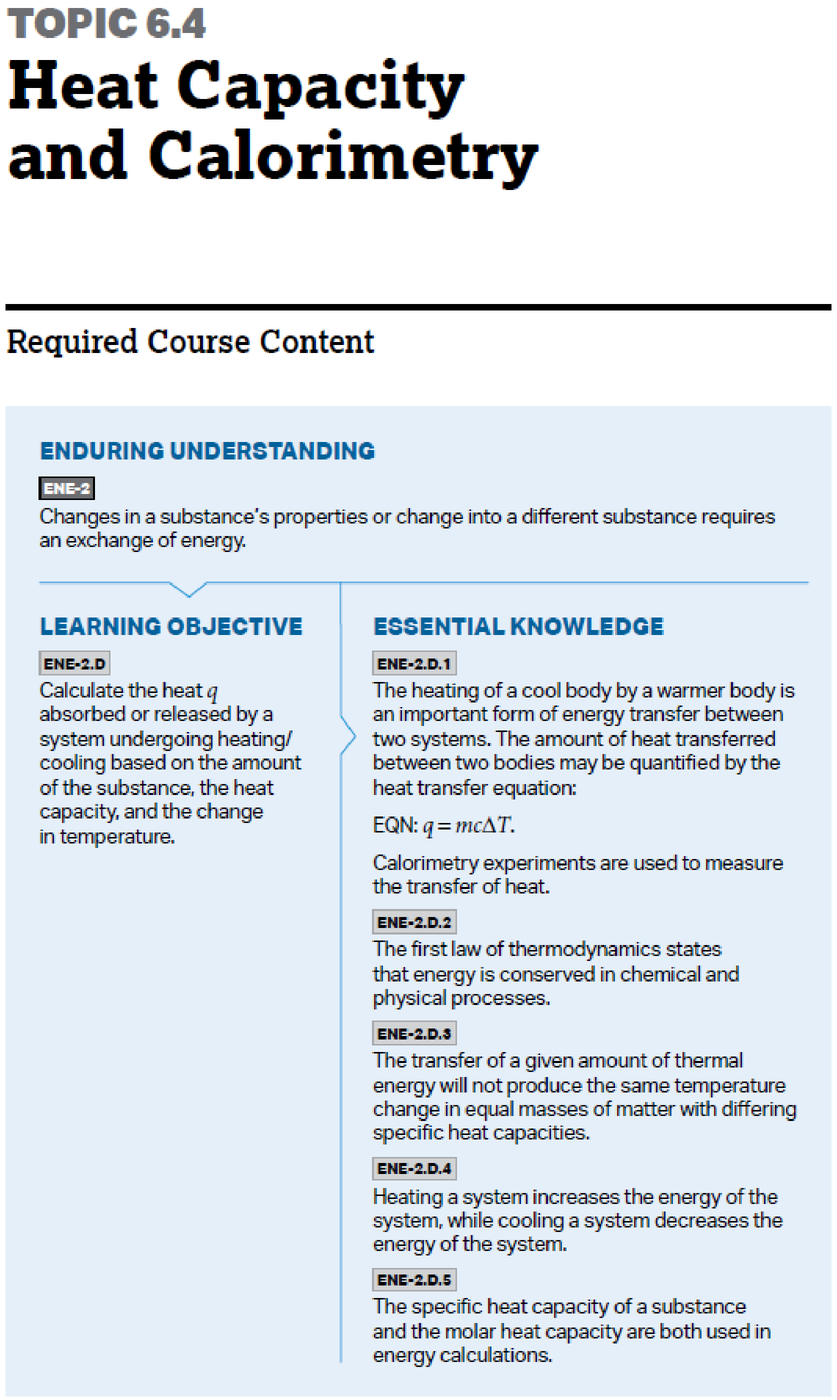
On the AP Exam, students must be able to translate between a balanced chemical reaction and a calculation involving the energies of bonds broken and bonds formed within the reaction. In addition, students will

Remove references to Big Ideas.

Updated Essential Questions:

- Why is energy released when liquid water becomes an ice cube?
- Why does your skin feel cold when water evaporates off of it?
- How does a thermal energy transfer affect temperature, states of matter, and chemical bonds?
- How can energy changes be tracked and measured when energy can't be seen?
- Why do combustion reactions that form carbon dioxide release energy?

Replace "Thermodynamics" with "**Thermochemistry**"



TOPIC 6.4

Heat Capacity and Calorimetry

Required Course Content

ENDURING UNDERSTANDING

ENE-2

Changes in a substance's properties or change into a different substance requires an exchange of energy.

LEARNING OBJECTIVE

ENE-2.D

Calculate the heat q absorbed or released by a system undergoing heating/cooling based on the amount of the substance, the heat capacity, and the change in temperature.

ESSENTIAL KNOWLEDGE

ENE-2.D.1

The heating of a cool body by a warmer body is an important form of energy transfer between two systems. The amount of heat transferred between two bodies may be quantified by the heat transfer equation:

EQN: $q = mc\Delta T$.

Calorimetry experiments are used to measure the transfer of heat.

ENE-2.D.2

The first law of thermodynamics states that energy is conserved in chemical and physical processes.

ENE-2.D.3

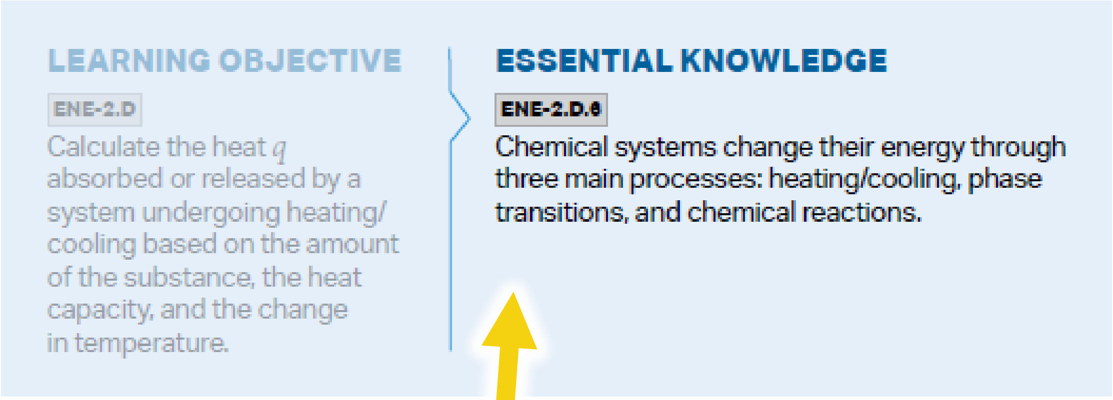
The transfer of a given amount of thermal energy will not produce the same temperature change in equal masses of matter with differing specific heat capacities.

ENE-2.D.4

Heating a system increases the energy of the system, while cooling a system decreases the energy of the system.

ENE-2.D.5

The specific heat capacity of a substance and the molar heat capacity are both used in energy calculations.



LEARNING OBJECTIVE

ENE-2.D

Calculate the heat q absorbed or released by a system undergoing heating/cooling based on the amount of the substance, the heat capacity, and the change in temperature.

ESSENTIAL KNOWLEDGE

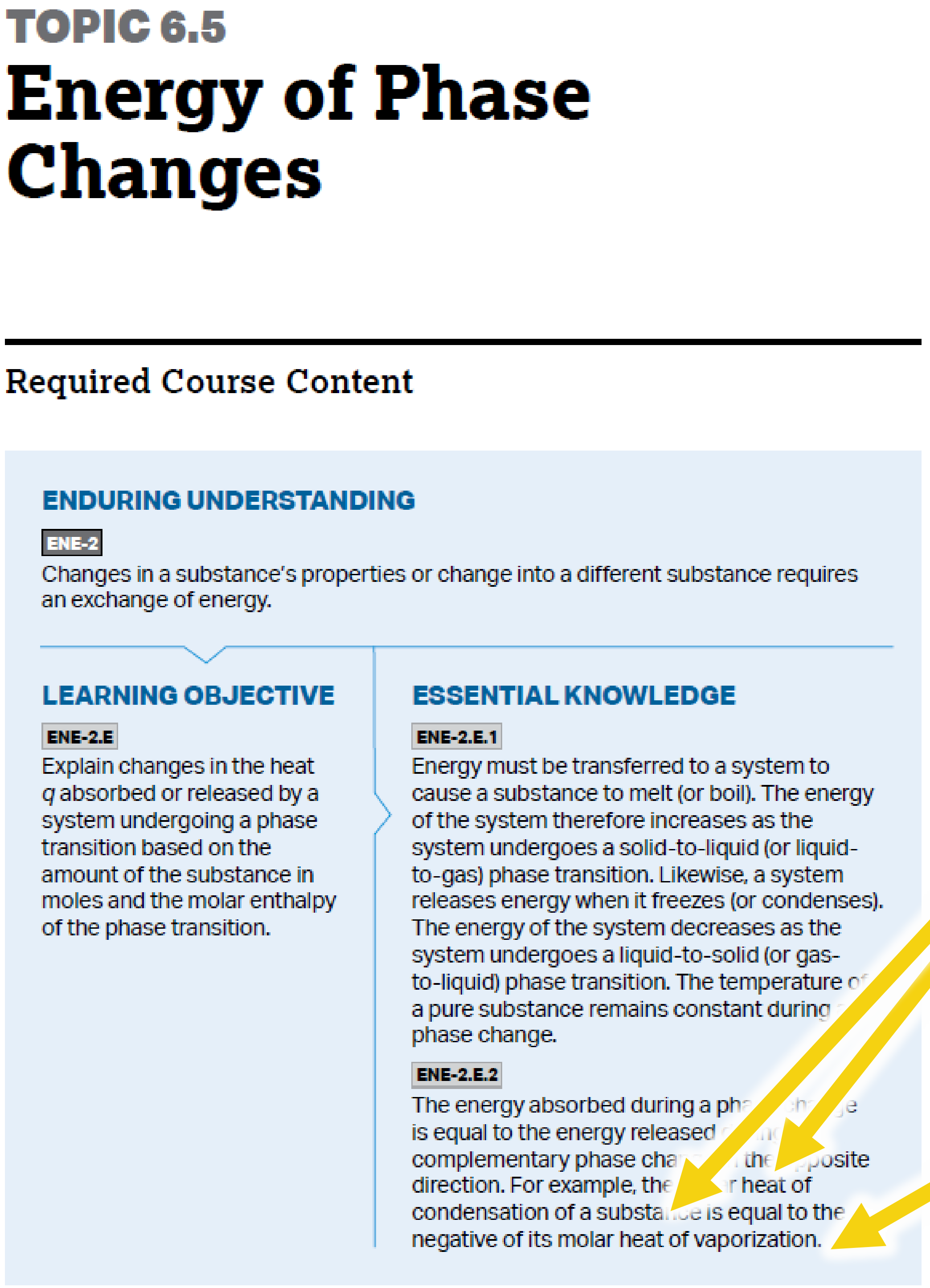
ENE-2.D.6

Chemical systems change their energy through three main processes: heating/cooling, phase transitions, and chemical reactions.

Add EK:

6.4.D.7

In calorimetry experiments involving dissolution, temperature changes of the mixture within the calorimeter can be used to determine the direction of energy flow. If the temperature of the mixture increases, thermal energy is released by the dissolution process (exothermic). If the temperature of the mixture decreases, thermal energy is absorbed by the dissolution process (endothermic).



TOPIC 6.5

Energy of Phase Changes

Required Course Content

ENDURING UNDERSTANDING

ENE-2

Changes in a substance's properties or change into a different substance requires an exchange of energy.

LEARNING OBJECTIVE

ENE-2.E

Explain changes in the heat *q* absorbed or released by a system undergoing a phase transition based on the amount of the substance in moles and the molar enthalpy of the phase transition.

ESSENTIAL KNOWLEDGE

ENE-2.E.1

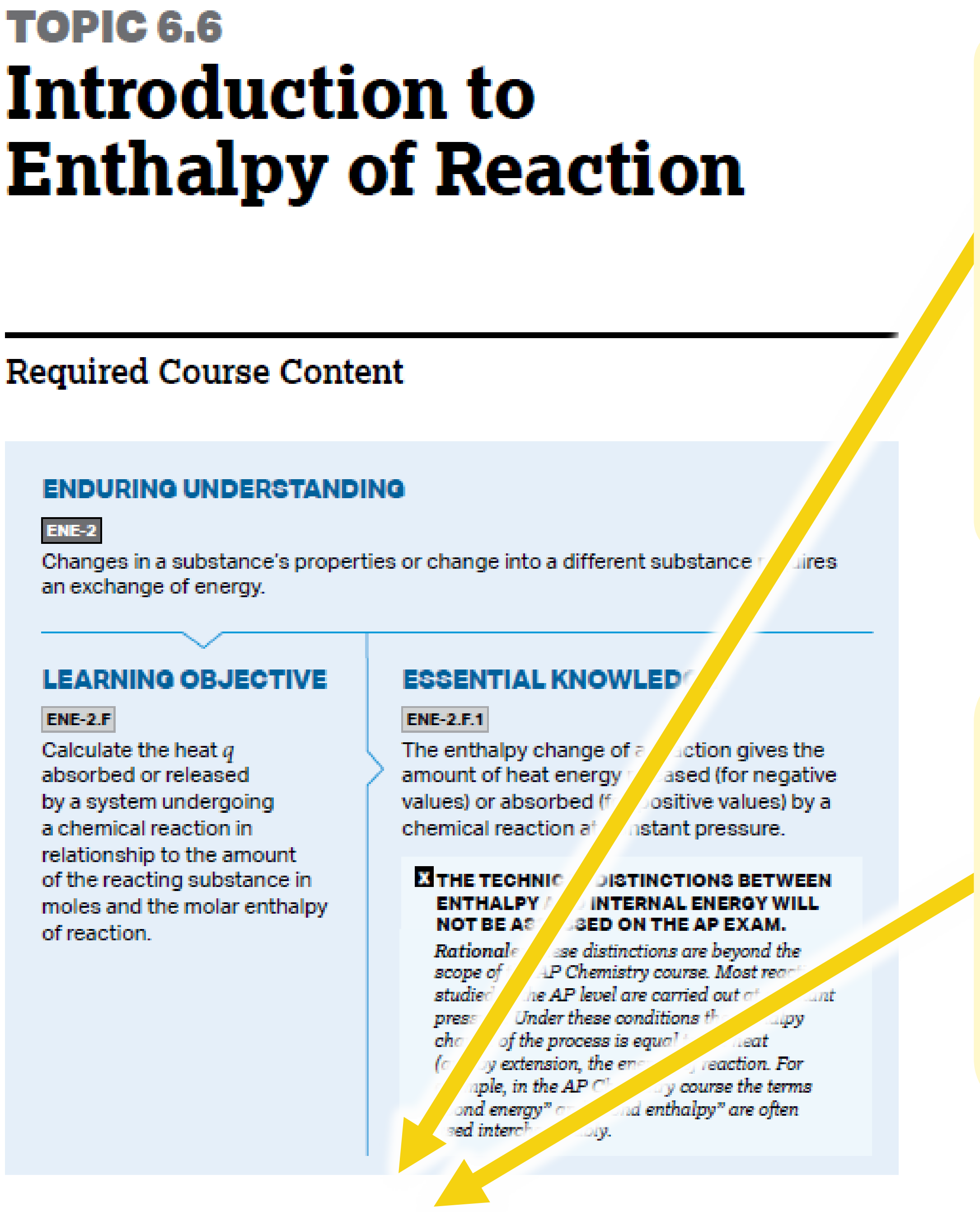
Energy must be transferred to a system to cause a substance to melt (or boil). The energy of the system therefore increases as the system undergoes a solid-to-liquid (or liquid-to-gas) phase transition. Likewise, a system releases energy when it freezes (or condenses). The energy of the system decreases as the system undergoes a liquid-to-solid (or gas-to-liquid) phase transition. The temperature of a pure substance remains constant during a phase change.

ENE-2.E.2

The energy absorbed during a phase change is equal to the energy released during a complementary phase change in the opposite direction. For example, the molar heat of condensation of a substance is equal to the negative of its molar heat of vaporization.

Change "heat" to "enthalpy"

Add: "Similarly, the molar enthalpy of fusion can be used to calculate the energy absorbed when melting a substance and the energy released when freezing a substance."



TOPIC 6.6

Introduction to Enthalpy of Reaction

Required Course Content

ENDURING UNDERSTANDING

ENE-2

Changes in a substance's properties or change into a different substance r ires an exchange of energy.

LEARNING OBJECTIVE

ENE-2.F

Calculate the heat q absorbed or released by a system undergoing a chemical reaction in relationship to the amount of the reacting substance in moles and the molar enthalpy of reaction.

ESSENTIAL KNOWLED

ENE-2.F.1

The enthalpy change of a ction gives the amount of heat energy r ased (for negative values) or absorbed (f ositive values) by a chemical reaction at nstant pressure.

☒ **THE TECHNIC DISTINCTIONS BETWEEN ENTHALPY INTERNAL ENERGY WILL NOT BE AS SED ON THE AP EXAM.**

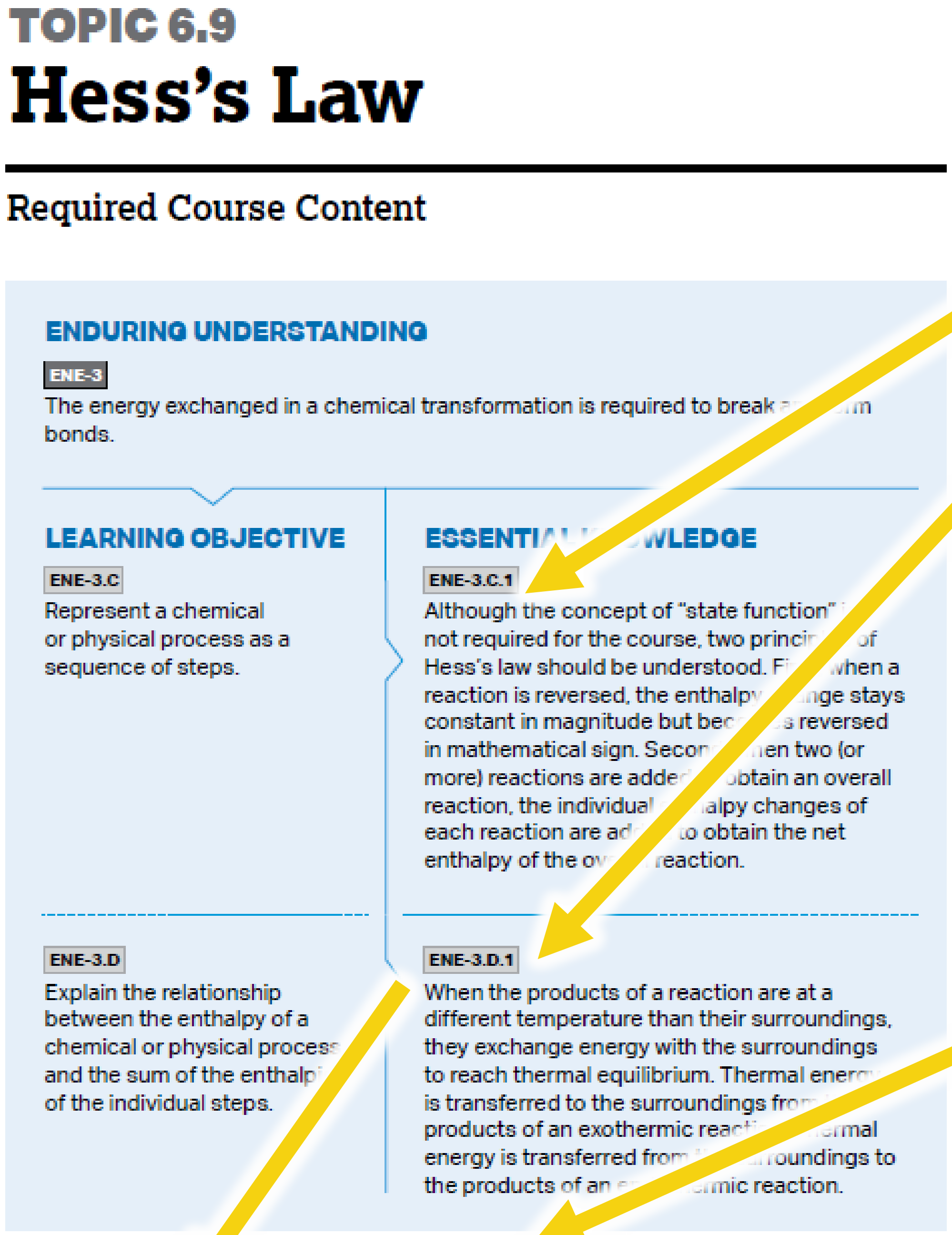
Rational se distinctions are beyond the scope of AP Chemistry course. Most reac studied he AP level are carried out at ant press Under these conditions th lpy cha of the process is equal eat (c y extension, the en reaction. For mple, in the AP C y course the terms ond energy" a nd enthalpy" are often sed interch bly.

Move EK from Topic 6.9 to Topic 6.6 as 6.6.A.2:

ENE-3.D.1 → 6.6.A.2
When the products of a reaction are at a different temperature than their surroundings, they exchange energy with the surroundings to reach thermal equilibrium. Thermal energy is transferred to the surroundings as the reactants convert to products in an exothermic reaction. Thermal energy is transferred from the surroundings as the reactants convert to products in an endothermic reaction.

Add EK

6.6.A.3
The chemical potential energy of the products of a reaction is different from that of the reactants because of the breaking and forming of bonds. The energy difference results in a change in the kinetic energy of the particles, which manifests as a temperature change.



TOPIC 6.9

Hess's Law

Required Course Content

ENDURING UNDERSTANDING

ENE-3

The energy exchanged in a chemical transformation is required to break a m bonds.

LEARNING OBJECTIVE

ENE-3.C

Represent a chemical or physical process as a sequence of steps.

ESSENTIAL WLEDGE

ENE-3.C.1

Although the concept of "state function" i not required for the course, two princi of Hess's law should be understood. Fi when a reaction is reversed, the enthalpy nge stays constant in magnitude but bec s reversed in mathematical sign. Secon en two (or more) reactions are adde btain an overall reaction, the individual alpy changes of each reaction are ad to obtain the net enthalpy of the ov reaction.

ENE-3.D

Explain the relationship between the enthalpy of a chemical or physical process and the sum of the enthalpi of the individual steps.

ENE-3.D.1

When the products of a reaction are at a different temperature than their surroundings, they exchange energy with the surroundings to reach thermal equilibrium. Thermal energ is transferred to the surroundings fro products of an exothermic reac rmal energy is transferred from roundings to the products of an rmic reaction.

Moved ENE-3.D.1 to Topic 6.6 as 6.6.A.2

Reorganize and **Add** EKs:

6.9.A.1

Many processes can be broken down into a series of steps. Each step in the series has its own energy change.

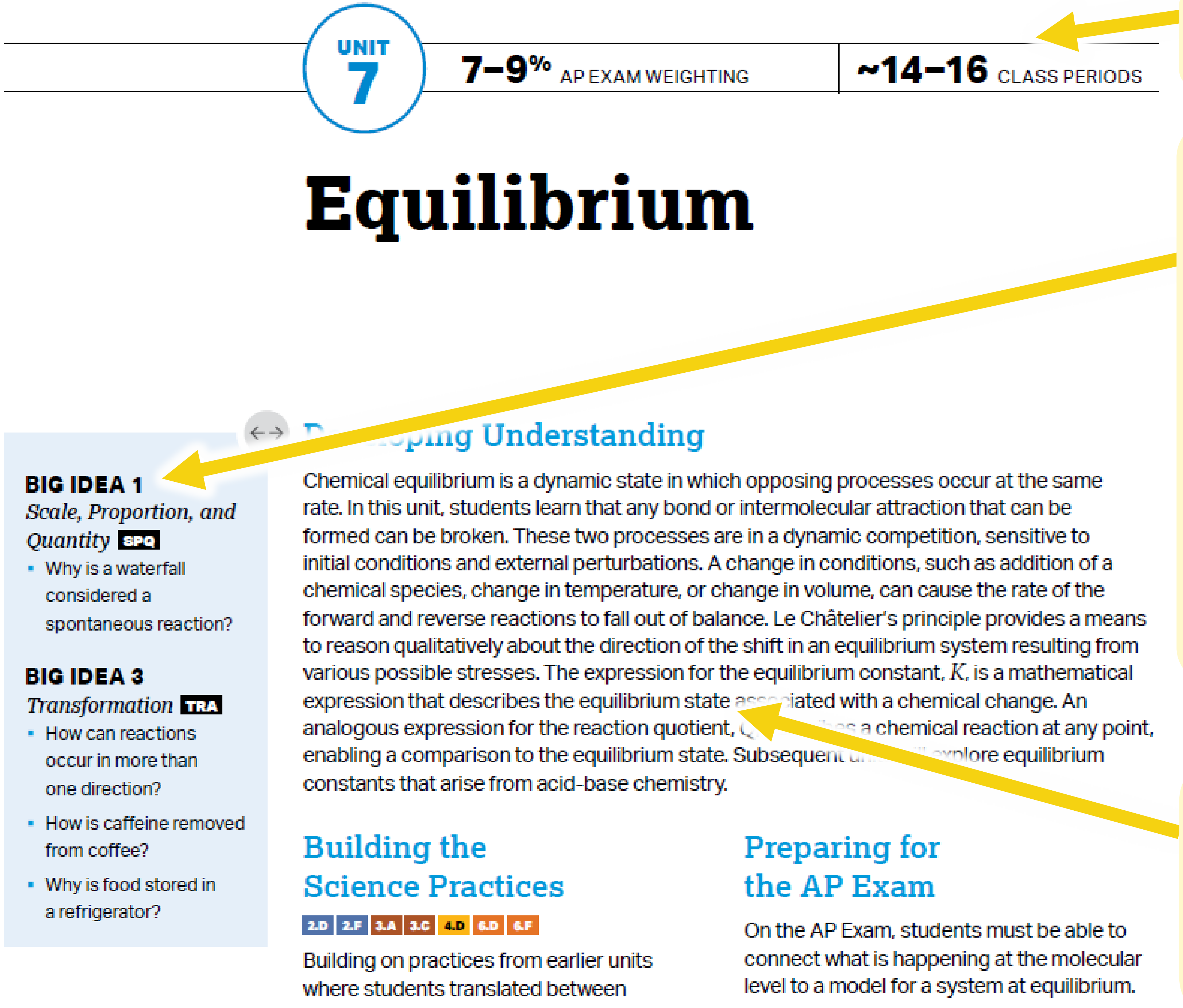
6.9.B.1

Because total energy is conserved (first law of thermodynamics), and each individual reaction in a sequence transfers thermal energy to or from the surroundings, the net thermal energy transferred in the sequence will be equal to the sum of the thermal energy transfers in each of the steps. These thermal energy transfers are the result of potential energy changes among the species in the reaction sequence; thus, at constant pressure, the enthalpy change of the overall process is equal to the sum of the enthalpy changes of the individual steps.

6.9.B.2

The following are essential principles of Hess's law:

i. When a reaction is reversed, the enthalpy change stays constant in magnitude but becomes reversed in mathematical sign.
ii. When a reaction is multiplied by a factor *c*, the enthalpy change is multiplied by the same factor *c*.
iii. When two (or more) reactions are added to obtain an overall reaction, the individual enthalpy changes of each reaction are added to obtain the net enthalpy change of the overall reaction.



UNIT 7

7–9% AP EXAM WEIGHTING

~14–16 CLASS PERIODS

Equilibrium

BIG IDEA 1
Scale, Proportion, and Quantity **SPQ**

- Why is a waterfall considered a spontaneous reaction?

BIG IDEA 3
Transformation **TRA**

- How can reactions occur in more than one direction?
- How is caffeine removed from coffee?
- Why is food stored in a refrigerator?

Developing Understanding

Chemical equilibrium is a dynamic state in which opposing processes occur at the same rate. In this unit, students learn that any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations. A change in conditions, such as addition of a chemical species, change in temperature, or change in volume, can cause the rate of the forward and reverse reactions to fall out of balance. Le Châtelier's principle provides a means to reason qualitatively about the direction of the shift in an equilibrium system resulting from various possible stresses. The expression for the equilibrium constant, K, is a mathematical expression that describes the equilibrium state associated with a chemical change. An analogous expression for the reaction quotient, Q, describes a chemical reaction at any point, enabling a comparison to the equilibrium state. Subsequent units will explore equilibrium constants that arise from acid-base chemistry.

Building the Science Practices

2.D 2.F 3.A 3.C 4.D 6.D 6.F

Building on practices from earlier units where students translated between

Preparing for the AP Exam

On the AP Exam, students must be able to connect what is happening at the molecular level to a model for a system at equilibrium.

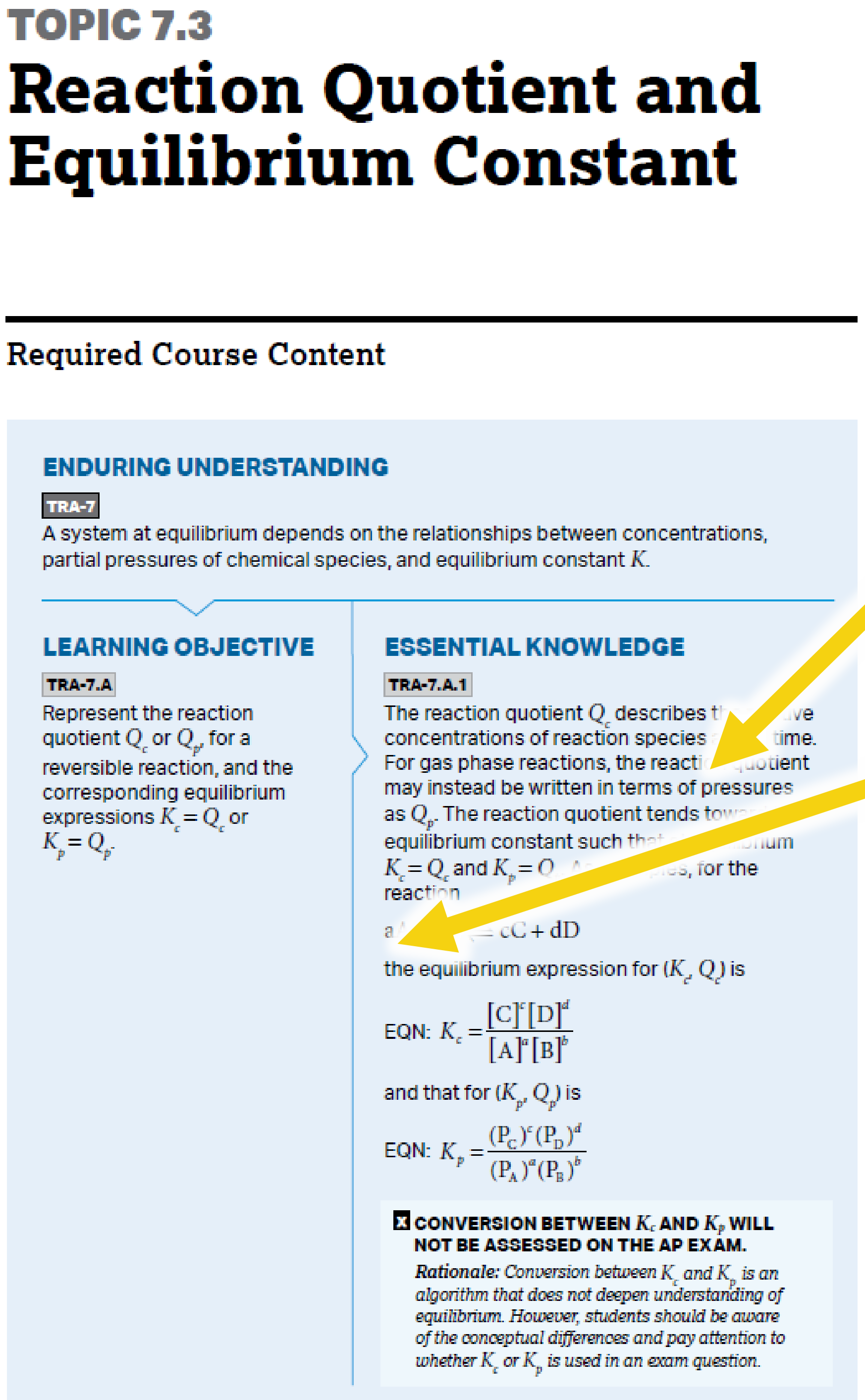
Adjusted from ~14-16 class periods to **~13-15** class periods

Remove references to Big Ideas.

Updated Essential Questions:

- How are the rates of forward and reverse reactions related to the direction that a reversible reaction proceeds?
- How can the composition of a mixture at equilibrium be predicted?
- How can an equilibrium system be manipulated to maximize product yield?
- Why do paramedics administer pure oxygen to people with carbon monoxide poisoning?
- What factors influence the degree to which a salt will dissolve?

Add: "The dissolution of a solid in a solvent can also be understood by applying the principles of chemical equilibrium because it is a reversible reaction. The relationship between salt solubility, pH, and free energy will be encountered in subsequent units."



TOPIC 7.3

Reaction Quotient and Equilibrium Constant

Required Course Content

ENDURING UNDERSTANDING

TRA-7

A system at equilibrium depends on the relationships between concentrations, partial pressures of chemical species, and equilibrium constant K.

LEARNING OBJECTIVE

TRA-7.A

Represent the reaction quotient Q_c or Q_p, for a reversible reaction, and the corresponding equilibrium expressions $K_c = Q_c$ or $K_p = Q_p$.

ESSENTIAL KNOWLEDGE

TRA-7.A.1

The reaction quotient Q_c describes t [illegible] ive concentrations of reaction species [illegible] time. For gas phase reactions, the reacti [illegible] quotient may instead be written in terms of pressures as Q_p. The reaction quotient tends tow [illegible] equilibrium constant such that [illegible] brium $K_c = Q_c$ and $K_p = Q$ [illegible] ples, for the reaction

a [illegible] $\rightleftharpoons$ cC + dD

the equilibrium expression for (K_c, Q_c) is

EQN: $K_c = \dfrac{[C]^c[D]^d}{[A]^a[B]^b}$

and that for (K_p, Q_p) is

EQN: $K_p = \dfrac{(P_C)^c(P_D)^d}{(P_A)^a(P_B)^b}$

☒ **CONVERSION BETWEEN K_c AND K_p WILL NOT BE ASSESSED ON THE AP EXAM.**

Rationale: *Conversion between K_c and K_p is an algorithm that does not deepen understanding of equilibrium. However, students should be aware of the conceptual differences and pay attention to whether K_c or K_p is used in an exam question.*

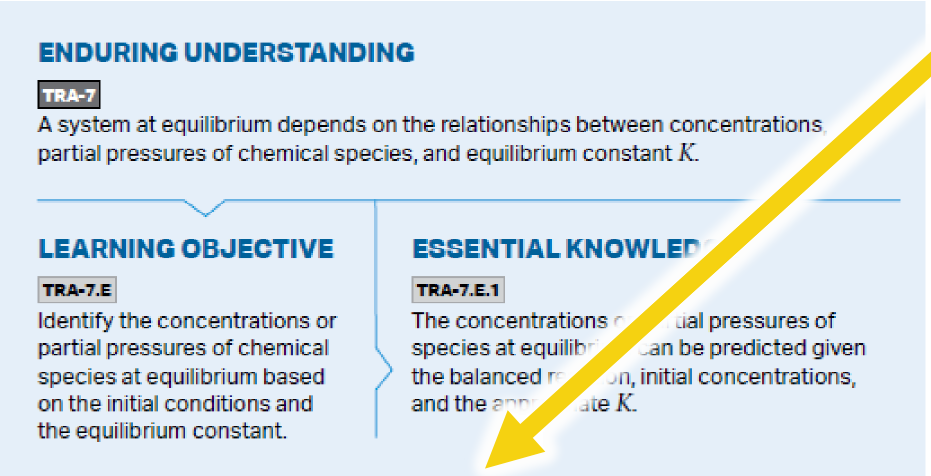
Add “partial”

Add “the law of mass action indicates that the equilibrium expression for (K_c, Q_c) is…”

TOPIC 7.7

Calculating Equilibrium Concentrations

Required Course Content



ENDURING UNDERSTANDING

TRA-7

A system at equilibrium depends on the relationships between concentrations, partial pressures of chemical species, and equilibrium constant K.

LEARNING OBJECTIVE

TRA-7.E

Identify the concentrations or partial pressures of chemical species at equilibrium based on the initial conditions and the equilibrium constant.

ESSENTIAL KNOWLED[illegible]

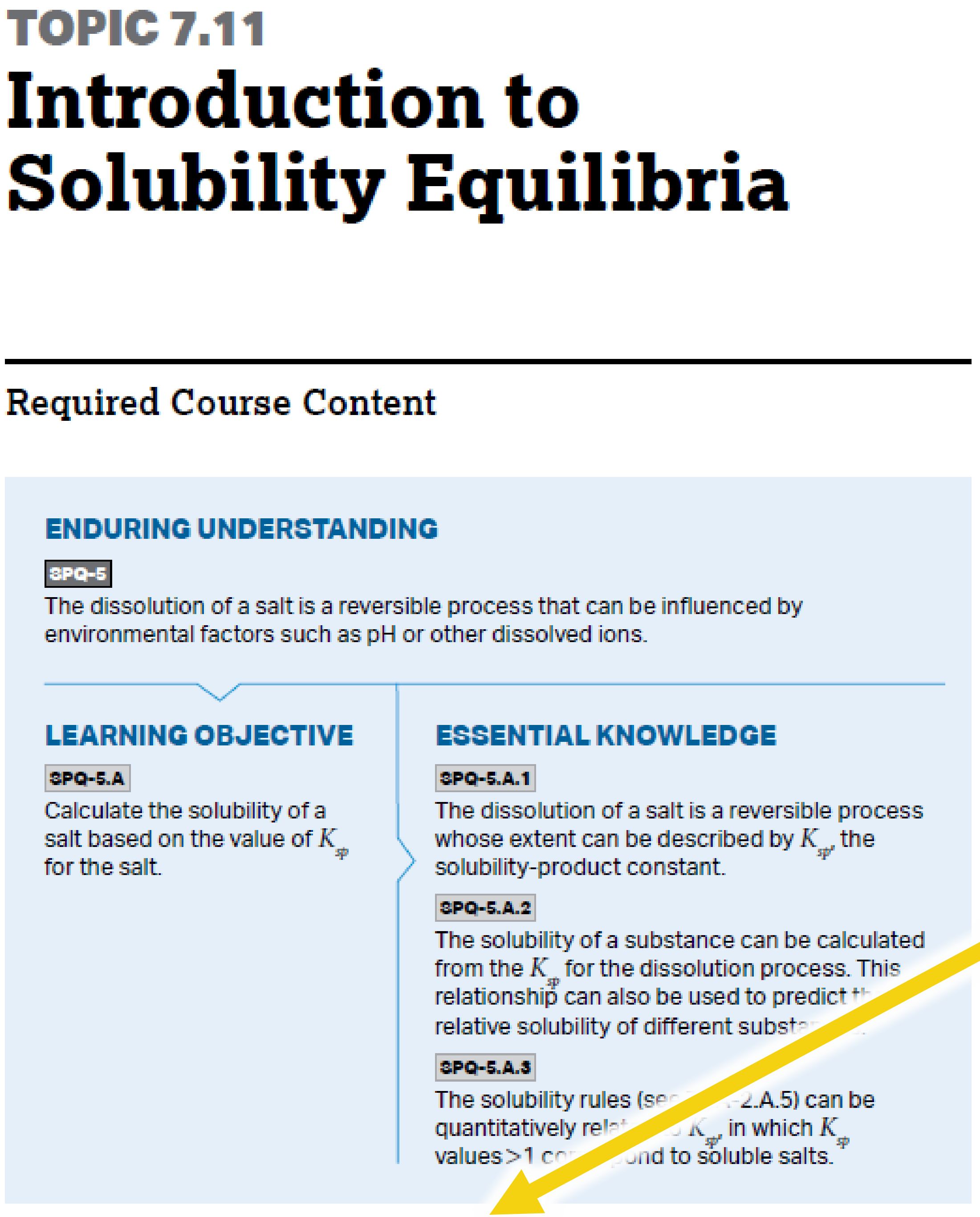
TRA-7.E.1

The concentrations [illegible] pressures of species at equilibri[illegible] be predicted given the balanced [illegible], initial concentrations, and the [illegible] K.

Add EK

7.7.A.2

When $Q < K$, the reaction will proceed with a net consumption of reactants and generation of products. When $Q > K$, the reaction will proceed with a net consumption of products and generation of reactants. When $Q = K$, the system is at dynamic equilibrium; both forward and reverse reactions proceed at the same rate, and the proportion of reactants and products remains constant.



TOPIC 7.11

Introduction to Solubility Equilibria

Required Course Content

ENDURING UNDERSTANDING

SPQ-5

The dissolution of a salt is a reversible process that can be influenced by environmental factors such as pH or other dissolved ions.

LEARNING OBJECTIVE

SPQ-5.A

Calculate the solubility of a salt based on the value of K_{sp} for the salt.

ESSENTIAL KNOWLEDGE

SPQ-5.A.1

The dissolution of a salt is a reversible process whose extent can be described by K_{sp}, the solubility-product constant.

SPQ-5.A.2

The solubility of a substance can be calculated from the K_{sp} for the dissolution process. This relationship can also be used to predict th[illegible] relative solubility of different subst[illegible]

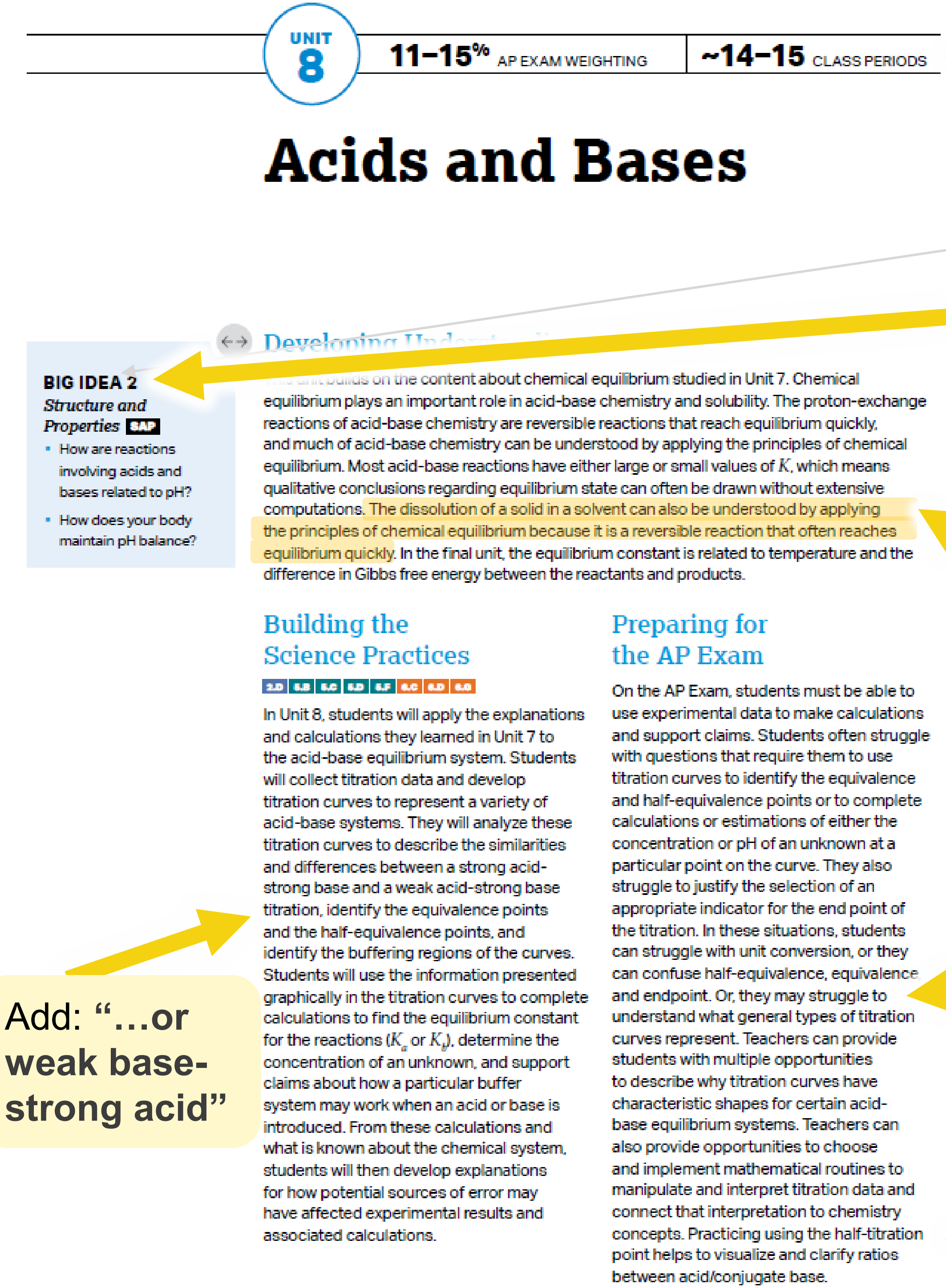
SPQ-5.A.3

The solubility rules (se[illegible]-2.A.5) can be quantitatively relat[illegible] K_{sp}, in which K_{sp} values >1 co[illegible]pond to soluble salts.

Add EK:

7.11.A.4

The molar solubility of one or more species in a saturated solution can be used to calculate the K_{sp} of a substance.



UNIT 8

11–15% AP EXAM WEIGHTING

~14–15 CLASS PERIODS

Acids and Bases

BIG IDEA 2
Structure and Properties SAP

- How are reactions involving acids and bases related to pH?
- How does your body maintain pH balance?

Developing Understanding

This unit builds on the content about chemical equilibrium studied in Unit 7. Chemical equilibrium plays an important role in acid-base chemistry and solubility. The proton-exchange reactions of acid-base chemistry are reversible reactions that reach equilibrium quickly, and much of acid-base chemistry can be understood by applying the principles of chemical equilibrium. Most acid-base reactions have either large or small values of K, which means qualitative conclusions regarding equilibrium state can often be drawn without extensive computations. The dissolution of a solid in a solvent can also be understood by applying the principles of chemical equilibrium because it is a reversible reaction that often reaches equilibrium quickly. In the final unit, the equilibrium constant is related to temperature and the difference in Gibbs free energy between the reactants and products.

Building the Science Practices

2.D 5.B 5.C 5.D 5.F 6.C 6.D 6.G

In Unit 8, students will apply the explanations and calculations they learned in Unit 7 to the acid-base equilibrium system. Students will collect titration data and develop titration curves to represent a variety of acid-base systems. They will analyze these titration curves to describe the similarities and differences between a strong acid-strong base and a weak acid-strong base titration, identify the equivalence points and the half-equivalence points, and identify the buffering regions of the curves. Students will use the information presented graphically in the titration curves to complete calculations to find the equilibrium constant for the reactions (K_a or K_b), determine the concentration of an unknown, and support claims about how a particular buffer system may work when an acid or base is introduced. From these calculations and what is known about the chemical system, students will then develop explanations for how potential sources of error may have affected experimental results and associated calculations.

Preparing for the AP Exam

On the AP Exam, students must be able to use experimental data to make calculations and support claims. Students often struggle with questions that require them to use titration curves to identify the equivalence and half-equivalence points or to complete calculations or estimations of either the concentration or pH of an unknown at a particular point on the curve. They also struggle to justify the selection of an appropriate indicator for the end point of the titration. In these situations, students can struggle with unit conversion, or they can confuse half-equivalence, equivalence, and endpoint. Or, they may struggle to understand what general types of titration curves represent. Teachers can provide students with multiple opportunities to describe why titration curves have characteristic shapes for certain acid-base equilibrium systems. Teachers can also provide opportunities to choose and implement mathematical routines to manipulate and interpret titration data and connect that interpretation to chemistry concepts. Practicing using the half-titration point helps to visualize and clarify ratios between acid/conjugate base.

Adjusted from ~14-15 class periods to **~14-16** class periods

Remove references to Big Ideas.

Updated Essential Questions:

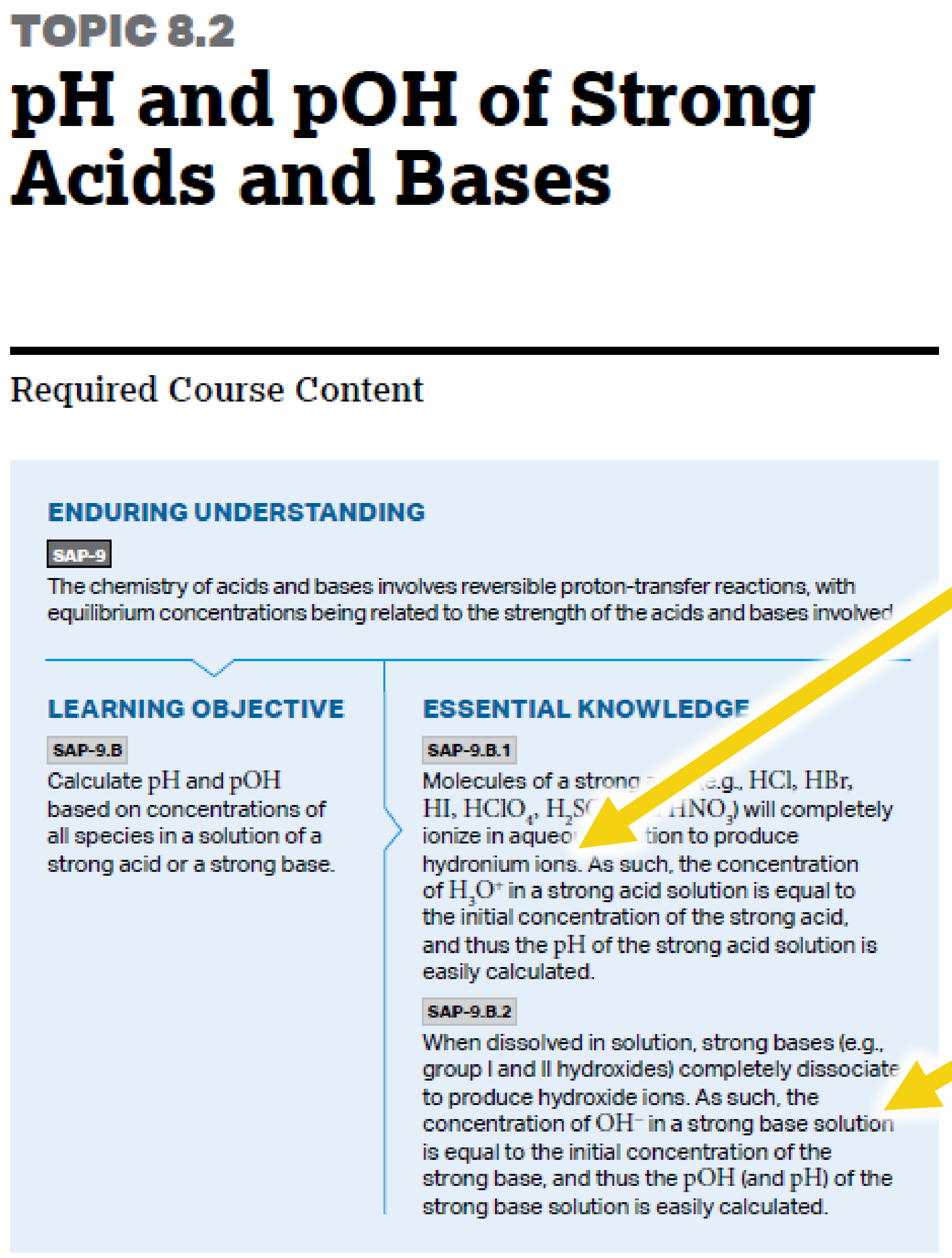
- How is pH related to the concentration and strength of an acid, a base, or a mixture of them?
- How does acid or base strength relate to the concentrations of reactants and products when a system reaches equilibrium?
- Why are some acids stronger than others?
- How does your body maintain pH balance?

Moved to Unit 7

Rephrase: Students may also struggle to understand what is represented in different types of titration curves.

Rephrase: The half-equivalence point is a helpful reference point to visualize ratios of acid/conjugate base, particularly when combined with particulate representations..

Add: "…or weak base-strong acid"



TOPIC 8.2

pH and pOH of Strong Acids and Bases

Required Course Content

ENDURING UNDERSTANDING

SAP-9

The chemistry of acids and bases involves reversible proton-transfer reactions, with equilibrium concentrations being related to the strength of the acids and bases involved

LEARNING OBJECTIVE

SAP-9.B

Calculate pH and pOH based on concentrations of all species in a solution of a strong acid or a strong base.

ESSENTIAL KNOWLEDGE

SAP-9.B.1

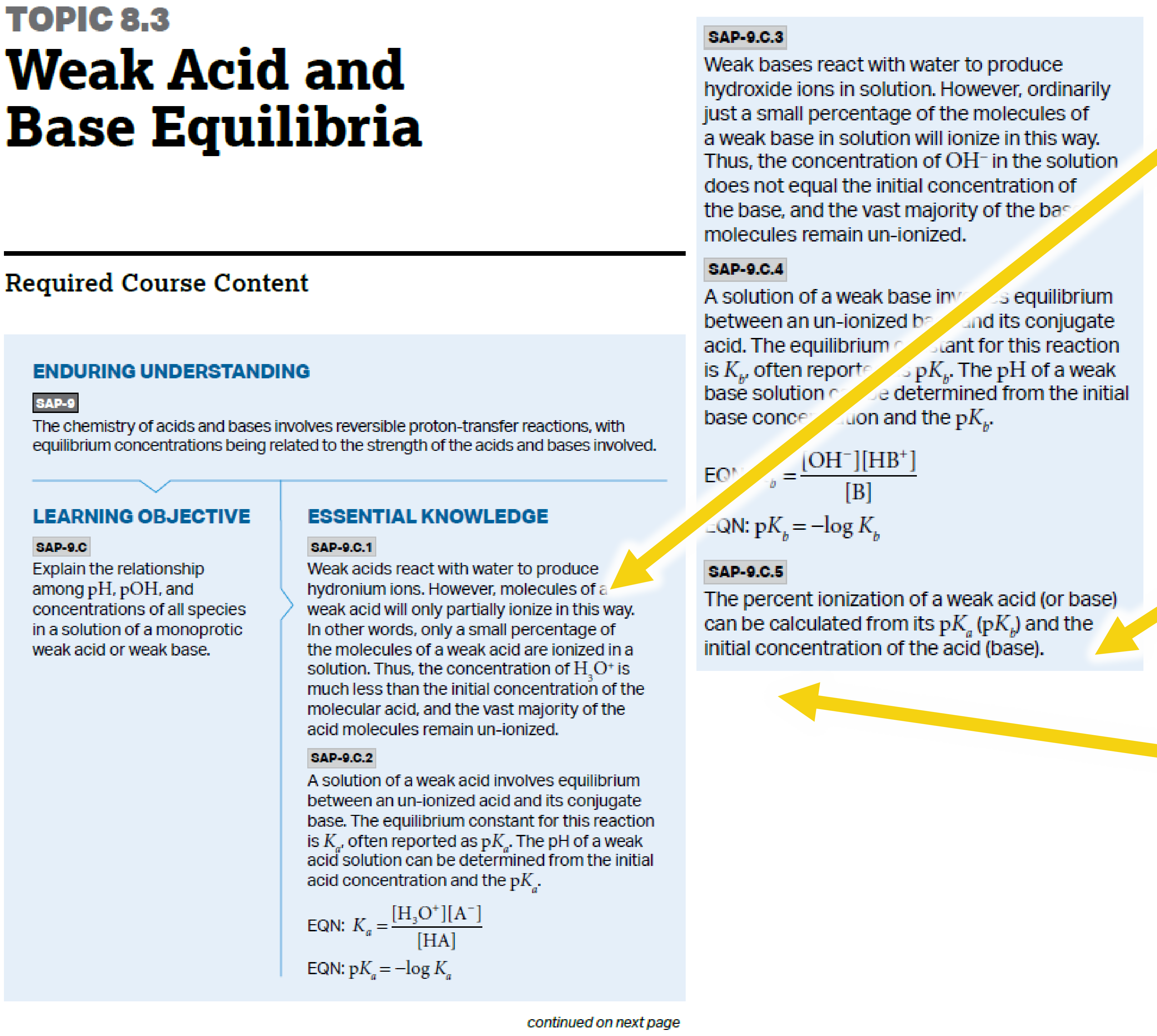
Molecules of a strong (e.g., HCl, HBr, HI, $HClO_4$, H_2S HNO_3) will completely ionize in aqueo tion to produce hydronium ions. As such, the concentration of H_3O^+ in a strong acid solution is equal to the initial concentration of the strong acid, and thus the pH of the strong acid solution is easily calculated.

SAP-9.B.2

When dissolved in solution, strong bases (e.g., group I and II hydroxides) completely dissociate to produce hydroxide ions. As such, the concentration of OH^- in a strong base solution is equal to the initial concentration of the strong base, and thus the pOH (and pH) of the strong base solution is easily calculated.

Add "and the conjugate base of the acid."

Rephrase:
"As such, the concentration of OH^- in a strong base solution is equal to the initial concentration of **a group I hydroxide and double the initial concentration of a group II hydroxide, …**"



TOPIC 8.3

Weak Acid and Base Equilibria

Required Course Content

ENDURING UNDERSTANDING

SAP-9

The chemistry of acids and bases involves reversible proton-transfer reactions, with equilibrium concentrations being related to the strength of the acids and bases involved.

LEARNING OBJECTIVE

SAP-9.C

Explain the relationship among pH, pOH, and concentrations of all species in a solution of a monoprotic weak acid or weak base.

ESSENTIAL KNOWLEDGE

SAP-9.C.1

Weak acids react with water to produce hydronium ions. However, molecules of a weak acid will only partially ionize in this way. In other words, only a small percentage of the molecules of a weak acid are ionized in a solution. Thus, the concentration of H_3O^+ is much less than the initial concentration of the molecular acid, and the vast majority of the acid molecules remain un-ionized.

SAP-9.C.2

A solution of a weak acid involves equilibrium between an un-ionized acid and its conjugate base. The equilibrium constant for this reaction is K_a, often reported as pK_a. The pH of a weak acid solution can be determined from the initial acid concentration and the pK_a.

EQN: $K_a = \frac{[H_3O^+][A^-]}{[HA]}$

EQN: $pK_a = -\log K_a$

SAP-9.C.3

Weak bases react with water to produce hydroxide ions in solution. However, ordinarily just a small percentage of the molecules of a weak base in solution will ionize in this way. Thus, the concentration of OH^- in the solution does not equal the initial concentration of the base, and the vast majority of the bas[illegible] molecules remain un-ionized.

SAP-9.C.4

A solution of a weak base inv[illegible]s equilibrium between an un-ionized b[illegible]nd its conjugate acid. The equilibrium c[illegible]tant for this reaction is K_b, often report[illegible] pK_b. The pH of a weak base solution c[illegible]e determined from the initial base conc[illegible]tion and the pK_b.

EQ[illegible] $_b = \frac{[OH^-][HB^+]}{[B]}$

[illegible]QN: $pK_b = -\log K_b$

SAP-9.C.5

The percent ionization of a weak acid (or base) can be calculated from its pK_a (pK_b) and the initial concentration of the acid (base).

continued on next page

Rephrase:
"Weak acids react with water to produce hydronium ions. However, only a small percentage of molecules of a weak acid will ionize in this way. Thus, the concentration of H_3O^+ is much smaller than the initial concentration of the molecular acid, and the vast majority of the acid molecules remain un-ionized."

Add "The percent ionization can also be calculated from the initial concentration of the acid (base) and the equilibrium concentration of any of the species in the equilibrium expression."

Add EK:

8.3.A.6

For any conjugate acid-base pair, the acid ionization constant and base ionization constant are related by K_w:

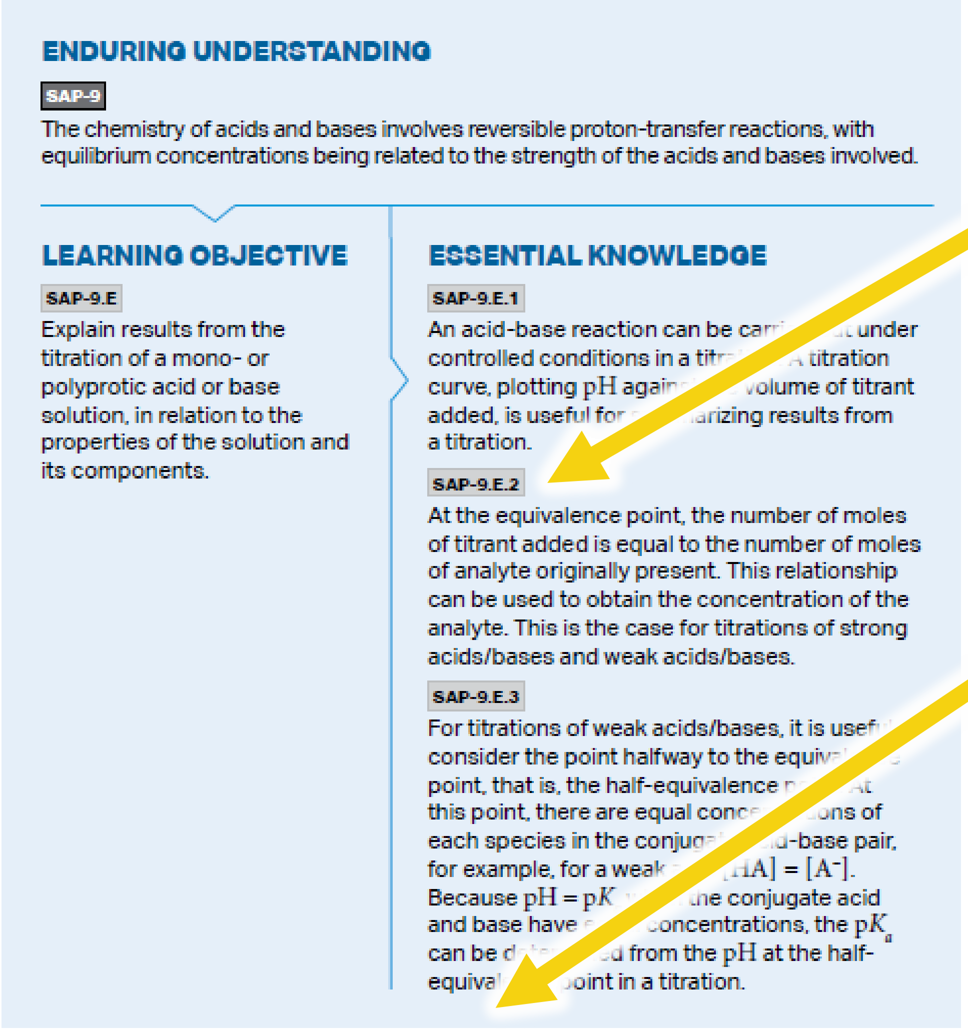
EQN: $K_w = K_a \times K_b$

EQN: $pK_w = pK_a + pK_b$

TOPIC 8.5

Acid-Base Titrations

Required Course Content



ENDURING UNDERSTANDING

SAP-9

The chemistry of acids and bases involves reversible proton-transfer reactions, with equilibrium concentrations being related to the strength of the acids and bases involved.

LEARNING OBJECTIVE

SAP-9.E

Explain results from the titration of a mono- or polyprotic acid or base solution, in relation to the properties of the solution and its components.

ESSENTIAL KNOWLEDGE

SAP-9.E.1

An acid-base reaction can be carried out under controlled conditions in a titration. A titration curve, plotting pH against the volume of titrant added, is useful for summarizing results from a titration.

SAP-9.E.2

At the equivalence point, the number of moles of titrant added is equal to the number of moles of analyte originally present. This relationship can be used to obtain the concentration of the analyte. This is the case for titrations of strong acids/bases and weak acids/bases.

SAP-9.E.3

For titrations of weak acids/bases, it is useful to consider the point halfway to the equivalence point, that is, the half-equivalence point. At this point, there are equal concentrations of each species in the conjugate acid-base pair, for example, for a weak acid $[HA] = [A^-]$. Because $pH = pK_a$ when the conjugate acid and base have equal concentrations, the pK_a can be determined from the pH at the half-equivalence point in a titration.

Add introductory clause,

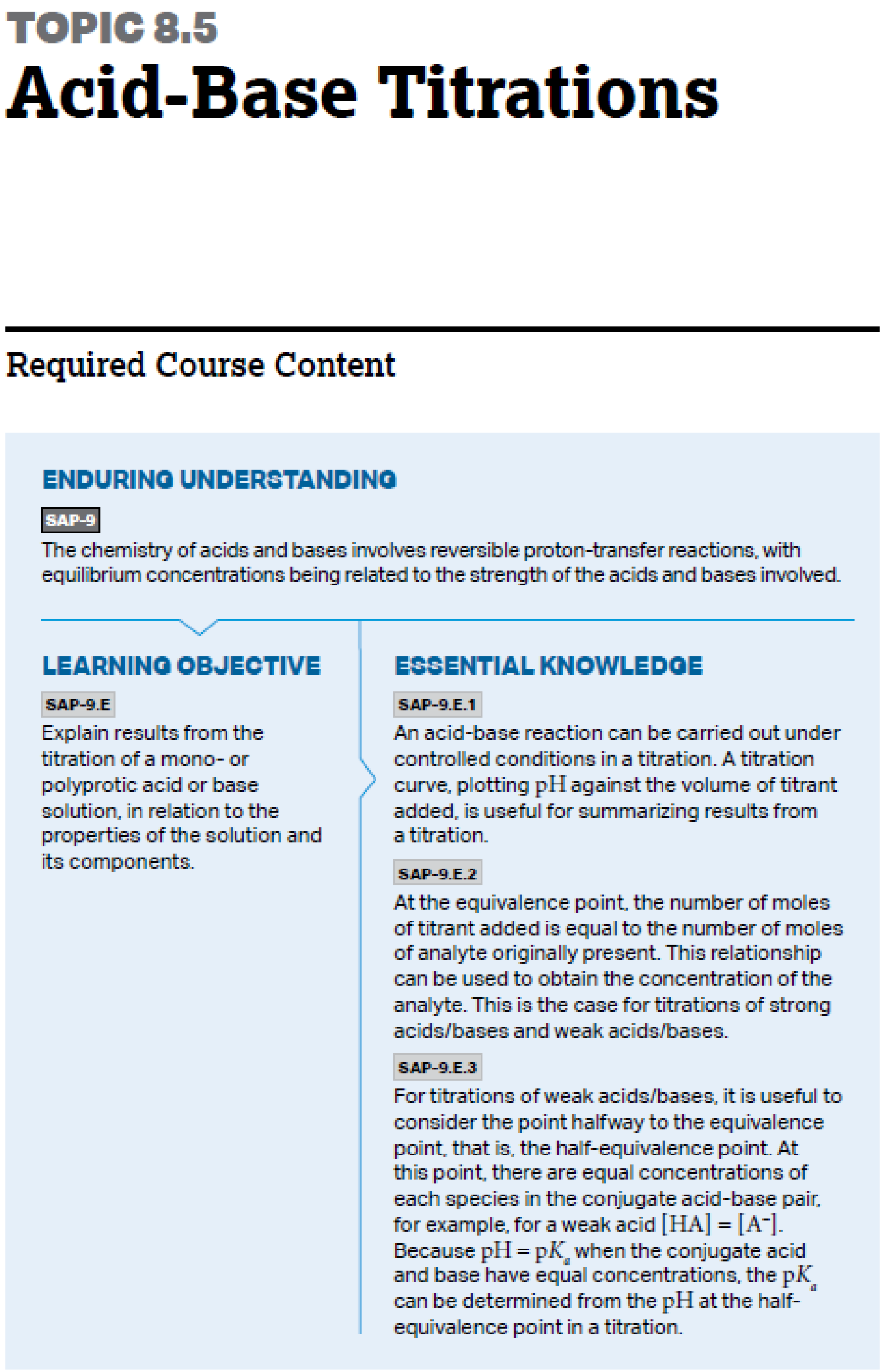
SAP-9.E.2

"At the equivalence point for titrations of monoprotic acids or bases, the number of moles…"

Add EK:

NEW 8.5.A.4 (move current SAP-9.E.4 to 8.5.A.5)

At the equivalence point, pH is determined by the major species in solution. Strong acid and strong base titrations result in neutral pH at the equivalence point. However, in titrations of weak acids or weak bases, some species present at the equivalence point can undergo proton-transfer reactions with the surrounding water, producing basic or acidic solutions.



TOPIC 8.5

Acid-Base Titrations

Required Course Content

ENDURING UNDERSTANDING

SAP-9

The chemistry of acids and bases involves reversible proton-transfer reactions, with equilibrium concentrations being related to the strength of the acids and bases involved.

LEARNING OBJECTIVE

SAP-9.E

Explain results from the titration of a mono- or polyprotic acid or base solution, in relation to the properties of the solution and its components.

ESSENTIAL KNOWLEDGE

SAP-9.E.1

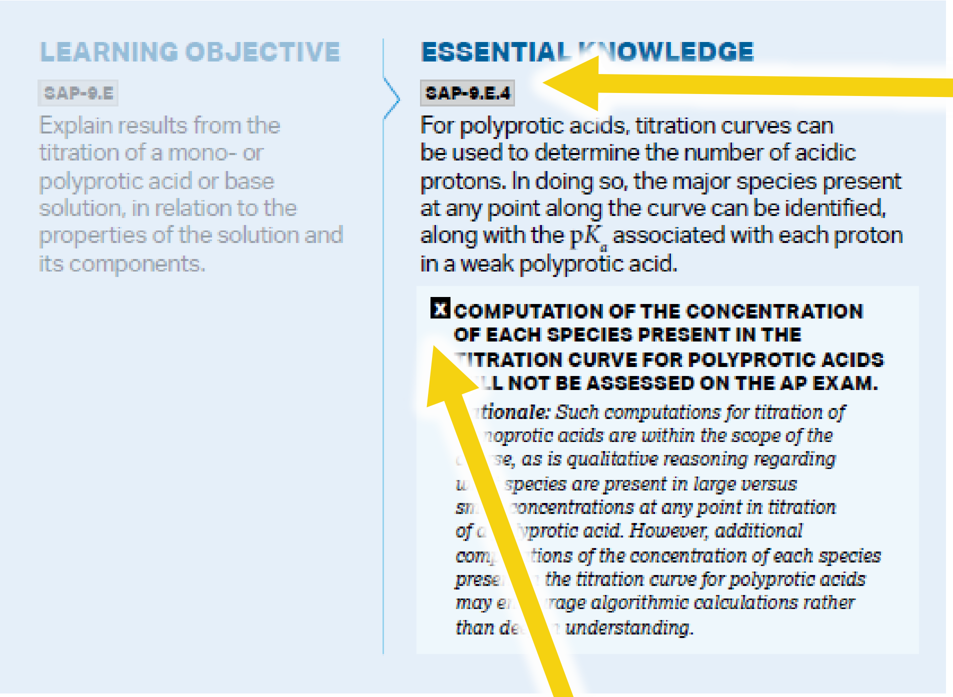
An acid-base reaction can be carried out under controlled conditions in a titration. A titration curve, plotting pH against the volume of titrant added, is useful for summarizing results from a titration.

SAP-9.E.2

At the equivalence point, the number of moles of titrant added is equal to the number of moles of analyte originally present. This relationship can be used to obtain the concentration of the analyte. This is the case for titrations of strong acids/bases and weak acids/bases.

SAP-9.E.3

For titrations of weak acids/bases, it is useful to consider the point halfway to the equivalence point, that is, the half-equivalence point. At this point, there are equal concentrations of each species in the conjugate acid-base pair, for example, for a weak acid $[HA] = [A^-]$. Because $pH = pK_a$ when the conjugate acid and base have equal concentrations, the pK_a can be determined from the pH at the half-equivalence point in a titration.



LEARNING OBJECTIVE

SAP-9.E

Explain results from the titration of a mono- or polyprotic acid or base solution, in relation to the properties of the solution and its components.

ESSENTIAL [illegible]NOWLEDGE

SAP-9.E.4

For polyprotic acids, titration curves can be used to determine the number of acidic protons. In doing so, the major species present at any point along the curve can be identified, along with the pK_a associated with each proton in a weak polyprotic acid.

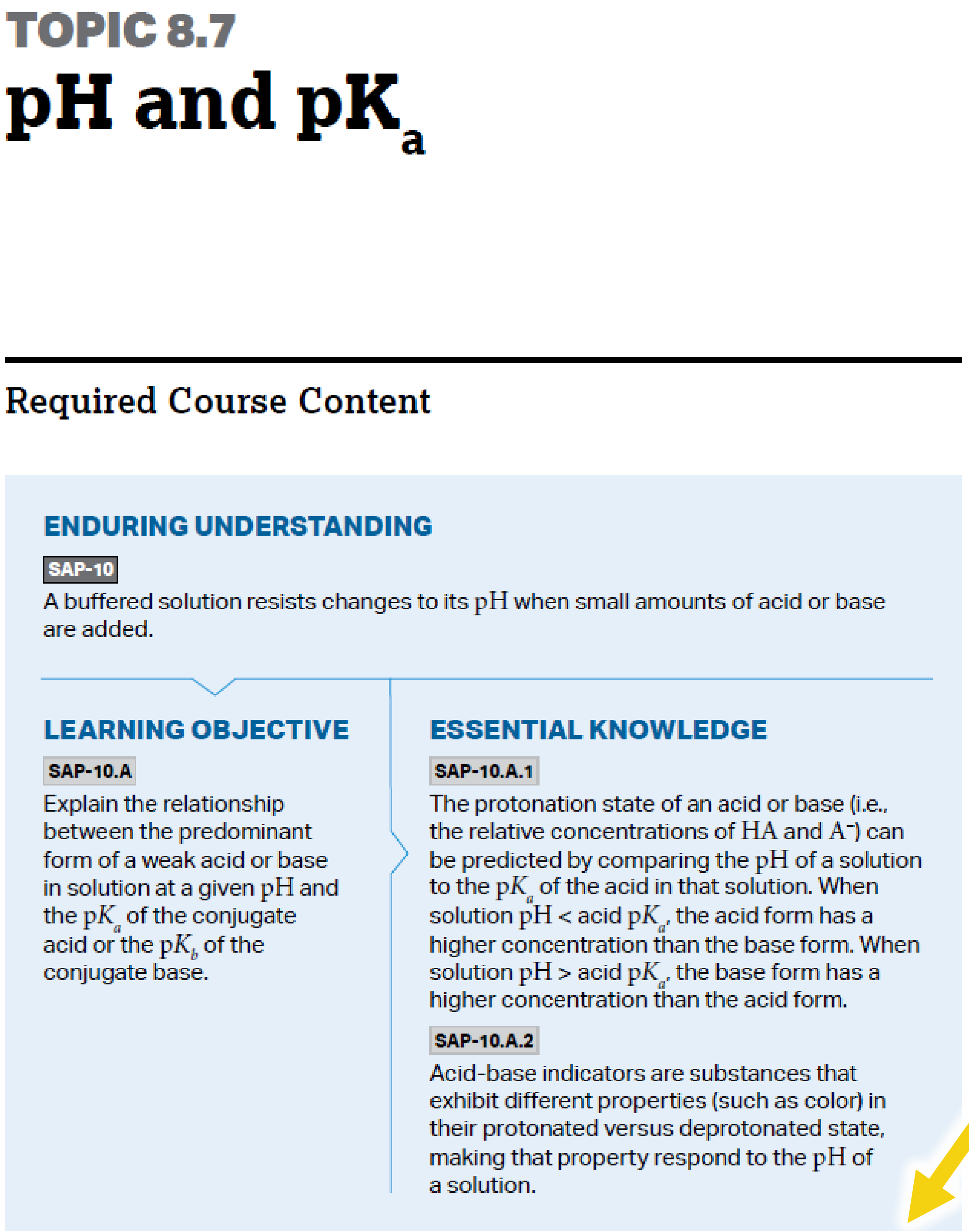
☒ **COMPUTATION OF THE CONCENTRATION OF EACH SPECIES PRESENT IN THE [illegible]ITRATION CURVE FOR POLYPROTIC ACIDS [illegible]LL NOT BE ASSESSED ON THE AP EXAM.**

[illegible]tionale: Such computations for titration of [illegible]noprotic acids are within the scope of the [illegible]se, as is qualitative reasoning regarding [illegible] species are present in large versus [illegible] concentrations at any point in titration of [illegible]yprotic acid. However, additional com[illegible]tions of the concentration of each species prese[illegible] the titration curve for polyprotic acids may e[illegible]rage algorithmic calculations rather than de[illegible] understanding.

Reassign SAP-9.E.4 as 8.5.A.5

Updated **Exclusion Statement:**

Computation of the concentration of each species present in the titration curve for polyprotic acids will not be assessed on the AP Exam. Such computations for titration of monoprotic acids are within the scope of the course (see 8.4.A.2 and 8.4.A.3), as is qualitative reasoning regarding what species are present in large versus small concentrations at any point in titration of a polyprotic acid.



TOPIC 8.7

pH and pK_a

Required Course Content

ENDURING UNDERSTANDING

SAP-10

A buffered solution resists changes to its pH when small amounts of acid or base are added.

LEARNING OBJECTIVE

SAP-10.A

Explain the relationship between the predominant form of a weak acid or base in solution at a given pH and the pK_a of the conjugate acid or the pK_b of the conjugate base.

ESSENTIAL KNOWLEDGE

SAP-10.A.1

The protonation state of an acid or base (i.e., the relative concentrations of HA and A^-) can be predicted by comparing the pH of a solution to the pK_a of the acid in that solution. When solution pH < acid pK_a, the acid form has a higher concentration than the base form. When solution pH > acid pK_a, the base form has a higher concentration than the acid form.

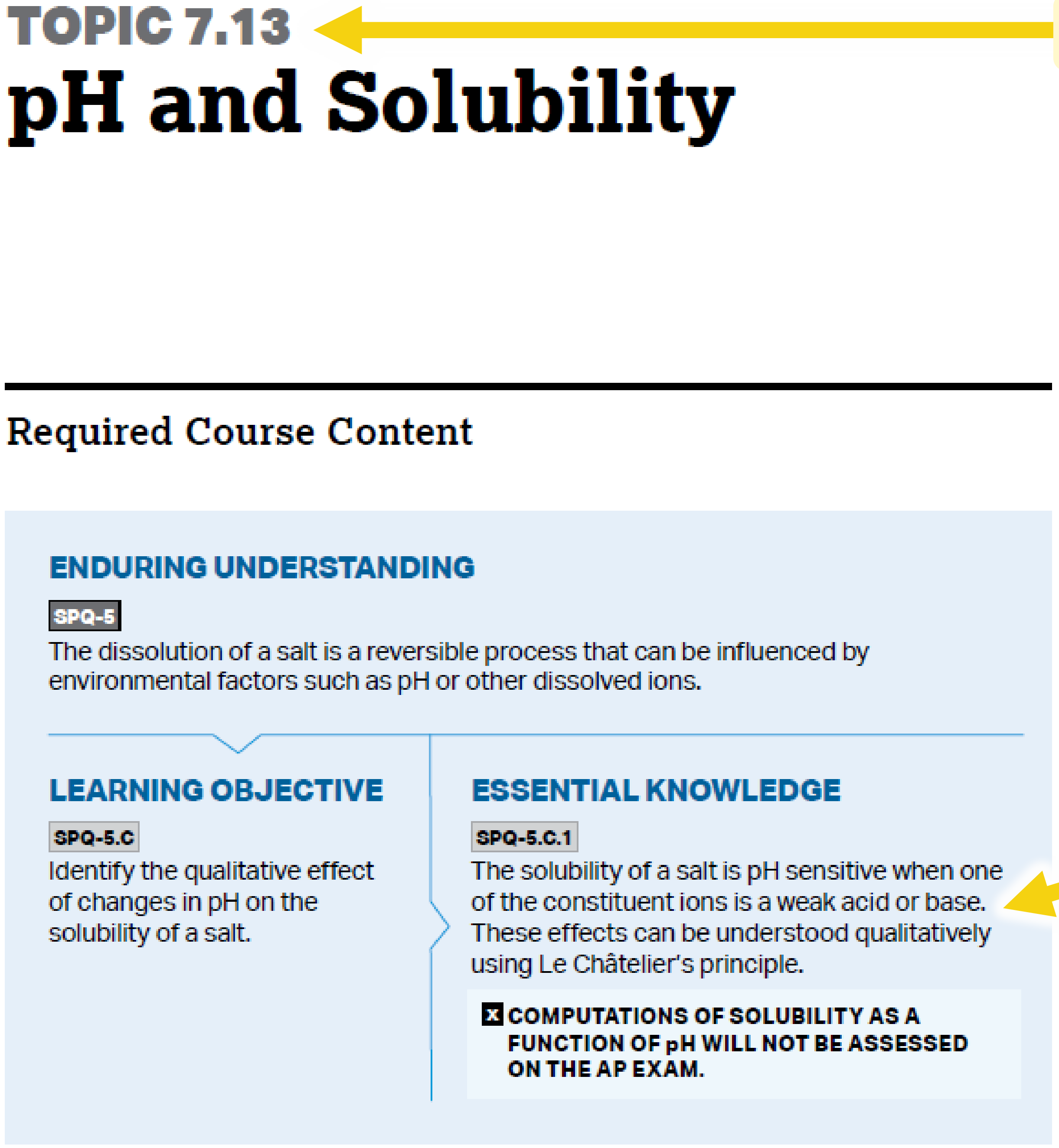
SAP-10.A.2

Acid-base indicators are substances that exhibit different properties (such as color) in their protonated versus deprotonated state, making that property respond to the pH of a solution.

Add EK:

8.7.A.3

To ensure accurate results in a titration experiment, acid-base indicators should be selected that have a pK_a close to the pH at the equivalence point.



TOPIC 7.13

pH and Solubility

Required Course Content

ENDURING UNDERSTANDING

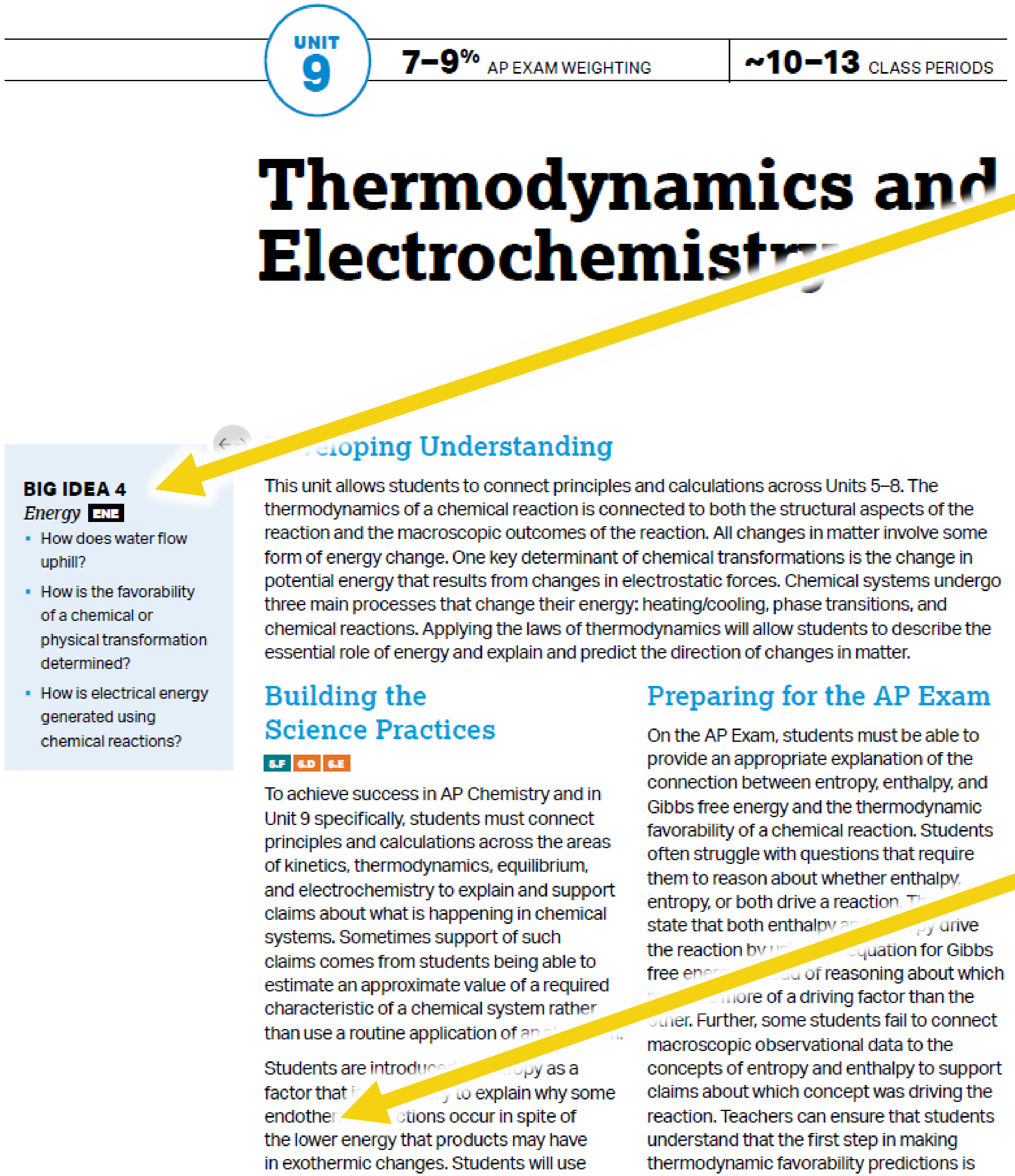
SPQ-5

The dissolution of a salt is a reversible process that can be influenced by environmental factors such as pH or other dissolved ions.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
SPQ-5.C Identify the qualitative effect of changes in pH on the solubility of a salt.	SPQ-5.C.1 The solubility of a salt is pH sensitive when one of the constituent ions is a weak acid or base. These effects can be understood qualitatively using Le Châtelier's principle. ☒ **COMPUTATIONS OF SOLUBILITY AS A FUNCTION OF pH WILL NOT BE ASSESSED ON THE AP EXAM.**

Renumber as Topic 8.11

Rephrase:
"…is a weak acid, a weak base, **or the hydroxide ion**."



UNIT 9

7–9% AP EXAM WEIGHTING

~10–13 CLASS PERIODS

Thermodynamics and Electrochemist[illegible]

BIG IDEA 4
Energy **ENE**

- How does water flow uphill?
- How is the favorability of a chemical or physical transformation determined?
- How is electrical energy generated using chemical reactions?

[illegible]eloping Understanding

This unit allows students to connect principles and calculations across Units 5–8. The thermodynamics of a chemical reaction is connected to both the structural aspects of the reaction and the macroscopic outcomes of the reaction. All changes in matter involve some form of energy change. One key determinant of chemical transformations is the change in potential energy that results from changes in electrostatic forces. Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions. Applying the laws of thermodynamics will allow students to describe the essential role of energy and explain and predict the direction of changes in matter.

Building the Science Practices

5.F 6.D 6.E

To achieve success in AP Chemistry and in Unit 9 specifically, students must connect principles and calculations across the areas of kinetics, thermodynamics, equilibrium, and electrochemistry to explain and support claims about what is happening in chemical systems. Sometimes support of such claims comes from students being able to estimate an approximate value of a required characteristic of a chemical system rather than use a routine application of an [illegible].

Students are introduc[illegible]opy as a factor that i[illegible]y to explain why some endother[illegible]ctions occur in spite of the lower energy that products may have in exothermic changes. Students will use

Preparing for the AP Exam

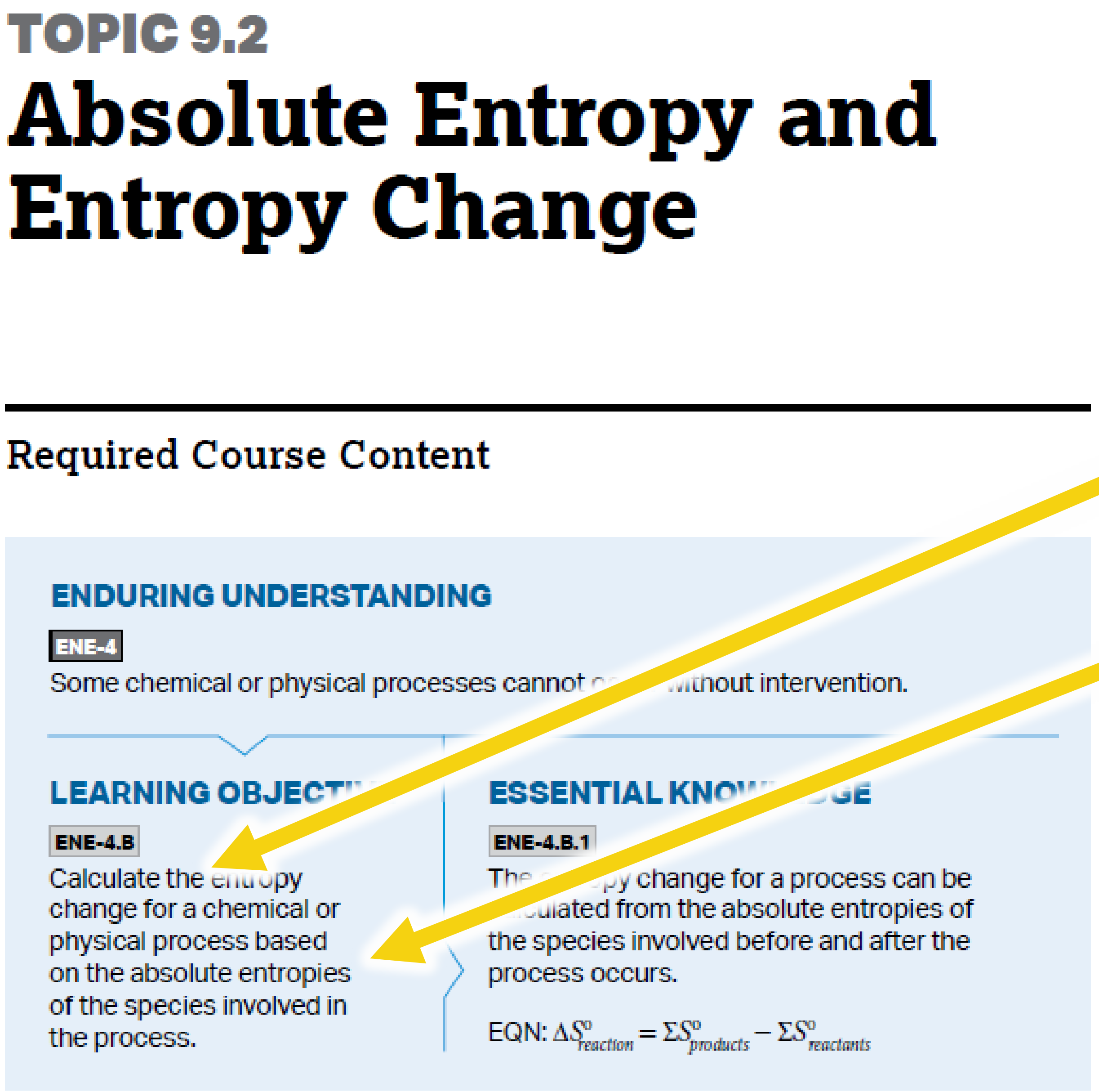
On the AP Exam, students must be able to provide an appropriate explanation of the connection between entropy, enthalpy, and Gibbs free energy and the thermodynamic favorability of a chemical reaction. Students often struggle with questions that require them to reason about whether enthalpy, entropy, or both drive a reaction. Th[illegible] state that both enthalpy an[illegible]py drive the reaction by u[illegible]equation for Gibbs free ener[illegible]ad of reasoning about which [illegible] more of a driving factor than the [illegible]ther. Further, some students fail to connect macroscopic observational data to the concepts of entropy and enthalpy to support claims about which concept was driving the reaction. Teachers can ensure that students understand that the first step in making thermodynamic favorability predictions is

Remove references to Big Ideas.

Updated Essential Questions:

- Why do some chemical reactions occur without intervention, but others require the input of energy?
- How can we determine the conditions under which a chemical or physical transformation is likely to occur?
- How is electrical energy generated using chemical reactions?

Rephrase:
“Students are introduced to entropy as a factor that is necessary to explain why some endothermic reactions occur in spite of the **higher** energy that products may have in **these** changes.



TOPIC 9.2

Absolute Entropy and Entropy Change

Required Course Content

ENDURING UNDERSTANDING

ENE-4

Some chemical or physical processes cannot occur without intervention.

LEARNING OBJECTIVE

ENE-4.B

Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process.

ESSENTIAL KNOWLEDGE

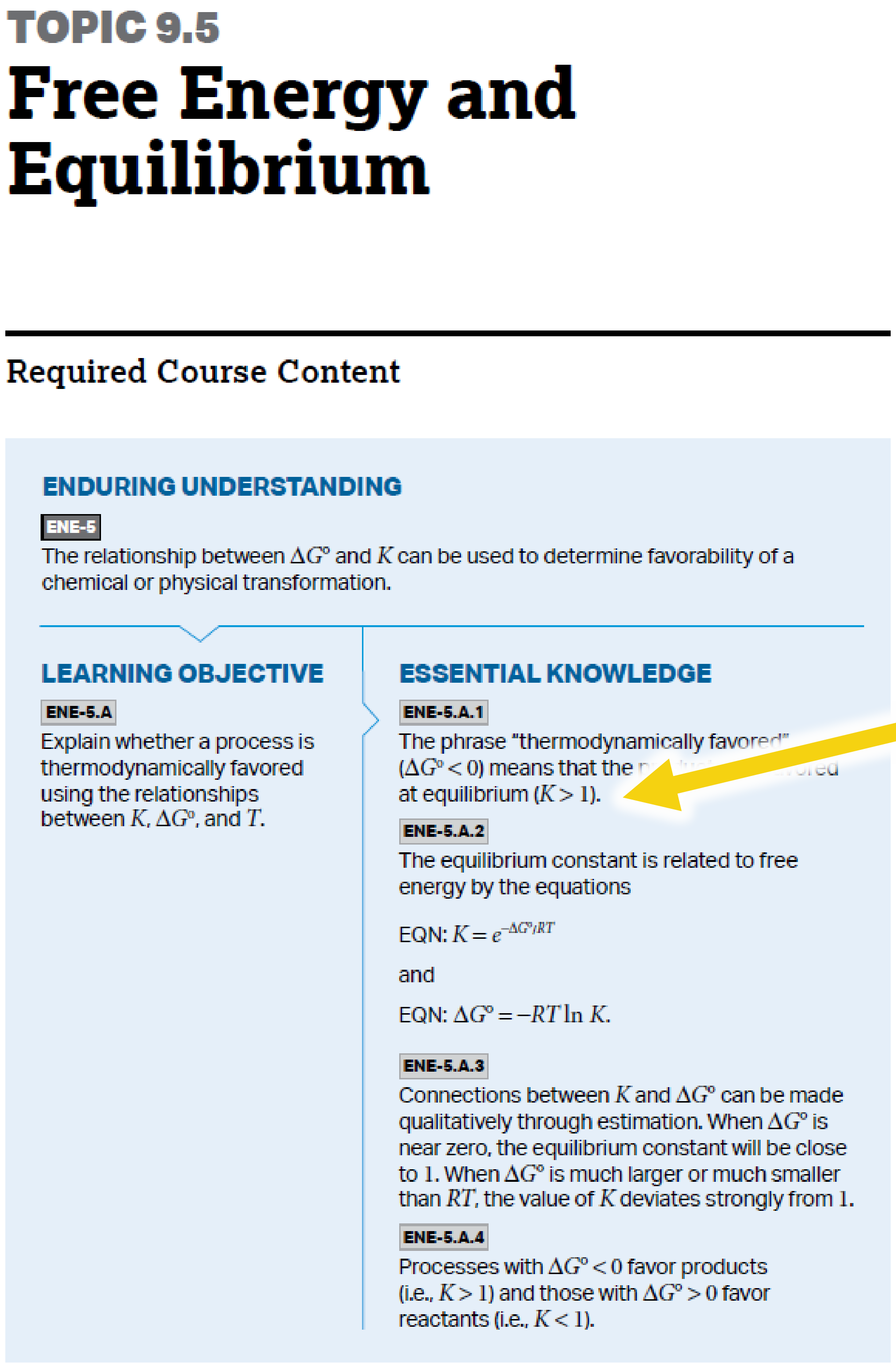
ENE-4.B.1

The entropy change for a process can be calculated from the absolute entropies of the species involved before and after the process occurs.

EQN: $\Delta S^{\circ}_{reaction} = \Sigma S^{\circ}_{products} - \Sigma S^{\circ}_{reactants}$

Add “**standard**”

Add “**(standard molar entropies)**”



TOPIC 9.5

Free Energy and Equilibrium

Required Course Content

ENDURING UNDERSTANDING

ENE-5

The relationship between ΔG° and K can be used to determine favorability of a chemical or physical transformation.

LEARNING OBJECTIVE

ENE-5.A

Explain whether a process is thermodynamically favored using the relationships between K, ΔG°, and T.

ESSENTIAL KNOWLEDGE

ENE-5.A.1

The phrase "thermodynamically favored" ($\Delta G^\circ < 0$) means that the products are favored at equilibrium ($K > 1$).

ENE-5.A.2

The equilibrium constant is related to free energy by the equations

EQN: $K = e^{-\Delta G^\circ/RT}$

and

EQN: $\Delta G^\circ = -RT \ln K$.

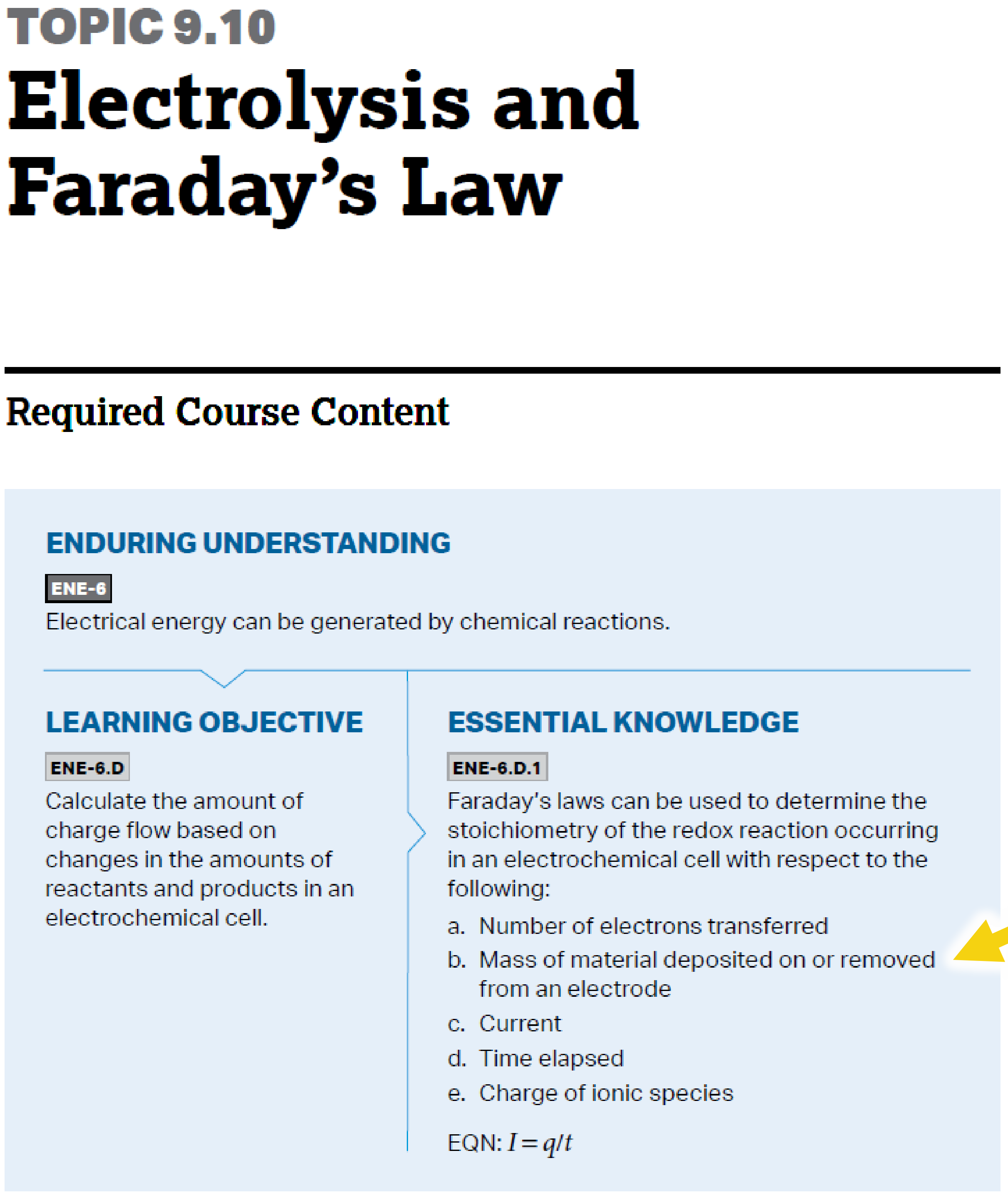
ENE-5.A.3

Connections between K and ΔG° can be made qualitatively through estimation. When ΔG° is near zero, the equilibrium constant will be close to 1. When ΔG° is much larger or much smaller than RT, the value of K deviates strongly from 1.

ENE-5.A.4

Processes with $\Delta G^\circ < 0$ favor products (i.e., $K > 1$) and those with $\Delta G^\circ > 0$ favor reactants (i.e., $K < 1$).

Add "**under standard conditions.**"



TOPIC 9.10

Electrolysis and Faraday's Law

Required Course Content

ENDURING UNDERSTANDING

ENE-6

Electrical energy can be generated by chemical reactions.

LEARNING OBJECTIVE

ENE-6.D

Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.

ESSENTIAL KNOWLEDGE

ENE-6.D.1

Faraday's laws can be used to determine the stoichiometry of the redox reaction occurring in an electrochemical cell with respect to the following:

a. Number of electrons transferred
b. Mass of material deposited on or removed from an electrode
c. Current
d. Time elapsed
e. Charge of ionic species

EQN: $I = q/t$

Rephrase:
b. Mass of material removed from or deposited on an electrode **(such as in electroplating)**